THE FORMATION AND IMPACT OF HAZARD CONTROL POLICY

A Study of the Regulation of White Lead Paint in Britain.

Robin Alan Williams

Presented in partial fulfilment
of the requirements for the degree
of Doctor of Philosophy

University of Aston in Birmingham

January 1984

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Government regulation of industrial hazards is examined in the context of the economic and technical processes of industrial development. Technical problems and costs of control are considered as factors in both the formation and impact of regulation. This thesis focuses on an historical case-study of the regulation of the hazard to painting workers from the use of lead pigments in paint. A regulatory strategy based on the prohibition of lead paints gained initial acceptance within the British state in 1911, but was subsequently rejected in favour of a strategy that allowed continued use of lead paint subject to hygiene precautions.

The development of paint technology and its determinants, including concern about health hazards, are analysed, focusing on the innovation and diffusion into the paint industry of the major white pigments: white lead ($PbCO_3.PB(OH)_2$)and its substitutes.

The process of regulatory development is examined, and the protracted and polarised regulatory debate contrasted to the prevailing 'consensual' methods of workplace regulation. The rejection of prohibition is analysed in terms of the different political and technical resources of those groups in conflict over this policy. This highlights the problems of consensus formation around such a strategy, and demonstrates certain constraints on state regulatory activity, particularly regarding industrial development. Member-states of the International Labour Organisation agreed to introduce partial prohibition of lead paint in 1921. Whether this was implemented is related to the economic importance of lead and non-lead metal and pigment industries to a nation.

An analysis is made of the control of lead poisoning. The rate of control is related to the economic and technological trajectory of the regulated industry. Technical and organisational characteristics are considered as well as regulatory factors which range from voluntary compliance and informal pressures to direct legal requirements.

The implications of this case-study for the analysis of the development and impacts of regulation are assessed.

Keywords

Hazard: Regulation: Policy: Paint: Lead.

Acknowledgments

This research was conducted with financial assistance from the Science Research Council of a research studentship award.

Many people have helped me in the protracted and onerous task of producing this thesis. The inspiration for the project dates back to discussions in 1978-9 with a variety of academics at Aston University and elsewhere in the 'Politics of Risk' Group.

I would like to thank the many companies that provided information including I.C.I. Ltd., International Paint Co.Ltd., Laporte Industries Ltd., and in particular Mr. G.E.Watts of Tioxide International Ltd., whose 1956 survey of pigment sales made possible the study of pigment diffusion.

The account of the regulatory development process for lead paint draws heavily on Home Office files made available by the Public Records Office. Mr. B.Henshaw and Mr. W.Douglas of the Department of Health and Social Security gave invaluable help regarding statistics on compensation for lead poisoning.

I am very grateful to colleagues in the Technology Policy Unit, in particular the participants in the study group on the analysis of the state, who provided a stimulating and supportive environment.

This thesis could not have been completed without sustained and meticulous assistance from Peter Williams with graphics, Mrs. L.Doogan, my typist, and Mavis Lloyd with proof-reading. Last, but not least, I thank my supervisor, Dr. H.F.Steward whose constant encouragement and ability to catalyse the development of new ideas has played an essential role in maintaining my interest and enthusiasm for the project over the six years of its inception.

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CHAPTER ONE

INTRODUCTION:
THE REGULATORY DEBATE

INTRODUCTION - THE REGULATORY DEBATE

Contemporary Debates about Regulation

The past decades have seen an escalating series of crises following the revelation of the effects of a new industrial chemical on the health of workers, the community and the environment. Notable events confronting the British Factory Inspectorate have included:[1]

1965 Bladder cancer in rubber workers
1972 Lead absorption at the Isle of Dogs and Avonmouth
1974 Angiosarcoma of the liver in PVC workers
1975 Asbestos caused disease amongst workers and community at Hebden Bridge
1976 Dioxin (TCDD), the explosion at a herbicide factory at Seveso, Italy.

These crises have stemmed, inter-alia, from increased knowledge about the toxic effects of materials - revealing that a material was toxic in a new way or to a greater degree than previously believed, and from the demonstration that the existing apparatus for regulating hazards had not succeeded in reducing harm to a politically/socially acceptable degree.

Often (and in all the above examples), the scientific and political recognition of the hazards has in turn stimulated concern about potential hazards from these materials in other areas of industrial activity and to other groups (at work, in the community to residents and consumers) and the general environment.[2]

Typically these newly discovered hazards have been what has been loosely termed 'chronic hazards' i.e. those arising from long-term exposure, even to very low levels of chemicals that may be otherwise apparently harmless. Unlike 'acute hazards', from short-term exposures to high levels of materials, which are readily demonstrated, monitored and controlled, the identification of 'chronic hazards' and the necessary monitoring and control of low emissions of chemicals requires considerable resources and possibly substantial changes in production technology.

Very large amounts of synthetic materials are entering the workplace and environment (probably 60-100 Million Tons, worldwide with 20-30 thousand chemicals manufactured in quantities greater than one ton).[3]

It has been estimated that some 100,000 chemicals are currently used in industry in the U.K. - a figure that is held to be increasing by 3-400 or more per year.[4] Whereas in the 1940s, some 50 industrial chemicals were known to cause occupational diseases/intoxication, now such chemicals are counted in hundreds. As a result of greater knowledge and awareness about toxicity, the potential danger to health from the thousands of other industrial chemicals, whose toxicity is little known, is a matter of concern.[5] "Only a few hundred of these have been submitted to (toxic hazard) registration procedures .... (of the) 4 million new chemicals .... there is probably only toxicity data for about 100,000 chemicals."[6]

It is very hard to identify the harmful effects of these materials, especially in the case of cancer and similar hazards where the effects only declare themselves after a long 'latent period'. Testing the toxicity of chemicals has largely been restricted to drugs, food additives and pesticides. Where industrial and commercial chemicals have been tested, testing "has often been rudimentary and directed principally towards the acute effect rather than the chronic".[7]

Public concern, and pressure from the trade unions have led to legislation to control this new generation of hazards. Precedent for this legislation has been set in the U.S.A. with the 1971 Occupational Safety and Health Act and the 1976 Toxic Substances Control Act. Parallel legislation in Britain has been the Health and Safety at Work etc. Act 1974. Regulations, under this Act, requiring notification of the use of existing chemicals, and the introduction of new chemicals have recently been introduced. Other EEC member states are introducing similar legislation to conform to the Sixth Amendment to the EEC Council Directive on the classification, packaging and labelling of dangerous substances.[8] Other advanced industrial nations are adopting similar legislation including Canada, Japan, Norway, Sweden and Switzerland.[9]

This legislation, and the different strategies underlying it, has raised an intense debate about how society should regulate known and potential risks arising from industrial production. The debate has centred around a number of inter-related issues:

1) <u>The Assessment of the Risks of a Material</u>

Discussion on this subject has focused on :

a) the validity of different testing procedures.

b) the conduct and interpretation of such studies.

A key area of discussion has been how the responsibility for determining and carrying out appropriate tests should be allocated, and in particular whether the state should legislate and enforce the standards for testing or whether this should be left to scientists and the companies involved in producing the materials to determine.

2) <u>The Decision-Making Process</u>

Two rather divergent approaches have emerged:

a) one, focusing on different philosophies of what risks are acceptable, has been associated with attempts to systematize the process of decision making for the regulation of risk in terms of the balance between the costs and benefits to the different parties arising from different regulatory options.[10]

b) the second has focused on the process of decision making and in particular the role of different parties in this process (e.g. labour or popular representatives, industry representatives, experts, the state). This has involved discussions of the consequences of different forms of the decision making process (e.g. public versus private fora, 'elite' versus 'representative' composition of bodies, consensual versus adversarial processes).

3) The Regulatory Process

The means by which the state regulates industrial hazards have come under scrutiny.[11] Discussion of the appropriate methods and degree of state intervention has discerned a variety of possibilities ranging from 'laissez-faire' to 'command strategies'. This discussion, which involves fundamental political differences about the programme of regulation to be adopted, has raised questions about the impact of government regulation on health, on production costs and on industrial innovation. Industry representatives have argued that stringent testing and control legislation will pose an excessive financial burden on industry and will restrict the introduction of new materials.[12]

Others have argued that industrial development has been geared towards certain technical and market goals and that health and safety have not been prioritised. Existing regulation has not adequately dealt with the hazards generated by industrial development. More stringent regulation is thus desirable and new forms of regulation may be needed. Industry protests about the economic and administrative burden that regulation would place on introducting new chemicals have been countere by proposals that the rate and direction of technological change should be controlled in the interests of 'social need', including the minimisation of hazard (for example by evaluating the need for, as well as the risks of, new materials).[13]

This has involved calls for state licensing of the industrial use of new chemicals. For chemicals already in widespread use it has been suggested that under certain conditions the use of a material should be prohibited - for example, where, because of the potential severity of harm or the conditions of use, the material cannot be used without unacceptable risk.

In recent years the most forceful argument for prohibition has been made in the case of asbestos. It is suggested that it is impossible to guarantee that this material will be used safely on grounds of i) the risk of cancer even from brief or low level exposures to asbestos fibres, and ii) its dispersed use over a wide range of industries and the longevity of the material which remains in a hazardous form through the processes of extraction, processing, consumption and disposal.[14]

Resolution of this debate requires greater understanding of the relationship between industrial innovation, industrial hazards, regulation and the control of hazards. It is useful to start by reviewing the major areas of investigation that have been conducted into this relationship.

Studies of the Regulatory Process

Studies in this field have tended to concentrate on certain aspects of this complex relationship in isolation. In so doing they have reflected the division of the regulatory debate described above (in particular 2. and 3.). This separation has affected the terms of the debate, and the outcomes of various studies. This separation can partly be related to the professional and disciplinary concerns of researchers in the field, but also has implications for, and is influenced by, different programmes of regulatory reform.

In particular, three main approaches can be distinguished in recent studies:

1) Studies of regulation as an example of state policy formation. These focus on the methods by which the state determines its regulatory actions for a hazardous process. Studies have been based on a variety of models of state/regulatory activity, and have focused on the role of knowledge, internal state processes, and interest groups in determining the outcome. The applicability and limitations of these models are discussed in the next section. At this stage it is sufficient to note a weakness, apparent in many such studies, of analysing state activity in isolation, divorced from the industrial processes which not only generate the risks, but also set the political and economic context within which the different interest groups and the state operate.

2) Studies of the 'costs and benefits' for the different affected parties, embodied in different regulatory actions. (e.g. risks to health and economic costs associated with regulation).[15]
Such studies have frequently involved the strongly prescriptive implication that it is possible to derive, from 'social attitudes' or previous regulatory actions, acceptable levels of risk or balances between risk and control costs that should be adopted in future regulatory decisions.
Risk/benefit and cost/benefit approaches to regulation have been subject to detailed criticism - of methodology, application and overall approach - which will not be reiterated here. Instead, attention is drawn to the major limitation of many such studies, which it is suggested, stem from their ahistorical approach, and their view of regulation as a technical rather than a political process.

Risk/Cost/Benefit analyses suffer from a frequent failure to analyse the determinants and origins of the industrial situation which poses the risks and determines the cost of regulation. Similarly, many of the other inputs into such models (e.g. levels of knowledge about a hazard, levels of 'acceptability' of risks and costs by different social groups) are themselves socially shaped by complex historical forces (economic, political, scientific, ideological).

Moreover, such approaches tend to misconceive the regulatory process as a rational decision making process, whereby some idealised subject (in the name of the state or of 'society') seeks to find an optimal solution on the basis of <u>information</u> about 'costs' and 'risks'. In these assumptions, the role of unevenly distributed economic and political power, both in setting the scene for and shaping the outcome of regulation, is frequently overlooked. (Many of these limitations are common to and can be traced back to major approaches to the analysis of state activity).

3) The impact of regulation on economic and technological development. A recent focus of studies, stimulated by the increasing scope of state regulation particularly in America, has attempted to examine the impacts of the economic and administrative burden on innovation and technological development in the regulated firm/industry.

Whilst such studies can be seen as a particular element of risk/benefit analyses, their overlap with one of the key questions of this investigation necessitates a more detailed examination.

There were two apparent starting points for these studies.

a) The first comprised a mass of data, often generated by the regulated industries, pointing to the economic costs of complying with recent regulations.[17] One study suggested that environment and worker safety regulations alone, introduced in the U.S.A. since 1967, had diverted 1.42% of business resources, equivalent to a ½% reduction in economic growth (and a 2.5% reduction in economic output per unit input.)[18]

b) The second approach focused on the indirect impacts of regulation, particularly on the rate of technological change. Longer term and potentially more substantial costs were seen as resulting where regulations caused a reduction in technological innovation. In particular it was suggested that testing and registration requirements for new chemicals would reduce the number of new materials introduced by increasing the cost of introducing new chemicals and causing delays prior to marketing. A starting point in this concern was the study by Peltzman in 1973 which concluded that pharmaceutical innovation in the U.S.A. had been substantially reduced as a result of the additional regulatory requirements of the 1962 Amendments to the U.S. Food and Drugs Act.[19] Similarly, regulation was seen as dramatically increasing the cost and lead-time of introducing new pesticides.[20] However, subsequent studies have suggested that regulation is only one of several factors behind these changes.[21]

Equally, whilst regulation has been frequently cited as a direct or indirect obstacle to technological development, it has also played a significant role in promoting successful innovation and diffusion.[22]

A large number of studies have been published on these issues, particularly since 1970.[23] However, in this literature, the regulation/innovation relationship is frequently oversimplified.[24] The generalisability and validity of many such studies is limited by weaknesses of methodology and conceptual framework.[25] Two major problems seem to have been :

i) methodological problems in determining 'regulatory impact'; in particular, the dangers of attributing causality to observed coincidence between changes in industry performance and in regulation, especially since regulation interacts with other changes in the industry. Studies need a 'baseline', for comparative purposes, for the effects of alternative regulatory scenarios or 'non-regulation'.[26]

ii) weaknesses in conceptualising the regulatory process; many studies failed to distinguish between different types of regulation (e.g. process, product, pro- /retroactive). A more fundamental limitation derived from the conceptualisation of the 'regulatory stimulus' as a simple 'one-off' event.

In contrast a study of regulation and innovation in the chemical industry which attempted to overcome some of the theoretical and methodological weaknesses in this field, concluded that the regulatory stimulus was complex, and varied over time. Informal aspects of the regulatory process were found to have equal or greater importance than the formal aspects. In addition substantial industry input was noted in drafting regulations.

Standards adopted were based largely on 'feasible technology', which in most cases was already in widespread industrial use, and compliance was typically readily achieved.[27]

Consideration of the latter issue suggests dangers inherent in the concept of 'impact of regulation'. This is not to suggest that regulation has no effect, but that the development of regulation interacts in many ways with industrial development itself. The relationship between industrial and regulatory development may vary (across time, industries, between countries etc.). The hypothesis is advanced, that understanding of this relationship is essential for any account of the effectivity of regulations (whether on risk, or the economic or technological development of industry).

The Current Investigation

Reasons for Selecting the Paint Industry

Many studies of regulation of the chemical industry (particularly those dealing with regulation and innovation) have focused on petrochemicals, especially biologically active materials (e.g. drugs, pesticides). Attention has thus been focused on the fastest growing and most innovative sectors.

The paint industry was selected for this investigation because :

1) The paint industry provides a useful contrast to previous studies of the chemical industry since it is on the margins of the chemical industry; it is less innovative than other sectors, and is typically a user of materials developed elsewhere.

2) The paint industry is a well documented area, with numerous trade journals, a trade association, a trade literature abstracting service and fairly detailed government statistics which extend back over a considerable period.

3) The method of application and areas of use of paint result in very dispersed use of paint, bringing a wide range of workers and the public into contact with it. In this respect it has parallels with other examples of widely dispersed toxic materials e.g. asbestos.

4) Whilst it would have been desirable to analyse the effects of the 'latest wave' of regulation, at the time of this research some elements of this regulation had not been fully implemented in Britain (e.g. testing requirements for new industrial chemicals) or were too recent for their effects to be fully assessed. In contrast to most of the newer sectors of the chemical industry, the paint industry had already been subject to substantial specific

regulation, initially of worker hazards and latterly of consumer etc. hazards (in particular, hazards associated with paint pigments).

During the course of the investigation, certain aspects of the regulation of hazard in the paint industry emerged which were of particular relevance to the issues under examination.

1) It became clear that health concerns and regulation had played a significant role in shaping technological development in the paint industry.

2) The paint hazard which had received greatest attention arose from the use of basic lead carbonate (white lead) as the premier pigment in paint, which had caused 'near epidemic' levels of lead poisoning amongst pigment and paint makers and paint users. In the first quarter of the Twentieth Century, a fierce controversy developed over proposals to prohibit the use of white lead. This policy was adopted by a government committee but subsequently not implemented by the British government. Technical considerations played a central role in the regulatory debate. This process became the primary focus of the investigation because of the opportunities it afforded for insight into the state regulatory process, and because of the parallels it afforded with contemporary debates about the prohibition of asbestos and other carcinogens.

3) The control of occupational lead poisoning from lead paints has a broader historical significance. The development of regulation for this hazard coincided with the establishment of regulatory institutions for occupational health in Britain as well as the International Labour Organisation.

Moreover, it appears that the resolution of the controversy surrounding the prohibition of white lead, has played a significant role in establishing the institutions and principles of regulating occupational health hazards in Britain and elsewhere.

The Approach of this Study

A brief examination of the major groups of studies dealing with the regulation of industrial hazards has revealed a number of shortcomings. Many of these conform to a reduction of a complex social process, involving political, economic, scientific/ideological elements, to one of its elements.

For example, the first two approaches examined address regulation from a perspective that is, respectively, primarily 'political' and 'technical/ economic'.

In contrast, the current investigation adopts an explicitly 'multi-disciplinary' approach. Although the main focus is an analysis of the political process of development of regulation (of the hazards of white lead pigment for paints), this analysis is located in the context of the technological and economic development of the industry as well as the extent of (recognised) harm (i.e. lead poisoning). The interactions between these elements are analysed. Thus, the industrial structure provides the basis for the different 'interest groups'; economic and technological development poses constraints on the regulatory process; the effects of regulation on technological diffusion and the effects of both on levels of harm are examined. This approach involves a critical reassessment of models of the relationship between state and society.

Such an analysis raises problems of determining 'causality' in a complex and highly interactive system. One study, which has attempted to address similar issues, adopted an international comparative approach, relating regulatory policy to differences in the industrial context and regulatory processes etc. in the U.K. and U.S.A.[28]

In the current study, an international comparative study could not be fully developed because of data limitations. Instead, the study focuses o a highly polarised regulatory debate, in which the regulatory strategy adopted by the state was subsequently reversed. This process of rejection of a regulatory strategy already accepted within the state, highlights the conflicts inherent in, and constraints on, the regulatory process.

The historical approach adopted in this study enables us to assess the development of regulation in the context of long term changes that were taking place, as well as the consequences of the regulatory strategy adopted (in contrast, many contemporary analyses appear so bound up in their immediate circumstances that the potential for alternative solutions, and the selectiveness of the strategy actually adopted may be overlooked). It is our belief that historical investigations are valuable in unravelling the fundamental processes conditioning state regulatory activity and its effects. An understanding of these processes which may (albeit in a different form) be operating today, can play a useful role in illuminating contemporary debates about regulation.

A Framework for the Study of the Regulation of Industrial Hazards

The development of an analysis of the history of regulation of (white lead paint) hazards requires a model of the regulatory process, as part of the wider relationship between the state and society.

However the study of regulation is not simply a matter of state political processes. The identification of hazards and of possible control strategies raises the key role of knowledge in regulation. The issues underlying the eventual rejection of proposals to prohibit the use of white lead draw attention to the limits to state intervention in production and require an understanding of the relationship between politics/the state and economics.

Finally, a framework is needed that can accommodate the wide variety of of 'interest groups' involved (sections of industry and labour, scientists) and the divisions and alliances between these groups and within the state, in influencing and determining the eventual policy adopted by the state.

The various models of the relationship between state and society, and of the regulatory process have been reviewed in order to develop a model that is adequate to the process being studied. Particular attention is paid to recent developments in state theory which seem very pertinent to this study.

Paradigms of the Relationship between the State and Society

Alford distinguishes three paradigms for the relationship between state and society : pluralist, elite and class.[29] Each focuses on a different context of political action (respectively, the actions of individuals/groups, the role of bureaucracies and the role of classes in political processes). These paradigms involve different models of the role of the state, which is seen as serving to maintain respectively : cultural consensus by mediating between interest groups, the domination of existing elites, and the continuation of existing class relationships.

Alford identifies areas which are neglected under each paradigm. Thus the pluralist perspective ignores the sources of inequalities in power and resources between different individuals and groups. Whilst it provides a model to analyse the behaviour of actors, it can only 'see' those causes which are expressed in current 'behaviour' or conflict.[30]

The elite model ignores the origin and nature of the differences between the bureaucracies that constitute 'industrial society' (e.g. their differing social and economic interests, their differing 'power'.).

It would seem that the 'pluralistic' and 'elite' paradigms do not offer an effective basis for an analysis of the development of regulation. For example, this process involves a range of agencies whose different positions and interests are defined in relation to production.

In contrast Alford describes class paradigms as having explanatory power over (political and economic) class relationships, and the 'limits to policy formation by the state'. On this basis it would seem an appropriate perspective for our analysis of regulation.

At the same time, Alford attributes certain weaknesses to class paradigms, notably that they assume class interests are perfectly represented in class organisations. Social and cultural diversity within classes are played down, thereby implying that policy formation around non-class issues is unproblematic.

This generalisation pinpoints certain negative tendencies within class paradigms, but is not an adequate representation of the great diversity within class analyses of the state. A brief review has therefore been conducted of various class approaches, with particular emphasis on recent developments in theories of the state that seem particularly fruitful for this analysis.[31]

It is not intended here to recapitulate the various 'class' theories of the state. There has been an intense debate on these matters, and many important advances have been made in recent years. Instead, the major developments are outlined, and their problems and utility for the current investigation are discussed.

Class Theories of the State

Marx - the problematic inheritance

Class theories of the state typically take as a starting point the writings of Marx and Engels (this section will be addressing Marxist analyses of the state). A unified, comprehensive analysis of the state is however lacking here. Instead what remains is a set of fragmentary, and partly contradictory writings.[32]

Jessop identifies three major themes in Marx's writings on the capitalist state, which can be broadly summarised as follows:

1) the form and actions of the state are founded on the relations of production (particularly the antagonism between capital and labour).
2) the state as an instrument of class rule (the capitalist state serving to secure the interests of the dominant [capitalist] class).
3) the state as the factor of cohesion in a society (carrying out necessary tasks for the reproduction of social relations.)[33]

A variety of formulations in Marx and Engel's writings express these themes, and there is a certain tension between their different elements. These formulations have in turn been interpreted in a variety of ways. One-sided and simplistic interpretation of certain elements has led to the prevalence of mechanistic and reductionist variants of Marxism.

In particular the unbalanced development of the first theme has resulted in a conception of the state as a mere 'reflection' of the 'economic base', (a view that is hard to reconcile with the political diversity of modern states given the similarity of their economic organisation).

Divergent interpretations of theme 2 have led to the view on the one hand of the state as a functional instrument of the needs of capital (e.g. the State Monopoly Capital theory) and on the other that the state is a neutral instrument which can be seized by non-capitalist classes and used for their own ends.

These reductionist forms of Marxism exhibit profound theoretical difficulties and offer little potential as a framework for this analysis. Thus the process of regulation of workplace hazards would appear as a simple reflection of 'economic' processes or the needs of the politically dominant class, thereby discounting the role of workers and other groups in fighting against the hazard

Gramsci and the neo-Gramscians

Against this trend towards 'economic determinism' there have been significant attempts to elaborate a theory of political processes notably by Gramsci, subsequently extended by Poulantzas and others, drawing on some of the more 'political' writings of Marx (his 'political' writings on European history, and inter-alia, observations on the Factories Acts in Capital).

These have focused on the specificity of ideological and political as material practices, not reducible to the relations of production. The relationship has been described by Poulantzas as 'relative autonomy'.[34]

Gramsci rejects the concept of the state as a simple expression of economic forces or the needs of the (capitalist) ruling class. Although for Gramsci, "the state is seen as the organ of one particular group [the bourgeoisie in capitalist society], destined to create favourable conditions for [its] maximum expansion", the interests of non-capitalist classes and groups are also represented. "The state is conceived of as a continuous process of formation and superceding of unstable equilibria between the interests of the fundamental groups and those of the subordinate groups - equilibria in which the interests of the dominant group prevail, but only up to a certain point, i.e. stopping short of narrowly corporate economic interest."[35] In this process the interest of the dominant group is presented as the general interest.

Underpinning this conception of the state is an articulated model of power. In contrast to conventional Marxist theory which focuses on the coercive role of the state, Gramsci sees power as a relation between classes and social groups. The ruling class achieves cultural and ideological domination, winning the active consent of subordinate classes and groups. This 'hegemony' of the ruling classes is conducted through the creation of alliances between the ruling class and subordinate classes and groups.

Power exists not only in and through the state, but through wider 'civil society' - which comprises the whole range of private organisations (trade unions, political parties, religions and cultural organisation, the family etc.) distinct from the process of production and from the coercive apparatus of the state.[36]

One consequence of this model is that the state is a locus of class struggle, in which non-capitalist interests can be represented.[37]

The struggle for hegemony takes place primarily in civil society. Here, a key role is accorded to intellectuals (the term is used in its broadest sense to include not only 'producers of ideas' but also the 'organisers' of social activities).

For the point of view of this study, two aspects of the Gramscian analysis are particularly useful:

1) the emphasis on the key role of intellectuals (whether in civil society, the state or production) in creating the ideological framework for and organising hegemony. For example, the delicate process of state "equilibrium formation" between dominant and

subordinate groups draws attention to the role of intellectuals in state policy formation.

2) in the analysis of power, emphasis is placed on divisions and alliances within and between social classes and groups. The unity of a class is not assumed but is created in a process of representation and organisation (here the state is seen as playing a vital role in unifying the capitalist class and organising its domination over other classes).

The writings of Gramsci and particularly of Poulantzas have been criticised for a tendency to cede total autonomy to the "political" and "ideological" "levels" of society (illustrated by the vagueness of the concept of relative autonomy which is little elaborated beyond the statement that the economic is "determinant in the last instance").[38]

The Gramscian model, applied to regulation (or other state intervention into production) would focus on the need to maintain [political/ideological] hegemony. Constraints on the state's ability to intervene in production would receive little attention. There is clearly a danger here of seeing the state as, in some sense, an 'independent actor' (i.e. a view being similar to the elite or pluralist models) without seeing the integration between political and economic power/processes.

Whilst the Gramscian model offers a valuable tool for analysing ideological/political processes in state action, it would seem necessary to modify it to facilitate theorisation of the economic processes and their interaction with political processes.[39] This is particularly problematic in this study, since we are trying to relate 'political' and 'economic' processes, and in particular the limits they pose on state action.

The State Derivation Debate

Recent work which would appear to be of relevance has attempted to identify the role played by the state in capitalist society, focusing in particular on changes that have taken place in this role in advanced 'Western' states over the last 100 years. Two approaches are examined: the 'State Derivation Debate' and the work of Claus Offe.

The 'State Derivation Debate' which developed in the Federal Republic of Germany, draws not on Marx's political writings, but his analysis of the capitalist mode of production in Grundrisse and Capital. It attempts to establish the necessity of the state for capital.

One group of writers (sometimes described as the capital-logic school) have attempted to derive the need for a state from the limitations of capital itself - variously:

- to protect capital from its own anarchic process of competition (e.g. the Factory Acts!).
- to perform (infrastructual) functions which capital cannot perform.
- to maintain the (judicial etc.) conditions for the production and exchange of commodities (including labour power).

This approach has been criticised for its focus on the 'needs of capital' as determining the necessity of the state, to the virtual exclusion of other classes, class struggles and non-economic variables. As such it threatens to degenerate into a sophisticated form of economic reductionism - the state as an expression of the collective needs of capital.[40]

A more stimulating approach attempts to derive the state from social relations as a whole, posing the question of why, under a capitalist society, these appear as separate economic and political relations. Holloway and Hirsch[41] attribute this separation to the need, under capitalism, to separate force from the immediate process of production.

The state is thereby separated from, but dependent on, the process of capitalist accumulation. Contradictions in the accumulation process (including the contradiction between capital and labour) are the dynamics behind the development of not only the accumulation process but also the state itself.

This analysis has implications for the state policy formation and action. Following Marx's observation that the state is 'divorced from the real individual and collective interests' of capital, Hirsch questions whether the state can adequately act in the collective interests of capital. (as the 'capital logic' school might imply). The state cannot get outside the contradictions of accumulation, but reproduces them within itself. The state is restricted to reacting to the results of the process of accumulation (rather than the needs of capital). Hirsch also argues that crises will play a major role in redirecting state activities (since it is this stage at which the needs of capital are most likely to become apparent), but since crises are a product of contradictory forces, there will be conflict over their resolution. The state response will take the form of (politically determined) trial and error management.

The state derivation debate has played a valuable role by emphasising the 'unity in separation' of economic, ideological and political social relations - thereby counteracting the tendency to isolate these different 'levels' of practice (particularly evident in structuralist Marxist analyses). However, this approach sidesteps the question of policy formation and implementation.

The initial analyses in the debate bore a rather broad historical sweep. To date, there have been but few examples of applying this approach to the analysis of specific policy developments.[42] It is not clear yet whether this is an intrinsic consequence of the theoretical and methodological limitations of the approach.

Claus Offe

The final approach examined is the rapidly developing work of Claus Offe, which focuses on the problems of policy formation and the state. A recent paper identifies the characteristics of the capitalist state as follows:

i) Exclusion - of the state from production; the state has no authority to order or control production.

ii) Maintenance - of conditions for Capital Accumulation; the state must deal with threats to this process.

iii) Dependency - of the state on the accumulation process for its 'power' and resources.

iv) Legitimation- the state must convey the image that it pursues the general interest of society as a whole.

State intervention in support of production was initially through maintenance of an infrastructure (e.g. legal system, communications). The resources involved were intrinsic to the existence of a state, and could be allocated on the basis of (political or legal) authority. In addition to this 'allocative' activity, the capitalist state in the Twentieth Century has been increasingly drawn in to providing necessary inputs to production (capital, labour and other necessary commodities) which private capital cannot provide for itself because their production was, for example, not profitable or too risky or was a public good (e.g. scientific knowledge) This is described as productive activity. In the modern capitalist state the state produces education, technological change, energy systems etc.

Policy formation and the allocation of productive activities is seen as problematic.

Though studies of state intervention and policy formation have typically focused on the content of the policies adopted (problem recognition, role of different interests in policy formation, consequences of policies adopted), Offe stresses that it is important to analyse the methods of policy formation available. He identifies three types of decision rules available - bureaucratic, technocratic and democratic/political - none of which appear capable of solving the policy problems of productive activity by the capitalist state.

- Bureaucratic decision rules are effective for static allocative activities, where goals are set in advance, (e.g. by legislation) but cannot be successfully applied to the complex, decision load of production (where they tend to be inefficient or ineffective).
- Technocratic (rational-purposive) decision rules can effectively achieve specific goals. However the goals of state productive activity are set by the accumulation process itself, and are contradictory. Extensive purposive productive activity by the state, in the form of planning, is likely to involve greater control over the accumulation process than individual units of capital are willing to concede.
- Democratic decision rules, in which the state's clients determine policy through the political process, cannot be guaranteed to produce the policies for productive state activities. The state cannot rely on the measures favoured by the politically dominant groups, since these may not be the same as the measures required to maintain accumulation. (For example, the short term/sectional needs may not conform to the long-term general needs of capital). Conflicts may emerge between pressures for democratisation of the policy process and the state's role of Maintenance of and Exclusion from Accumulation.

Thus Offe concludes that none of the methods available for policy formation implementation of productive state activities has a potential for success, since they each generate specific contradictions and therefore tend to violate rather than establish the relationship between the state and the accumulation process. Though the state constantly attempts to reconcile the contradictions of its different policy-instruments, a stable strategy for the state, to develop and implement the productive activities needed for the accumulation process, is not available.

In an earlier paper,[44] Offe argues that capitalist states exhibit political selectivity (from their internal structure rather than, or as well as their environment) to be able to distil the broad interests of capital out of the competing short-term interests expressed through the pluralist political system, and to protect capital against anti-capitalist consciousness and struggle. Offe distinguishes four mechanisms of selectivity:

- structure - the range of access of the state, and its organisational and information resources
- ideology - of political institutions, leading to selective perception and articulation of social problems.
- process - institutional rule structures give some policies an increased chance of implementation while excluding others
- repression - use of force in certain circumstances.

This selectivity is not generally revealed (viz the state's legitimatory function) but becomes apparent in situations of political conflict. Offe suggests that there will be increasing contradictions between the state's actions to maintain accumulation and its legitimating role which in turn tend towards either breaches of legitimation or counter-tendencies such as reprivatisation of state economic functions.

Findings from this Overview of 'Class' Theories of the State

It is beyond the scope of this paper to attempt to synthesise the different approaches within Marxism to analysing the relationship between the state and classes, and the process of capital accumulation. However, it will be seen that the models that have been examined are far removed from crude instrumental or economic determinist analysis. Thus it is not possible to simply "read off" from particular actions by the state either the objectives and needs of a particular class or the imperative of economic processes.

Whilst it appears that a 'Gramscian' model, focusing on the creation of hegemony, is the most fruitful for analysing the process of regulation, it needs elaboration to pay more attention, i) to the relationship between state action and the accumulation process, and ii) to the structural characteristics of state policy making processes.

Jessop has attempted to bring together the implications of recent Marxist analyses of the state.[45] In place of analyses which posit the state as a 'thing' whether a subject or an agency of a particular class, he suggests that the state should be analysed as a system of political domination - State power is a 'necessary element in the reproduction of the capital relation', and also in turn a 'complex, contradictory effect of class (and popular democratic) struggles'. Jessop questions whether a theory of the capitalist state in general is possible. Whilst the state has an essential role in securing the preconditions for capital, and its structure and forms of intervention must be transformed as capitalism develops, state intervention has limitations in carrying out that role and is subject to influence by struggles. The state's action must therefore be analysed in its historical specificity.

The effect of these discussions it to open up new areas for concrete analysis within a Marxist framework. Whilst this case study may not allow definitive choice of one particular approach, it does demonstrate the value of this body of theory in developing a more adequate understanding of state activities while at the same time providing an empirical basis for further developments in state theory.

In the next section, the analyses which have been made of the process of state regulation of industrial hazards will be examined in the light of theories of the relationship between 'state and society'. On this basis, a framework for the current analysis is presented.

Models of the Process of Regulation

The writings of Marx in Capital on the Factories etc. Acts constitute one of the first attempts to analyse the process of regulation of industrial hazards.[46] Subsequently, there have been many historical accounts of the development of Factory legislation in Nineteenth-Century Britain.[47] Unfortunately the scope provided by the subject matter for historical detail is not matched in many of these works either by depth of analysis or theoretical contribution. Whilst some of the observations made by Marx reappear in a fragmentary form in these later accounts there is little evidence of either a critique or a development of these ideas.

These latter works concentrate on the activities of the reformers, their supporters and opponents in fighting for the enactment and enforcement of legislation. The underlying framework, often unspecified, is the evolution of the 'modern state', with its legal and administrative apparatus to limit the extent of the competitive system of production and protect those (workers) who were unable to protect themselves.[48]

The necessity, nature and limits of such intervention are rudimentarily analysed. In some accounts, history appears as a process of fulfilment of a 'pre-ordained' regulating state. Similarly regulation, once established is seen as having its own momentum, leading to its extension to other industries. The effects of the political process in the uneven achievement of state intervention are analysed.[49]

Factory legislation has constituted one of the main examples in accounts of the development of social administration and government intervention in economics in the Nineteenth Century. Within this approach there has been a debate about the role of 'Ideology' (viz. Benthamite thought) and 'Force of Circumstance' in stimulating this development.[50] In the latter, the state/government is seen as a 'subject', engaged on an evolutionary process of recognising and acting on social problems.[51]

Bartrip has argued that these models have little explanatory power, in the case of steam boilers, where the state failed to act against a known hazard.[52]

There has been surprisingly little investigation of the impact of regulation. The major exception is provided by numerous reports produced by professionals within the state or in private industry with responsibility for the control of industrial hazards. The objectives of such studies have been practical rather than analytic. Where reduction in harm has been noted, the main emphasis has been on 'charting progress' rather than distinguishing the precise components of the change and their determinants.

The analysis which has taken place into 'regulatory impact' has, in the main, been concerned with evaluating the activities of the enforcement agencies.[54] In contrast to the view of the 'social administration' school, a critical analysis has emerged which sees the enforcement agencies as ineffective against the power of employers and ultimately as adopting the same world view as the regulated industry or employers as a whole. This is expressed in low levels of prosecutions and the development of a consensual relationship between inspectors and employers.[55]

One approach, which can be traced back to some of the observations by Marx[56] sees the discrepancy between passage of legislation and its (non) enforcement as resulting from a collision between public political pressure (through Parliament) and (private) resistance by the ruling class to interference with the process of production. Carson sees this as the start of a process of 'conventionalisation' of Factory Crime, by which breaches of the law were seen as formal offences, treated differently to other areas of crime.[57]

Another approach, with roots in elite theory sees the regulatory agency as becoming 'captured' by the regulated industry. Though the agency was formed as a result of political pressure, and initially independent of the regulated industry the regulator eventually succumbs to its pressure and adopts the perspective of the regulated industry.[58] This explanation has been criticised for its conceptual inadequacy. It isolates enforcement agencies from the broader political context, and in particular assumes that the regulated industry was monolithic, with uniform interests (whereas in practice, 'a complex web of opposing and aligned interest' are at work which includes important divisions within the state and amongst the workforce).[59] There is a tendency in both these 'Marxist' and 'elite' approaches to assume that a consensual attitude by inspectors, and low levels of prosecution indicate lack of influence by the inspectors and non-compliance by employers.[60]

Given the existence of this controversy, there has been a surprising lack of empirical investigation of the impact of regulations - whether by the 'social administration school' (to examine the criticisms made of the regulatory process) or the 'critical school' (who have to confront the undoubted reduction in injury and fatality rates at work over the years). Such an exercise raises substantial problems.[61] There are substantial methodological difficulties in interpreting statistics relating to harm.[62] More fundamentally, the degree of harm is linked to economic cycles in the short term,[63] as well as longer term economic and technological change. Bartrip, in his study of steam boiler injuries, notes that legislation (to record accidents rather than to regulate boiler use) was not passed until the incidence of injury was already past its peak for technological and social reasons.[64]

In a study of local variation in the decentralised regulatory development of British air pollution legislation, Scarrow notes :

1) a significant degree of voluntary compliance (increased by inter-alia the wealthiness and the absence of coal mining industry, in the area).

2) significant differences in the propensity to declare smoke control areas (increased by inter-alia, the wealth/resources of the local authority and the perceived need [e.g. high levels of pollution, bronchitis]).[65]

Clearly the effects of regulation will have to be measured against underlying social, economic and technological dynamics. It would also seem to be misleading to divorce consideration of enforcement of regulations from the process of regulatory development itself.

Whilst the political process of regulatory development provides an important focus for studying regulation, the current investigation seeks to understand the process of regulation in its wider context, not only at the political/ideological/juridical level but also of economic and technological development.

Neither the 'social administration' nor the 'critical' school are adequate to this approach. An alternative framework has therefore been developed by re-examining Marx's observations on the Factories Acts, and considering how they might be elaborated in the light of recent developments in Marxist theory and the critique of existing analyses of regulation.

Marx's Theory of Regulation

In Capital, Marx is concerned to analyse the dynamics of the pure Capitalist Mode of Production.[66] The state is not theorised in this way. However, this account includes a number of observations on the development of factory legislation, and its political economic and technological determinants. These remarks are historically specific (and must be seen in the light of the emergence of the capitalist system of production as well as of a framework of state intervention into production), and fragmentary (in part contradictory). However they provide a useful starting point for a Marxist analysis of regulation.

Two main approaches to this analysis can be discerned: one focusing on regulation and the accumulation process, the other focusing on the political struggles leading to regulation. These two processes occur simultaneously. Contradictions can emerge between the two processes.

The different elements appearing in Marx's analysis are summarised below.

Regulation, Accumulation and the Interests of Capital

1) Capitalist competition tends to shorten the worker's life (e.g. by increasing duration of work), thereby reducing the availability of labour as a commodity and increasing the value of labour power by increasing the cost of labour reproduction. It is therefore in the [collective] interest of capital to limit this process to conserve the labour commodity. (p.376, p.623).

2) The existence of capital as individual competing units prevents the introduction of improvements in working conditions 'beyond' a certain point without the intervention of the state (p.611) even though these might be in their long-term, collective interests. Thus individual units and sectors of capital resist the introduction and enforcement of state regulation of their activities. (p.409, p.605)[67]

3) Regulation promotes the expansion of the capitalist mode of production by destroying pre-existing forms of [e.g. domestic] production (p.635) and promotes the development of forces of production (it favours the use of machinery, improved techniques and large scale industry) (p.604, 607), thereby increasing the concentration of production. In this process, though the duration of labour is reduced, its intensity is increased. Production is not only maintained but increased. (p.604)[68]

4) Once it has been applied to a sector, the surviving units of capital therefore 'welcome' regulation. It also creates pressure for the extension of regulation to other sectors of production,

i) by encouraging intensification of competition in other industries,

ii) capital in regulated industries demands equality in the conditions of competition. (p.621)

(this division in the ranks of capital shifts the balance of forces in the political struggle for regulation (p.409 - discussed below).

5) Whilst forms of regulation have matured the forces of production and benefitted (at least the larger, newer sections of) capital, this is not always the case. Certain degrees and forms of regulation were impermissable where and when they disrupted the process of accumulation itself (e.g. by the sudden expropriation of thousands of small producers if the ventilation requirements of factory legislation were suddenly enforced, p.612). Thus regulation has particular limits at a given time. These may become visible as a result of a lack of fit between the political process leading to regulation and the accumulation process - and expressed in terms of a failure to enforce legislation.

6) Regulation by generalising and maturing capitalist relations of production, also matures the contradictions and antagonisms of that process. (e.g. by increasing the size and homogeneity of the working class), thereby building the conditions for its overthrow and the creation of a new mode of production. (p.635)

The Political Struggle for Regulation

Differences in the rate and extent of regulation between different industries and at different times are analysed in terms of a highly complex balance of forces in Parliament and society as a whole. This balance of forces derives from not just the strength of labour vis a vis capital, but also divisions within capital and its political organisations and the development of alliances with sections of capital, labour and other strata.

Regulation here is seen as a concession wrung by the workers from the ruling class (p.390). The strength of the working class varied (e.g. it waxed during the growth of the Chartist Movement, increasing the strength of the 10 Hours Movement, but waned following the collapse of the Chartist Party p.393-7).

The major determinant of success was divisions within the ruling class. Thus the antagonism between agricultural and industrial capital, expressed in Parliament in the division between Tory and Whig was favourable to factory legislation, whilst the coincidence of interest of these two class fractions in the mining industry explained the 'delays and chicanery' surrounding mining safety legislation (p.626). Certain events (e.g. the 1848 uprising in France) reunited the ruling class (at a political level - in this case to oppose implementation of the 10 Hours Act, p.397). The division between regulated and unregulated sectors of capital, between these voluntarily (and compulsorily) complying and those not complying with regulation led to pressures at the political level for the extension and even enforcement of regulation (p.409, p.621-2, p.412). Thus the alliances of interests (the political representatives of not just the working class but also sections of the ruling class and other 'disinterested strata') supported the extension of factory legislation. (p.409) These alliances were influenced by broader political and ideological objectives.[70]

Regulation has to be viewed in its wider political and ideological context and could be conceded to secure legitimation and defuse class antagonism. (p.392, p.405) Parliament and the Factory Inspectorate were sensitive to these political pressures and to wider social values.[71] In addition the establishment of the principle of factory legislation, generated a juridical and ideological basis for its development and extension. The Factory Inspectorate in particular are seen as playing an active role in identifying health and safety problems and the need for further legislative developments.[72]

Thus for Marx, the history of the development of regulation is understood in relation to the technological and economic development of capitalist production and the political process in Parliament and beyond. These two processes are developing concurrently and interact. Contradictions between the political pressure for regulation and resistance from capital (at the point of production) were expressed in two ways :

1) in the passage, but non-enforcement of legislation whether by Parliament failing to provide adequate enforcement officers, (p.390, p.625) or because of the influence of manufacturers on the magistracy at local level. (p.401-4) as well as on judicial interpretation.[73]

2) in the piecemeal development of legislation (p.412) as well as granting exemptions and lower standards for some industrial sectors. (p.412, 406).

<u>The Interpretation of Marx's Analysis of Regulation</u>

Marx found that the early factory legislation accelerated the development of the capitalist mode of production and operated in the long-term interests of capital as a whole. Regulation was resisted by the affected sections of capital because it conflicted with its short-term sectional interests.

One possible interpretation of this, which has been advanced by some analysts, including the 'capital logic school' is that state regulation simply functions to advance the general interests of capital (against the narrow interests of individual units of capital).

However, such an interpretation begs more questions than it answers. For instance, it is clear that some forms of regulation would conflict with, not promote, the general conditions of capital accumulation. How does the state determine the regulatory strategy to be adopted? This takes us back to (Hirsch and Offe's) broader questions of how (and whether) it is possible for the state to recognise and implement (in this case regulatory) policies that will guarantee and maintain the process of accumulation.[74]

The critiques of the 'capital logic' school by Hirsch and by Offe are of value here. Hirsch questions whether the state can adequately act in the collective interests of capital, since the state is restricted to reacting to the results of the accumulation process(rather than the general, long term needs of capital which are not normally apparent), in a process of trial and error management of economic policy.

Similarly Offe questions whether the state has available mechanisms for policy formation that do not conflict with its exclusion from direct control over production.

The capital logic school, in contrast to the other Marxist approaches reviewed would seem to offer little assistance for an analysis of the political turmoil that characterised the development of regulation, not simply of overcoming the sectional resistance of capital, but of determining the content and extent of regulation to be adopted at a particular phase.

The development of regulation cannot be understood as a simple expression of the developing general needs of capital (whether its narrow economic needs or including its broader political needs). In place of such a 'class functionalist' approach, it is suggested that regulation should be seen as the result of a process of struggle, namely:

1) as one element of the state's necessary role in securing the conditions for continued capitalist economic development,
2) which is an area of conflict between different interests, and influenced, indeed stimulated by political pressures.
3) the form of the states intervention therefore varies not only with changes in the economic structure but also the political process.[75]

The development of regulation has therefore to be analysed in its specific (political and economic) historical context.

Regulatory activity is bound by complex and contradictory forces - of economic and technological development, (determining the hazard, the potential for control and the interests of different parties to control).- of political process (the articulation of different interests, their representation in [civil] society and through the state, balance of forces).

Since the form and content of regulation is determined by such complex historical processes it is important to analyse changes that have taken place, since Marx's analysis, in the economy, and civil society and the state. It is necessary to consider which aspects of Marx's analysis are historically specific and which might have more general relevance. On this basis an account of regulation will be developed that might be appropriate to advanced capitalist societies, drawing on recent developments in Marxist analyses of the state.

Subsequent Developments which a Marxist Analysis must take into Account.

1) Changes in Production

Marx was analysing the newly emergent capitalist economy, still surrounded by precapitalist forms of production. Whilst Marx's analysis of the role of regulation in maturing the forces and social relation of production (e.g. mechanisation, concentration) might have a general applicability, in a more advanced capitalist economy, the accumulation process will have a different form and will generate different (and Marx would suggest more profound) contradictions.

In particular, the generalisation and maturation of capitalist production has been marked not only by increased scale of production, but also by a greatly increased scientific and technological base of production. This not only creates different conditions and problems for state regulatory policy formation but it also may affect the process whereby capitalist production generates health hazards.

The Marxist analysis of industrial hazards sees these as an example of the transference (externalisation) of the social costs of production, generated by individual capitals in pursuit of profit, to the individual worker and society as a whole.[76] At the time of Marx's writing, concern focused on the sheer intensity and duration of labour i.e. to quantitative aspects of the production process. The increased technological base of production has been associated with the rapid introduction of new materials, new energies, new mechanical principles and new forms of organisation of production. It has been suggested that production technology is developing at an accelerating rate and is often more advanced than the technology for controlling the hazards of this production.[77]

As the hazards arising from the brute intensity of labour come under control (in the face of technical development and of regulation of production), attention has shifted to hazards arising from the qualitative aspects of production.[78] Regulation of these hazards will pose new problems for state intervention and may have different consequences for the development of production.

For example, latterday regulation seems to have continued to be a factor promoting the concentration of capital. However, with increasing stringency of regulation, the argument that regulation is economically functional for capital by reducing the reproduction cost of labour seems harder to maintain. The shift of the thrust of regulation from general ('quantitative') to specific ('qualitative') aspects of production might create a situation where regulation constrains the direction of industrial development sought by capital. Thus the implications of further regulation for the [long term] interests of capital are likely to be more ambiguous than the initial phase of regulation analysed by Marx.

2. Changes in the Political Process leading to Regulation

There has been a marked reduction in the sharpness of struggles over factory legislation. This may be linked to the changes noted above, namely that unregulated industries constitute a smaller and weaker portion of capital. Similarly regulation dealing with 'qualitative' aspects of production will tend to be directed towards specific sectors of production. Subsequent legislation may thus have a narrower scope than initial legislation and therefore offer less opportunity for concerted resistance by capital. In addition it is clear that regulatory struggles have become 'institutionalised'. The major features of this institutionalisation are summarised below:

a) The results of earlier struggles have assumed the form of more general rights.[79]

b) Alongside and underpinning this process is the development of state and private institutions which have a powerful mediating role in developing controls over conditions of work.[80] Inter alia this is marked by the professionalisation of factory inspection[81] and the development of the administrative apparatus of the state for policy formation and implementation in this area.

The use of enabling legislation, and the subsequent ability to apply detailed legal controls under this by the passage of Regulations and Orders, removed many developments from the public adversarial arena of Parliament to a private arena in which the state administration dealt directly with the affected parties.

c) This elaboration of political mechanisms is accompanied by an equally significant increase in the role of expertise in identifying hazards and the means of their control.[82] A body of knowledge, techniques and principles of occupation and environmental health and safety emerged. This expertise became articulated and developed its own scientific channels and professional bodies.

This change is discussed in more detail below. At this stage it is sufficient to point out that these experts, and their knowledge was not 'neutral', but was embedded in the politics of production and its regulation. In regulatory policy formation, political conflicts were in part arbitrated and their results legitimated through the activities of experts.[83]

d) In addition to national institutions, there was a growing involvement of international bodies (governmental, professional and economic) in questions of industrial hazards. Their emergence coincides with this particular case study.

Gramsci's concepts are of particular relevance in analysing these developments:[84]

- the growth of the apparatuses of civil society and its buttressing of the state,
- the establishment of minimum conditions of health and safety as an achievement of working class and popular struggle and a hegemonic concession by capital,
- the role of civil society and the state in maintaining hegemony - and within these, the crucial role played by intellectuals.

These developments must not be seen as a simple 'incorporation' of health and safety issues, but as a change in the process of dealing with conflicts over regulation of hazard. Whilst many regulatory developments have been removed from the arena of open political struggle, industrial hazards remain intrinsically an area of conflict of interest between capital and labour. Moreover, it is suggested that new contradictions emerge in the process of production and its regulation.

3. Increasing State Intervention in Economic Development

The past hundred years has seen the increasing involvement of the state beyond simply providing 'infrastructual' support for production (e.g. the legal system) but in providing direct inputs to production (ranging from state-funded knowledge-production and support for industrial development to state ownership of basic industries). The state's responsibility for industrial regulation thus becomes supplemented with a responsibility for industrial promotion. This increased state intervention requires expansion and differentiation of state apparatuses.

There is thus greater scope for tensions to arise between sectors of the state according to their functions and the degree to which each articulates various industrial and social interests within the state apparatuses.[85] At the same time, the opportunities for state intervention in industrial development to control hazards are greatly enhanced. However the exercise of such opportunities involves problems which will be discussed below.

4. The Increasing Role of Experts and Knowledge

In the process of regulatory policy formation, knowledge has had a political/ideological as well as a technical role. It has provided not only the technical options for regulation, but also a vehicle through which conflicts are resolved, and has served to legitimate the particular option adopted.

The increasing role of knowledge and expertise in regulatory development reflects not only the political institutionalisation of regulatory policy formation, but also a change in the regulatory project leading to an increasing need for information in this process:

1) Knowledge in the Identification of Hazards

Initial assessments of the extent and mechanisms of harm were crude, but adequate to the brutality of the production process. Improved standards of safety required more precise determination of the hazard (and the means of its control). In addition the successful control of 'immediately experienced' hazards (fire, explosion, mechanical hazards, acute toxicity) in addition focused attention on to (health) hazards that were expressed after considerable workplace exposure. At the same time, the acceleration of industrial/technological development dramatically increased the number of potential sources of harm.

Knowledge about harm was substantially shaped by the economic and politico-legal circumstances in which it was created. Indeed the means by which new hazards came to be scientifically and politically 'recognised' in the history of occupational health have typically shown more resemblance to a process of political struggle than a process of scientific discovery.[86]

It is not intended here to conduct a detailed analysis of the 'politics of knowledge' about hazards, since this plays a relatively minor role in our case study.

2) Knowledge in the Control of Hazards

The hazard controls being established at the time of Marx's analysis related primarily to the organisation of production, affecting the use of child labour and the length of the working day, and latterly to basic general health requirements (e.g. sanitation and general ventilation). Application of specific control technologies to deal with the hazards of specific processes was a more recent development, and required a far greater technological input, involving detailed knowledge of the production process concerned as well as of control technologies.

The increased technological basis of production created new hazards, as well as new opportunities for control. Realisation of the latter however might be constrained in the situation where the objectives of technological development were determined by private capital. In the absence of countervailing factors, it is suggested that technological development would prioritise market goals over hazard avoidance. As a result, innovation and diffusion of the technology of production appears to have taken place more consistently and at a greater rate than that of the technology to control those hazards.

The State's Need for Knowledge in Regulatory Policy Formation

The increased role of knowledge in regulatory policy formation poses a threefold problem for the state, regarding the existence, accessibility and accuracy of information and expertise.

It will be noted that much of this knowledge, particularly relating to production, is generated within or is the preserve of private industry. The uneven development of, and private control over areas of knowledge needed for regulatory policy formation can be a substantial constraint on state intervention. A variety of attempts by the state to fulfil its needs for information and expertise can be noted.

The state may encourage private capital to supply the information and technology needed to regulate/control hazards. This strategy has political effects on the regulatory process.[87] In addition, the state was able to tap the detailed knowledge of existing production technology acquired by its enforcement agencies (e.g. the Factory Inspectorate).[88] Where such knowledge/technology was not available, the state might be obliged to produce it itself.[89]

The Changing Nature of the Conflicts and Problems of the Regulatory Process

The changes described above in the political, technological and economic circumstances of regulation amount to a significant shift in the conflicts and contradictions inherent in the regulatory project. Whilst the conflicts of interest surrounding regulation, that Marx identified, continue, their form may change (e.g. the conflict between capital and labour about the establishment of regulation is subsequently expressed in terms of conflict over the balance between the level of risk and expenditure on hazard to be incorporated into legislation). However new contradictions may arise in the face of rapidly changing production technology, revolving around the state's exclusion from the process of industrial innovation compared to its responsibility to regulate the consequences of this process.

Regulation has been reactive to the effects of changing technologies of production. This has been characterised by a delay of 20-30 years or more in some cases between the introduction of a hazardous technology, the scientific and political recognition of the hazard and its regulatory control. The uneven development of regulation has continued (a result of the previous history of regulatory struggles, the nature of the hazard e.g. to the environment, the consumer, workers at different stages in the production process, the representation and resources of the different interests involved and the resulting balance of forces expressed through the state apparatuses). As a result of this complex history, state regulatory activity has frequently been fragmented, with different agencies responsible for controlling the hazards of a single industrial process to workers, consumers and the general environment, or different standards applying to an occupational hazard in different sectors of industry.[90] These changes have been expressed in crises for and failures of the existing legal/administrative arrangements for regulation. These crises in turn have provoked periodic reforms of the regulatory system.[81]

Limitations on the Development of Regulation

Following Marx, regulation is seen not as an external force acting on an (otherwise static) economy but as highly integrated into the process of development of production. The development of regulation is seen as a product of a political process and an economic process which may be in tension with each other.

Whilst for Marx the major struggles surrounded the initial establishment of regulations, subsequent struggles have been concerned with the form and extent of further regulation of industrial hazards.

It is proposed that there were particular conditions for the successful application of further regulation. The technical and economic context of regulation had a significant effect on the political viability of different forms of regulation. These are discussed with particular reference to a reactive process of regulation (i.e. which operates retrospectively to industrial development).

The Role of Technological and Economic Factors as Constraints on the Process of Regulation

"Is it not so that safety standards are oriented to what is technically feasible, and that in a commodity-producing society the historical supposition for the technically feasible is what is economically justifiable".[92] J.Hallerbach (1978).

Though it is possible to identify technical limits to the degree of hazard control that can be applied at a particular stage, and hence to the extent of regulation that can be introduced, in practice these do not appear to have determined the stringency of standards adopted, or whether regulation is introduced and enforced.

A major determinant of the political viability of a regulatory proposal is the degree of resistance by capital, which itself is a product of the economic effects of regulation on, and the structure and organisation of capital (and in particular that sector to be regulated). Regulation which poses a significant threat to the development of the accumulation process is unlikely to succeed. These 'economic limits' to regulation are not fixed, but are balanced against the strength of political forces towards regulation (determined by the degree of hazard and the representation of the forces supporting regulation).

Control technology has an immediate effect on the 'economic limits' to regulation insofar as it sets the (investment or production) costs of controlling that particular hazard (relative to the economics of production in that sector). Control technology also has important effects on the political process of regulation, influencing the ability of the proponents of regulation within and outside the state, to project an economically and technically viable regulatory strategy.

Success in retrospective measures to deal with the hazards of pre-existing production processes depends on the availability of effective "add-on" control technologies at a price which is acceptable to that sector of capital. State requirements for capital to install "add-on" control technology are likely to meet considerable resistance since they are likely to increase capital costs without increasing production. Where these costs are particularly high, the successful application of retrospective regulations may not be possible.

A (technologically or economically) more viable hazard control solution than "add-on" safety technology in the long term is likely to be the development of an intrinsically safer production technology. In the case of occupational hazards this often involves mechanisation, obviating the need for workers to come into contact with the hazardous process. However this is unlikely to be achieved retrospectively by a reactive regulatory system - except insofar as subsequent generations of production technology are designed to conform to the regulation introduced.

One specific circumstance in which retrospective regulation is likely to be successful is where a new generation of production technology is being introduced, as part of the economic and technological development of the industry, which confers not only economic benefits but is also less hazardous than its predecessor. Resistance by capital is likely to be weakened because the change offers economic benefits. More significantly the existence of firms which have 'voluntarily' adopted safer technologies (whether as a result of economic or political pressures) will not only 'divide the opposition' but also can generate a countervailing pressure supporting regulation by giving these firms a competitive advantage over non-compliant firms (an example of regulation favouring the concentration of capital).[93]

These circumstances also favour regulation since the knowledge required for controlling the hazard is available (within industry and hence via the Factory Inspectorate to the state), and the existence of already compliant firms makes non-compliant firms more politically vulnerable.

These observations regarding the circumstances for successful introduction of regulation suggest that the 'direct economic and technological impact' of regulation will be fairly limited, and would appear in many cases to merely bring the standards in the more backward enterprises into line with good practice in the industry.[94] Indeed, such an approach is explicit in both the legal phraseology and the enforcement of hazard regulation.[95]

However it is important to note that technological and economic development may be substantially influenced by informal pressures, which can be as important as formal regulation.[96] These include the threat of extension of regulation, pressures from enforcement agencies, other legal provisions (e.g. for compensation or notification of injuries), and political pressures from affected groups or from wider social concern.[97]

These considerations suggest that the technical, economic and political conditions for the successful control of industrial hazards by the introduction of 'retrospective regulation' are markedly narrow. However, an open failure by the state to respond to articulated pressure for the control of recognised hazards would pose a crisis of legitimation for the state (and possibly for the economic system). To offset this possibility, it is suggested that the political regulatory system operates in a very selective manner, to give some outcomes a better chance of success than others thereby preventing the proposal or implementation of regulatory policies that would conflict with the development of capital (e.g. by threatening to eliminate or interfere with the profitability of a significant sector of capital). The first stage of this selectivity is the 'recognition' that regulation is necessary and feasible. The major component of this has been the struggle to identify the existence and causation of a hazard not only scientifically but also politically. In addition regulation may be seen as unfeasible where technical and economic circumstances limit the ability (e.g. of trade union, consumer etc. groups, or the state) to pose a credible regulatory control strategy.

Where a hazard has become recognised, but circumstances for successful regulation do not exist, the selectivity of the state policy process may be expressed by the mobilisation of alternative regulatory outcomes than the enforcement of effective hazard control. These are discussed below in the case of the control of occupational hazards under codes of process-specific Regulations in British factories.

Whilst such selectivity in part operates within 'civil society' it also exists within the internal activity of the state. Offe's analysis of the mechanisms of selectivity of state policy-making can be applied here.[99]

i) Structural selection mechanisms would include the exclusion of the state from control over production and its consequent dependence on industry for technology, and information needed for regulatory policy formation.

ii) Selectivity of state rule making processes includes the development of consensual mechanisms with the regulated industry for the introduction of regulation, thereby affording considerable opportunity to influence the outcome. This is one example of the significance of the form of representation and access by different interests to state decision making in shaping the regulatory process. Whilst direct representation of workers developed in the early stages of occupational hazard regulation,[100] representation of the victim group in environmental and consumer hazards may be less developed, and state agencies frequently adopt a responsibility by proxy for such interests.[101]

iii) Ideological selectivity of the state is expressed through its adherence to a regulatory philosophy which, for example, embodies a balance of risk against the cost of control.[102]

The Pattern of Development of Regulation of Occupational Health Hazards in Britain

Marx's initial observations have been elaborated into a more general framework for analysing the process of regulation and the tensions and contradictions inherent in that process. This framework will be applied to the overall development of regulation of occupational health hazards in Britain, focusing in particular on the characteristics of workplace regulation in the period of this case-study, which was based on the state prescribing certain safety measures to be adopted for specific production processes. The technical and economic limitations of such regulatory activity, and the problems this poses for state political/policy processes a discussed.

Main Phases in the Regulation of Occupational Hazards in Britain

Four phases can be distinguished in the regulation of occupational hazards in Britain:

1) 1802-1901. Establishment and generalisation of basic Factory Legislation

   This was conducted by Parliament passing series of laws (the Factories Acts) which laid down basic conditions to apply in workplaces, as well as establishing procedures for enforcement and for monitoring known occupational hazards (diseases, accidents). This legislation did not typically include process specific requirements.

2) 1890-1970. Development of Industry/Process Specific Regulations

   These were drawn up under the "enabling" powers of the Factories etc. Acts; policy making being conducted through government Departments

They laid down certain safety measures to be adopted in the specified industries/processes.

3) After World War II. <u>Development of Occupational Hygiene etc. Standards</u>
In particular, workplace hygiene standards were developed for exposure to chemical and physical stresses (including noise, light, heat, vibration, radiation), within which any process could be operated. Such standards were first set systematically in the U.S.A. in 1945. Their use was not formally recognised in Britain until the 1960s. Standards were developed through expert committees, often outside the state.

4) 1974 and subsequently. <u>Development of Pro-Active Legislation</u>
The 1974 Health and Safety at Work etc. Act and associated legislation constituted a significant reform of regulatory practice. It had three major objectives:

1) the enactment of general duties to keep work processes 'safe',
2) to require safety to be incorporated into the design of future work processes and systems,
3) to require testing of new materials and equipment (e.g. toxicity testing chemicals).

This legislation in addition reformed the fragmented structure of regulatory agencies. Policy formation was to be achieved by the development of a tripartite Health and Safety Commission (including industry, union and state representatives) to determine policy and expert advisory committees.

The Emergence of Process-Specific Regulations

In the latter part of the Nineteenth Century, a state regulatory strategy began to be established based on prescribing detailed precautions to be adopted for specific production processes. Such a strategy conformed to the empirical tradition of the English legal system, based on specific provisions that were interpreted according to the letter of the law (in contrast to the 'continental' legal system in which general legal rights and the spirit of the law played a greater role) as well as to the political circumstances in which legislation could be won (i.e. the powerful resistance to legislation made it easier to gain a Parliamentary majority for legislation affecting a small, specially hazardous sector of industry than for industry as a whole). Thus legislation was introduced to deal with specific social evils.[103]

Drafting such legislation posed major problems for the state, since it required not only legal experience, but a substantial amount of technical knowledge of production processes and their control. This need for specific legislation was problematic in the face of the wider range of, often rapidly changing, industrial processes.[104] Whilst specific Acts of Parliament could be used to develop such regulation, this process was slow and not well suited for the technical tasks involved (nor, it might be suggested, as a means of mediating between the interests involved).

To overcome these problems, a new method of regulation evolved, whereby detailed rule making was transferred to the state administration (under enabling powers defined in Acts of Parliament, with Parliament in addition carrying out an overseeing role). The development of these arrangements is marked by the creation of more elaborate consultation mechanisms at the same time as moving towards centralisation and uniformity of standards.

Under the 1864 Factory Act, employers could be requested to draw up 'Special Rules' for the conduct of their business and submit them to the Home Office for approval. However employers' rules had proved of little value and the power was withdrawn in 1878. Such rules could continue to be requested under specific Acts of Parliament. In particular an Act of 1883 required occupiers of white lead factories to draw up such rules (as well as laying down specific precautions to be adopted).[105] Whilst the use of employers' Special Rules minimised the legislative and technical responsibility and the problems of mediation with employers for the state, they had obvious shortcomings of ~~lack of~~ variability in stringency and technical base of standards adopted, and administrative inefficiency.

The 1891 Factories Act gave the Home Secretary powers to regulate 'dangerous trades'. Here the Home Office drew up Special Rules. These were then submitted to every employer involved. Each employer could accept them, negotiate amendments or appeal to a public enquiry against the Rules. (There was no provision for appeals by workers until 1895). This involved a substantial process of negotiation, after which a variety of modifications of the Special Rules might apply to a given industry. The 1901 Factories Act amended this procedure by allowing copies of the rules (called Regulations) to be published centrally, and by allowing a centralised appeals procedure. The process was thus speeded up, and only one code would be in force in an industry. The Regulations were then laid before Parliament and unless challenged (a rare event) became legally binding.[106]

In practice, employer and employee representatives would be involved in direct discussions with the Home Office about the Regulations while they were still in draft form (and sometimes were involved at an earlier stage), thereby acquiring agreement to the provisions in advance and minimising recourse to the appeals procedure. (In addition the Home Office had powers to exempt classes of firms from specific clauses of the Regulations).

In drafting the Regulations, the Home Office were able to draw on the experience and technical expertise of the Factory Department. [N.B. whilst the Special Rules under the 1891 Act typically followed a Departmental Enquiry, established by Parliament, Regulations were typically in response to investigations conducted within the Home Office by the Factory Department.]

Regulations thus offered the potential for a more rapid and flexible method of regulating industrial hazards than the time-consuming Parliamentary process. Some 30 sets of Regulations on specific industries or processes were thus passed between 1901 and 1926.[106]

The use of Regulations shifted the main policy and decision making arena from Parliament to the administration. This had several effects:

i) The administration provided a more systematic basis than Parliament for the initiation of regulation, with a more direct role for its technical , the Factory Inspectorate.

ii) Whilst the opportunity for public political pressure was thus reduced, the affected parties had a more systematic opportunity to express their interests.in the drafting of Regulations. In this way, Regulations were introduced on a consensual basis.[108]

iii) The more direct role of the Factory Inspectorate in the original drafting, and subsequent negotiations over Regulations enabled them to utilise their detailed knowledge of the industries under their jurisdiction, which included not only knowledge about the dangerous processes themselves but also any control measures that had been introduced by the more advanced firms.

The evolution of this policy formation process for occupational hazards represents an attempt by the state to overcome the problems of the preceding regulatory process. However it also involves the establishment of new mechanisms of selectivity in state regulatory activity.

Selectivity in the Development of Process Specific Regulations

Where a hazard has become 'politically recognised', but the technical and economic conditions for the acceptance of effective regulation are not met, the selectivity of state policy processes can be observed in a range of outcomes:

1) Failure to regulate - this may provoke sharp conflicts between those interests supporting and opposing regulation, which would in turn threaten to undermine the state's need to convey itself as having a neutral role in class and other conflicts. Non-regulation may be a possible solution where those interests supporting regulation are weak.[109]

2) A more frequent outcome has been to substantially delay the introduction of regulation.[110] (Although this has short-term ideological costs, delays may allow for the development of the economic and technological conditions for Regulations to be introduced).[111]

3) Introduction but non-enforcement of Regulations (whether by the administration or the judiciary).

4) Introduction of Regulations that are inadequate to the task of controlling the hazard.[112]

In the latter two cases, the ideological function of regulation can be seen as taking priority over its technical function to reduce hazards. However, such a strategy is open to political challenge where it demonstrably fails to reduce hazards.

Although this process is intrinsically less easy to demonstrate, it is suggested that selectivity operated in situations where the conditions of the acceptance of state regulation were met. Here selectivity would influence choices between available control technologies/regulatory strategies to favour the adoption of solutions which imposed minimal costs for and constraints on production.

Since this case-study focuses on the (unsuccessful) proposal of the prohibition of a toxic material, it is useful to examine the problems posed for policy formation and implementation of this regulatory/control strategy.

The Prohibition Strategy

Prohibition is defined as a regulatory strategy which forbids the use of a hazardous material. In contrast, Regulation allows the continued use of the material, subject to defined safety precatuions.

In Britain the Prohibition strategy has been implemented in three cases of occupational hazard.

White Phosphorous in Match making

White phosphorous, used in match making, was responsible for necrosis of the jaw amongst workers. Its use in match making, and the importation or sale of matches containing white phosphorous was prohibited in 1908,[113] following a resolution from the International Association of Labour Legislation.[114]

Whilst the use of phosphorous was essential in match making, a substitute was available in the form of the other allotrope of phosphorous, red phosphorous, which was held not to cause this hazard. The prohibition could thus be effected with only minor changes in the production process.

Carcinogenic Mineral Oils for Lubricating Mules in Spinning

The 1953 Mule Spinning Regulations[115] forbad the use of (shale) mineral oils in lubricating the spindles of self-acting mules in spinning, which had been identified as a cause of (malignant) epitheliomatous ulceration (in particular scrotal cancer) from the beginning of the century, and a 'notifiable disease' since 1919.[116]

Use of shale oil was not essential for the production process and substitutes (viz. animal and vegetable oils) were readily available. By 1953, when the regulations were introduced, the use of mules in spinning had virtually ceased.

Other, more important (economically and in terms of hazard) uses of carcinogenic mineral oils were not prohibited - indeed their use was increasing rapidly in this very period e.g. as lubricants/coolants in metal cutting.[117]

Carcinogenic Aromatic Amines

The Carcinogenic Substances Regulations 1967[118] prohibited the manufacture or use of certain carcinogenic aromatic amines in factories with three exceptions:

i) use of the material in research

ii) production of the material as an intermediate in synthesising other materials - which had to be carried out in a closed system

iii) use of materials containing up to 1% impurities of these carcinogenic substances.

Certain other aromatic amines are also regulated, and can only be used with certain restrictions. These materials were widely used, as raw materials in the dye stuffs industry and as additives in other chemical processes (e.g. Beta-Naphthylamine used as an anti oxidant in rubber tyres).

The existence of a bladder cancer hazard in these industries had been known since the turn of the century, and the cause identified since 1946. The manufacture of B-Naphthylamine by ICI stopped in 1949. By the time the Regulations were introduced, substantial use of these materials had ceased in this country [119] (although recently attention has focused on possible cancer risks of dyes based on one of these carcinogenic amines - benzidine).[120]

Although the prohibited materials were of major importance for the processes they were used in, the availability of homologous materials (not regulated/ thought to be carcinogenic) facilitated the development of substitutes.

A number of points are immediately apparent :

1) Prohibition has been used to regulate toxic materials capable of causing severe harm, by long-term exposure even to small quantities of a material.

2) It has been used in situations where it had little impact on the process of production in use because substitute materials, which could be adopted without substantial changes in the production process, were either readily available or had already been introduced by the time prohibition was implemented (this was in all cases a substantial period after the identification of the hazard).

3) Prohibition has been an uncommon regulatory strategy.

The Difference between Prohibition and Regulation

The distinction between Prohibition and the conventional strategy of Regulation is blurred in the case of mule spinning, where the material banned is incidental to the production process. Similarly the exemption allowing the use of carcinogenic amines as a chemical intermediate in closed systems meant that for some sectors of the chemical industry their use was Regulated rather than Prohibited.

There is thus a certain overlap between the Regulation and the Prohibition strategy; both are examples of process specific regulation. However, Prohibition of a material that is of central importance to the product or production process of the regulated industry, or of economic importance to other industries conforms to an extreme case of process specific regulation. It poses different (and potentially much deeper) problems for policy formation than Regulation. In particular :

1) Whereas the (economic) costs and (health) benefits of Regulation are met directly by employers and workers in the regulated industry, the impact of Prohibition extends potentially to the raw materials suppliers and consumers of products of the regulated industry. All three industries (suppliers, users, consumers) máy thus experience costs of transition to new materials and altered operating costs subsequently. The transition costs will be very high if their production processes are dedicated to a particular material (and may e.g. for raw material suppliers result in the displacement of one industrial sector by another).

2) The impacts of Regulation produce a pattern of interests supporting and opposing regulation which have already been discussed (e.g. division between capital and labour and between older/smaller and newer/larger sections within the regulated industry). Prohibition generates a very different set of impacts, and potentially a much more complex pattern of interests, spread across supplier, user and consumer industries.

3) The problems of mediation between interests and consensus formation are consequently more complex for Prohibition than Regulation. The state is faced with a need to decide which industries/interest should be represented, and to which most weight should be given.

4) Prohibition involves a degree of state intervention that is potentially much greater than Regulation, not only because of its potential economic impact, but more importantly because of the redirection of production processes and relationships between industries that it involves. (In contrast, Regulation affects the conduct of production, but leaves the production process unchanged. Consequently it can be applied on an incremental [e.g. function by function] basis.)

5) The problems of policy formation are greater with Prohibition than Regulation. The technical problems are different and potentially more profound as well as covering a wider segment of production, and the state's information requirements are much greater.

While Regulation requires the (economic and technical) availability of specific control technology, Prohibition requires either the (economic and technical) availability of materials which can be substituted with no change in the production processes, or if such perfect substitutes are not available, the necessary changes in production technology. Moreover, adjustments in other phases of the whole chain of production are also likely (suppliers, users, consumers).

In developing a policy for Regulation, the states information needs are mainly restricted to the technical and economic consequences of applying control technology to a process. In developing a Prohibition policy the state needs,

i) direct information about the characteristics of the production process itself,

ii) information about the economic performance of industry (of a much broader sort than under Regulation and including for example relationships between industrial sectors).

The nature of the problems for state policy formation and implementation for Prohibition will vary according to the production process involved (particularly regarding ease of substitution). However this brief examination demonstrates that these problems are potentially harder to resolve than with Regulation, and in particular that a broader degree of state intervention may be involved. These problems will be examined in more detail in the case of the Prohibition of white lead in paints.

The Reform of the Regulatory System based on Industry/Process-Specific Regulations

To conclude this chapter, a brief examination is made of the subsequent development and reform of the regulatory process (for occupational hazards). This aims to indicate the continued operation of some of the factors identified in the analysis of industry-specific Regulations, and to demonstrate the potential value of historical studies of regulation in understanding the contemporary regulatory debate.

The development of the system of Industry/Process specific Regulations has been analysed as a consequence of changes in the economic, technological and political circumstances of 'the regulatory project'. Contradictions and tensions inherent in the system of retrospective regulation of industrial hazards were discussed. It is suggested that the subsequent development and reform of the regulatory system can be understood as a response to the continuation of these changes, the exacerbation of the tensions underlying process specific Regulations leading to failures of, and challenges to, the adequacy of the existing regulatory system. Though detailed analysis is beyond the scope of this thesis, it is useful to make some general indications regarding the development of occupational hazard legislation in Britain (focusing particularly on toxic materials).

1) The development of the science and technology of industrial hygiene (and in particular monitoring equipment) allowed the establishment of 'occupational hygiene standards' for exposure to contaminants in the workplace etc.[121] This allowed a new form of regulation, in place of performance standards (specifying how a process was conducted), of compliance standards (the consequences of a process, however conducted, for the workplace environment) which could be applied to all workplaces.

   In Britain the state set few industrial hygiene standards, but adopted (as guidelines without legal status) the Threshold Limit Values set by the American Conference of Governmental Industrial Hygienists.[122] Hygiene standards were used as a supplement to and method of interpreting the provisions of existing Factory Laws and Regulations.[123]

2) <u>The Health and Safety at Work Act 1974</u>

   This Act reformed the structure of regulatory agencies for industrial hazards, instituted new methods of policy formation and new means of regulation.[124] These can be related to problems in pre-existing arrangements.

   i) The enactment of industry/process specific Regulations had failed to keep pace with technological development in the regulated industries themselves, let alone the new industries and processes that were being introduced.[125]

ii) The existing regulatory apparatus, reflecting the specific history of its establishment, was fragmented into a variety of Inspectorates (Factories, Mines etc., Offices etc., Agriculture, Railways, Nuclear Establishments) often within different government departments. Better coordination of resources, policy and standards were sought between these agencies, and with those bodies dealing with environmental and consumer hazards.[126]

iii) A series of political crises had arisen from the demonstrated failures of the existing apparatus to control industrial hazards,[127] throwing in doubt the adequacy of enforcement and policy formation procedures.

iv) The discovery of 'new' hazards (especially chronic health hazards such as cancer) from some of the vast number of industrial chemicals undermined the conception of toxicity as a characteristic of specific 'poisons', and made untenable the presumption that a material was 'innocent until proven guilty'.[128] Instead, pretesting of industrial chemicals (e.g. on experimental animals) was called for.

The state might have attempted to deal with these developments by an extension of process-specific Regulations. This would require a massive increase in the coverage (and stringency) of Regulations.

The sheer size of this task would pose a substantial policymaking problem for the state and would involve a greatly increased degree of state intervention. It could be argued that such a strategy involving detailed specification of safety precautions would have entailed an unacceptable degree of state intervention verging on direct control over the process of economic development in the interests of hazard avoidance.

In the event, the solution adopted to regulatory reform exhibits contradictory tendencies, with 'trade-offs' for example between the scope and stringency of regulation, that serve to satisfy pressures for improvement and extension of the regulatory system, while maintaining the exclusion of the state from direct control over the development of production.

Thus the Act is based on general legal duties for employers to maintain the safety etc. of the workplace. These are frequently qualified by the phrase "so far as is reasonably practicable" which explicitly allows a compromise to be made between control costs and the degree of hazard avoidance. The use of specific Regulations is to be supplemented by the production of 'quasi-legal' and non-legal Codes of Practice and Guidance Notes.[129] This move away from legislated standards was intended to allow the more rapid drafting and updating of technically complex and rapidly changing standards. The Robens' Report, on which the Act was based, included a strong call for a return to 'laissez-faire' approaches to safety, away from increased state intervention, emphasising the need for increased role and responsibility for employers and self regulation.[130]

In contrast, the Act reflects pressures for democratic control and accountability of regulation by giving trade unions a role in both regulatory policy formation (through the tripartite Health and Safety Commission) and at the workplace (with consultative rights for union safety representatives and committees).

A major aspect of the Act is the inclusion of 'pro-active' requirements for testing and design to determine the hazards of industrial processes and products in advance of their application. These can be seen as both an attempt by the state to protect workers by identification and hopefully control hazards in advance of the establishment of new production facilities and also force individual units of capital to protect its new processes from the risk of regulation as a result of unforseen hazards.[131]

The design and testing of new products and processes are the responsibility of industry itself. This reliance on industry generated information about hazards and production processes in part fulfil and in part obviate the state's information needs.

Though a definitive examination of reform of workplace regulation has not been attempted, the above considerations suggest that the processes underlying the development of specific Regulations have continued to operate, albeit in a different form, during the period of regulatory reform.

CHAPTER TWO

THE OVERALL DEVELOPMENT OF THE PAINT INDUSTRY

THE OVERALL DEVELOPMENT OF THE PAINT INDUSTRY

Introduction

As noted in the previous chapter this study examines the relationship between the development of industrial technology, harm to workers and other groups, and the regulation of the hazards of that technology. The study focuses on the technology of white pigments used in paints and its regulation.

The next chapter documents and analyses the innovation and diffusion of pigment technology. However, first it is necessary to locate that process of technological change in the context of the overall development of the paint industry.

This chapter briefly describes the changes that have taken place in the paint industry, its technology and markets. In particular attention is directed to :

1) The development of the paint industry and its markets.

2) The pattern of technological change in the paint industry and its key determinants.

3) The major innovations and their diffusion into use in paints in turn of each of the major constituents of paint: resin, solvent, additives, pigments as well as paint application technologies. In this account the major determinants of the changes that have taken place are indicated. Cases are noted where concern about health and environmental hazards and government regulations have influenced this process.

4) Finally a quantitative analysis is presented of the pattern of concern about hazards to health and the environment arising from the paint industry.

The Development of the Paint Industry and Its Markets

The industrial manufacture of paint materials in Britain dates back to the Seventeenth Century; by 1850 there were about 250 manufacturers of varnishes, pigments and paste paints, increased to over 400 by the beginning of the Twentieth Century.[1]

At this time, a specialised paint mixing industry was little developed. Most paints were mixed 'on site' by craftsmen from raw materials (pigment, linseed oil, dryers), a practice which continued amongst housepainters until the Second World War. The first 'ready mixed' paints were introduced in 1870 and achieved significant use in Britain by 1912.[2] This change over allowed considerable labour savings, and reduced the craft status of painting work.[3]

Thus the responsibility and expertise of paint formulation was gradually transferred to a paint industry which was emerging slowly at the interface between raw material manufacturers/distributors and paint users. A large number of paint making firms were established at the end of the Nineteenth Century,[4] most of which employed fewer than 200 workers.

Though the number of paint making establishments by 1968 was, at 397, not much different from 1900, this disguises a massive process of concentration. Thus while establishments employing over 500 workers accounted for a negligible proportion of net output in 1900, they contributed 12.4% of output in 1935 and 61.5% in 1970.[5] Statistics of changes over time in employment size distribution of paint industry establishments are given in Table 2.1.

The bulk of the paint making industry is involved in mixing the products of other sectors of the chemical industry, though the larger paint firms may make their own resins (especially alkyds). However, although the

TABLE 2.1 Changes in Size Distribution of Paint Industry Establishments

a) Percentage Contribution to Net Output of Paint Industry Analysed by Employment Size within Industry.

Year	Percentage Contribution to Net Output by Establishments Employing 1-24 Workers	25-99 Workers	Over 100 Workers
1930	15.8	26.3	57.9
1935	16.2	29.5	55.2
1948	10.8	26	63.1
1951	9.5	22.9	67.9
1954	8.7	21.2	70.1
1968	9.5	9	81.7
1970	13		87

Source: Historical Record of Census of Production[4] 1907-1970

b) Percentage Contribution to Net Output and Total Employment of the Paint Industry by Establishments Employing over 500 workers. 1900-1970.

Year	% of Net Output	% of Total Employment
1900	0	0 *
1935	12.4	12.9
1951	31.9	31.7
1970	61.5	54.3

Source: Historical Record of the Census of Production 1907-1970.

* F.Armitage, The British Paint Industry 1967 op.cit.

paint making industry achieved a separate identity from raw materials manufacturing during the Twentieth Century, the process of industrial concentration has increased the linkage between (the larger) paint making firms and the pigment and resin manufacturers.

The continued existence of the smaller paint firms is a consequence of the relatively limited processes they are engaged on (i.e. mixing and packaging of materials), as well as the existence of local market niches. However the larger firms have economies of scale and are able to maintain a more substantial research effort.[6] This technological and economic advantage is likely to lead to increased industrial concentration.

The much higher capital requirements of raw material production (of resins, pigments and solvents) is associated with a near monopoly situation amongst producers.[7]

Figures for Paint Industry Sales and Employment and capital investment for 1907-1970 are given in Table 2.2.

TABLE 2.2 Paint Industry Sales, Employment and Capital Investment 1907-1970.

Year	Total Sales and work done	Total Employment	Administrative, Technical, and clerical employees as percentage of total employment	Net Capital Investment During Year
	£ million	Thousands	%	£ million
1907	..	13.8	24	..
1912	..	15.7	..	..
1924	..	20.0	31	..
1930	..	23.5	32	..
1935	..	24.1	40	..
1948	83.8	34.6	39	2.5
1949	84.5	35.8	40	2.3
1950	91.0	37.1	42	..
1951	111.8	37.8	42	2.7
1952	105.1	37.1	45	2.6
1953	105.9	36.9	45	2.0
1954	111.2	38.0	46	3.2
1955	122.3	39.6	46	4.6
1956	126.5	40.7	46	4.9
1957	138.0	41.4	47	5.5
1958	143.9	41.1	48	5.0
1963	160.4	38.6	49	2.8
1968	184.9	32.4	49	3.3
1970	209.0	31.1	47	3.9

.. Not available

Source: <u>Historical Record of the Census of Production 1907-1970.</u>

The Paint Industry's Market

At the turn of the century the paint market was not substantially internally differentiated - broadly similar painting materials and methods were used (though industrial products might be finished with lacquer, and top coats of varnish might be applied).

The paint market can be broadly divided into two categories:

- the painting of buildings - with decorative paints
- painting industrial products - with 'protective' paints.

(N.B. despite the distinction between protection and decoration, both properties are clearly sought in most painting applications).

Currently, about 50% of paint (by volume) is used to protect industrial goods.[8] Although statistics are not available on this matter, industrial paint markets have clearly grown more rapidly than building paints, since 1900 (when it probably amounted to less than 1/3 of total paint consumption - estimated on the basis of numbers employed in painting.).[9]

Of industrial paint users, motor vehicle manufacturing is the largest (accounting for about 1/3 of industrial paint consumption in recent years) followed by furniture and allied trades (about 10%) with a range of industries being significant recent users including shipbuilding and marine engineering, cans and metal boxes, domestic appliance manufacturers.

About half of all decorative paints are sold through retail outlets. Though some of this may be purchased by professional painters, a major proportion is applied by the home occupier.[10]

Comparison between Paint Industry and Chemical Industry as a Whole

Table 2.3 compares the paint industry (SIC Minimum List Heading 274) with the rest of the British chemical industry (SIC Order V), and with All Manufacturing Industries.

TABLE 2.3 Comparison between the Paint Industry and the Chemical Industry and with All Manufacturing Industries in Britain.

	Chemical Industry	Paint Industry	Paint Industry as a Percentag of Chemical Industry.
Total Sales 1970 (£ Million)	3861	209	5.4
Net Output 1970 (£ Million)	1693	96.3	5.7
Capital Expenditure 1970 (£ Million)	384	3.9	1.0
Capital Expenditure 1951 (£ Million)	50.1	2.7	5.4
* Research and Development Expenditure 1972-3 (£ Million)	135.2	3.8	2.8

	All Manufacturing Industries	Chemical Industry	Paint Industry
Growth in Sales (£) 1951-1970 %	305.5	415.1	186.9
Growth in Net Output (£) 1951-1970 %	362	486.8	234
Growth in Net Output (£) 1907-1951 %	1073	1610	1522

Source: Historical Record of Census of Production 1907-70

* Reuben and Burstall, The Chemical Economy 1973 op.cit.[11]

Figure 2-1 compares the U.K. Paint and Chemical Industries in terms of a) labour productivity and b) intensity of capital investment. These indicate that, relative to sales (and net output), the paint industry has recently devoted a far smaller proportion of its resources to capital expenditure and to Research and Development than the chemical industry. The gap between investment in the paint and the chemical industry is widening.

Though the growth in net output of the paint industry between 1907 and 1951 was comparable with the chemical industry as a whole (and faster than for U.K. manufacturing industries as a whole), in the 1951-1970 period the paint industry has lagged behind the rest of manufacturing industry and the chemical industry in terms of growth in sales, and productivity.

The International Performance of the British Paint Industry

At the turn of the century, the British paint industry was second in size only to the U.S.A., and Britain was a major expórter of paint materials - primarily to 'captive markets' in the British Empire. Though paint imports have been negligible, exports have fallen substantially since the Second World War. As a result, the British paint industry once the biggest in Europe, has grown more slowly than its European counterparts, and has been overtaken by Germany (whose paint industry achieved approximately 12½% annual growth rate in the 1950s and 1960s compared to only 3% in Britain).

This economic decline has been matched by a decline in relative technological performance. Thus while in the inter-war years British firms accounts for 45%-50% of U.K. paint patents, that figure was down to 22% by 1967.[12]

FIGURE 2-1(a) Comparison between U.K. Paint Industry and Chemical Industry Labour Productivity 1907-1968.

Net output per worker for manual workers and for all employees 1963 values.

Source: Calculated from - G.B. Business Statistics Office Historical records of the Census of Production 1907-1970.

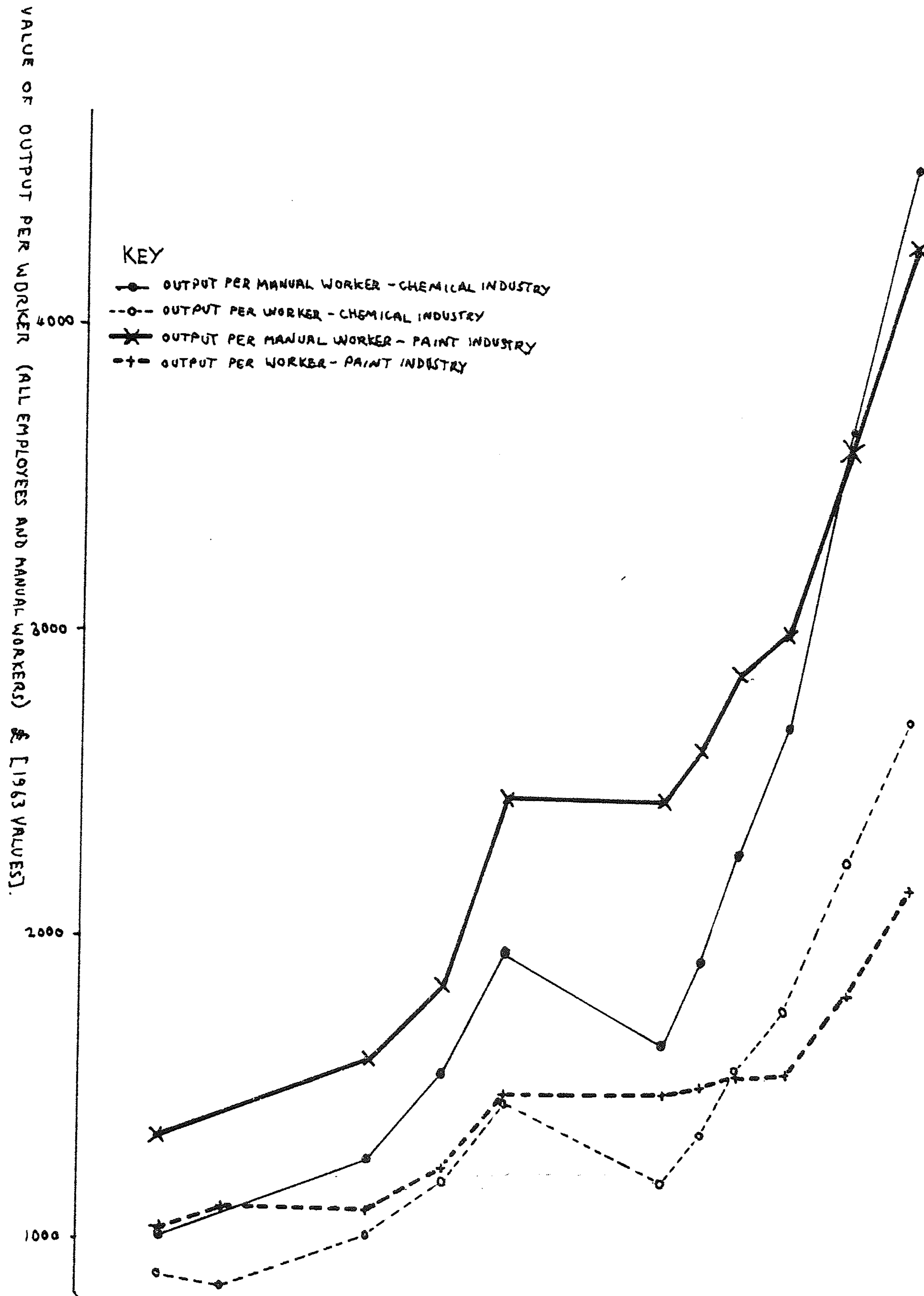
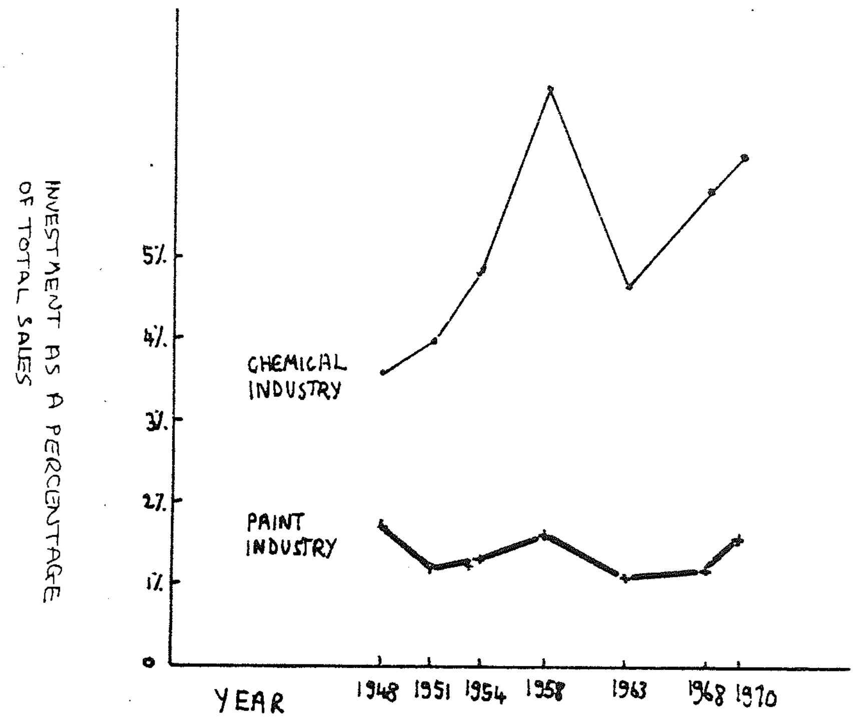
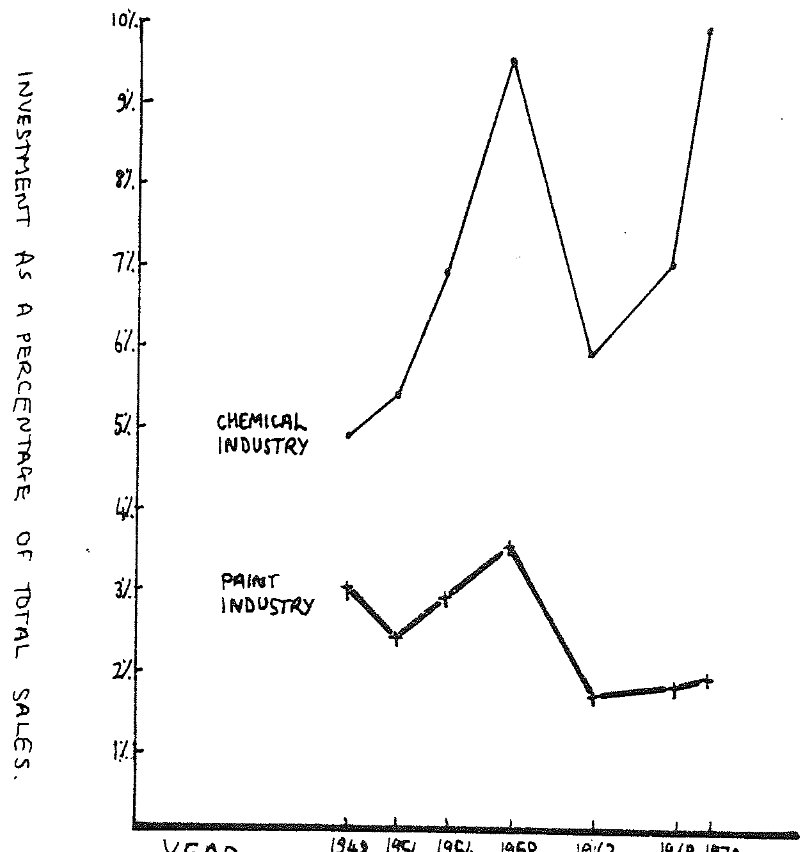


FIGURE 2-1. (b) Comparison between U.K. Paint Industry and Chemical Indust
Capital Investment as a percentage of total sales 1948-197

1. Investment in Plant and Machinery (acquisitions less disposals).



2. Capital Investment (acquisitions less disposals).



Technological Factors Reducing Demand for Paint

Growth in paint markets overall, particularly amongst advanced industrial nations, has been offset by the increasing use of materials not requiring surface coating in both industrial products and in buildings, in particular plastics (consumption of which have grown very rapidly since 1945), but also stainless steel, aluminium glass and cast concrete.[13]

The Pattern of Technological Change in the Paint Industry.

Definition of a paint and its constituents

The traditional definition of a paint was a liquid applied to adhere to a solid surface yielding a coating that would protect and decorate it. The liquid paint consisted of finely divided solids (i.e. pigment) in a non-volatile medium thinned to application consistency by a volatile solvent.[14] The subsequent development of new painting systems such as powder coating, in which resin is applied as a colloíd in air, without a solvent, necessitates a more complex definition of 'surface coatings'.

We can consider a paint as a mixture of four classes of materials: pigment, binder, solvent, and a variety of auxiliary materials (additives).

* Pigment - a finely divided solid, insoluble in both binder and solvent or water, which gives opacity, colour and durability to the coating (and other properties e.g. corrosion resistant pigments). Often they are augmented by the use of 'extenders' such as barytes, china clay, blanc-fixe, which cheapen the paint. Paints without pigments are known as varnishes.

* Binder - a resin, which serves to bind the pigment into a continuous film that adheres to the object being painted, and is resistant to water, chemicals and blows.

* Solvent - the mixture of pigment and resin binder are typically dissolved in an organic solvent to reduce its viscosity and allow application by brushing or spraying. This solvent then evaporates allowing the binder to set. Sometimes the 'solvent' itself is part of the resin system, and polymerises with other resin components to form the film (e.g. styrene in unsaturated polyester resins). The resin may be suspended rather than dissolved in the solvent (e.g. emulsion paints, PVC organosols). Surface coating systems are being developed, including the application of resin and pigment as a colloid in air (powder coating), which do not involve solvents.

* Additives - These materials include driers (which catalyse polymerisation of the resin), anti-oxidants (to prevent skin formation in the can), surfactants (to maintain the pigment in suspension), and preservatives (to prevent degradation of the paint in the can or on the solid film by bacteria, fungae, algae, marine organisms insects etc.).[15]

The different constituents are combined to produce a paint with the necessary properties for decorating and protecting the surface to be painted, and for the method of application.

The Development of Paint Technology

Prior to the 20th century, paint technology had developed very slowly. Virtually the only application method was by brushing, and a limited range of materials was available.

At the turn of the century, the typical paint was based on linseed oil (a 'drying-oil resin' see below), to which a 'drier' (lead or manganese salt which catalysed polymerisation) was often added, thinned with turpentine (solvent) and pigmented with white lead, and/or a range of (mainly mineral) pigments. Varnishes based on shellac and rosin (natural resins) were used as well as water based paints - distempers - based on animal glue or casein pigmented with whiting. Thus typical paints might consist of some 3-6 ingredients. 20 pigments, 9 resins and one solvent are mentioned as being used in the U.K. paint industry.[16] A brief chronology of resins and solvents in use prior to 1900 is given in Table 2.4.

Development of the paint industry was stimulated during the 19th Century by the need to protect iron structures (bridges, ships and other products of the Industrial Revolution), but scientific and technical developments did not occur until after the first World War, with the introduction of sprayed Nitrocellulose lacquers for the car industry.

Since that time, paint technology has developed relatively rapidly. A variety of application methods are available (though largely limited to painting industrial products). There has been a dramatic shift in the chemical composition of paints, away from naturally available biological materials and minerals (or minerals of simple preparation) towards synthetic chemicals. An estimated 1500 materials are currently used in paint manufacture.[17] A contemporary paint will consist of a mixture

TABLE 2.4. A Brief Chronology of Paint Resins and Solvents used up to the 20th Century.

	RESINS	SOLVENTS
11th Century	Animal Glue	Water
13th Century	Linseed Oil	
17th Century	Rosin Shellac	Turpentine
18th Century	Gums & Resins from India Gum Copal Amber Nut Oil	
19th Century	Casein	

Source: F.Armitage, The British Paint Industry Pergamon, Oxford 1867.

of up to 20 ingredients.[18]

Some of the key features of this transformation will be briefly charted.

It is convenient to examine the development of vehicle systems (i.e. resins and solvents) separately from that of pigments.

Developments in Paint Vehicle System and Application Technology

Significant Innovations since World War I

Table 2.5 lists significant innovations in the resins and application technologies used in painting in Britain since World War I (Column 3, listed by date of appreciable use).[19] The precise date of a significant innovation in technology is hard to determine, since a technological or economic modification may be more significant, from the point of view of changes in the technology of painting, than the original discovery of a material or technical principle.

Where another date is recorded in the literature as being of note in terms of the original invention or a significant modification these are listed.[20] in columns 1 and 2 respectively.

There has typically been a long period between the discovery of a new material/principle and its appreciable use. (For example: 1840-1920 - Nitrocellulose lacquers, 1909-1927 - Phenolic Resins, 1912-1935 - Alkyd Resins, 1920-1940 - Urea/formaldehyde Resins, 1937-1951 - Polyurethanes, 1940-1955 - Epoxides.) This time lag between invention and application has decreased over the years.

Despite important changes introduced between 1920 and 1927, paint technology was a relative backwater until the 1950s.[21]

The most significant developments in paint technology appear to have been

TABLE 2.5 Significant Innovations in Paint Vehicles and Application Technology Introduced Since World War I.

	ORIGINAL INVENTION	SIGNIFICANT MODIFICATION	DATE OF APPRECIABLE USE	
1.	1840 Collodin Varnish 1880 Nitrocellulose	1920 (Depolymerised cellulose	1920	Nitrocellulose Lacquers
2.	1900		1920	Spray Gun
3.	1909 (Phenol-Formaldehyde) Novolac Resin in U.S.A.	1917 Oil Soluble Phenolics (German 4hr. Varnish)	1927	Phenolic Resins
4.	1912 Alkyd resin (Patented 1914)	1921 (Drying) Oil Modified Alkyds (Produced by ICI 1927)	1935	Alkyd Paints
6.			1935	Chlorinated Rubber
7.	1920 Uren Formaldehyde Resin patented	1930's Fast Cure Resins	1940	Urea/Formaldehyde Resins in finishes.
8.	1939 Melamine Formaldehyde Resin	Late 1930's Fast Cure Resins	1945	Melamine Resins in finis
9.	1940	1935 Butadiene-Styrene Rubbers on Mkt. 1940 Butadiene-Styrene	1948	Butadiene/Styrene Based Emulsions - since replac by (10)
10.	1917 PVA Adhesives (Germany) 1928 Polyvinyl Acetate	1940-PVA Emulsion Paints 1945 Developed in Germany	1948	PVA Emulsion Paints
11.	1930's Technology Established	1940 Commercial Production, USA slow development because of high labour cost of polishing - UK 10% of market.	1950-1	Unsaturated Polyesters
12.	1948 PATENT		1953-4	Electrostatic Spray
13.	1940 "PREPARED"	1947-50 Commercial Production of resins	1955-6	Epoxide Resin Paints
14.		1954 U.K.Production	1956	Thixotropic Alkyds
15.			1957	Airless Spray
16.	1937 Polyurethanes Synthesised	1942-5. Polyurethane '2 pack' paints Developed and used in Germany	1948-51	Polyurethane 2-pack "lagg
16a			1959	Urethane Oils
17.	1944 Synthesised		1960	Siliconised Resins
18.	1901 Acrylic Resins Synthesised	1936 Acrylic Resins for "Perspex" and some Enamels/lacquers	1960	Thermoplastic acrylic Automobile finishes
19.			1960	Thixotropic Emulsion Pain
20.			1961-2	Electrophoretic Painting
21.			1962	Curtain Coating
22.			1962	Coil Coating
23.			1964	Electrostatic Powder Spra
24.	1958 U.S.A. INTRODUCTION		1965	Thermosetting Acrylic Automotive finishes
25.			1970	PVC-Non-Aqueous Dispersio
26.	1950's PTFE Non-stick Enamels	1965 Polyvinylidene Fluoride Resins (PVDF)	1970	PVDF Dispersions, Powder coat and other applicatio

Adapted from: G.de W.Anderson, J.O.C.C.A. September 1974, p.293-9, op.cit.
: F.Armitage, The British Paint Industry, 1967, op.cit.
: American Chemical Society, Chemistry and the Economy, 1973, op.cit.

stimulated by changes outside the paint industry itself - notably

i) demands from industrial users of paint, for new paint materials and application technologies with improved performance in certain respects starting with the requirements of mass production in the motor industry (paints that were quicker to apply and to dry.)

ii) the availability of the products of the petrochemical industry. The role of materials supplies in 'promoting' technological change is particularly evident from the disruption attendant on war. For example, restrictions on the availability of lead during the first World War resulted in increased use of lead free pigments. Conversely the need to utilise massive overcapacity of certain wartime products, following the cessation of hostilities was held to be of major significance in two of the most significant long term changes in paint vehicles - the introduction of nitrocellulose lacquers after World War I and the introduction of emulsion paints (water-dispersed paints based initially on butadiene/styrene copolymers) after World War II.[22]

In general, the paint industry has not been the originator of most of the new paint materials adopted, but has merely taken up opportunities to utilise materials developed elsewhere (in particular from the plastics industry). The chief exception to this is alkyd resins. (see below). The picture is somewhat different with pigments, since this industry initially operated almost exclusively for paint production; pigment producers were frequently involved in paint production, and new pigments were developed for paint application. Since World War I however, wider ranges of application have emerged (principally in rubber and plastics) and the paint and pigment industries have become distinct.

The Development of Paint Resins

The development of paint resins can be seen in terms of attempts to resolve conflicting requirements for the material during its application and its performance in the paint film.

- Achievement of a sufficiently fluid paint required the uncured resin to have low polymer sizes. In contrast, high polymer sizes were needed for durable resin films.
- To reduce the number of coats of paint required, thick films were advantageous, however these were slow to dry.

The major developments will be briefly described.[23] Before the first World War, paints were based on two drying systems - simple evaporation and drying oils. (these were also distempers based on water soluble animal glue, but the resin for these was so poor that they could only be used in limited circumstances - e.g. factory walls.)

1) Simple evaporation

   A solution of resin (e.g. shellac resin) in turpentine was the basis of french polish, japanning varnishes, lacquers. Evaporation of the solvent left a tough layer of resin. However only very thin coats could be applied; many coats were needed, the process was slow, labour intensive and used large volumes of solvents. Moreover the lacquer film was vulnerable to heat, water and solvents because of the small polymer size in the finished paint film.

2) Drying oils

   These are unsaturated vegetable oils, such as linseed oil, which dry by oxidation of carbon-carbon double bonds providing cross linkage between the hydrocarbon chains. Paints with this drying mechanism can be applied in thicker coats than those based on simple evaporation.

The subsequent cross-linking increased polymer size leading to more resistant paint films.

Drying oils would be partly polymerised by heating in open containers. Driers (catalysts e.g. lead or manganese salts) would be added to promote drying. The resin would be thinned with turpentine to application viscosities. [N.B. linseed oil based paints were used at much greater viscosities than contemporary liquid paints and had to be 'stippled' on to the surface using a brush]. House paints were based on this system. Varnishes (for carriage painting) were based on solutions of natural 'copal' resins (partly depolymerised by heating) in drying oils.

There were several problems with these resins :

i) The coats required several days to dry and harden.

ii) The oxidation process led to yellowing of the resin, impairing the use of lighter colours.

iii) There was considerable variation in the supply, properties and price of the raw materials.

iv) Because of this variation, the materials were usually prepared on site by the painter, who required considerable experience to be able to manipulate the material properties. In the cooking process up to 30% of the raw materials were lost.

The major innovations in paint resins achieving significant use in the inter-war years were based on these two drying mechanisms. (Solvent evaporation, drying oils). 'Synthetic' (i.e. petrochemical, rather than biological) materials were introduced to give greater control over raw materials and the range of final products. Greater durability, and faster drying were achieved.

Oil Soluble Phenolics

One of the first areas of application of synthetic resins was in 'oil-soluble phenolics'. Phenol/formaldehyde condensation products (dating from 1909) have low solubility in drying oils. Changing the phenol base, the reaction conditions or reacting the partially polymerised resin with other materials allows development of resins soluble in drying oil. These were introduced in Germany, named '4-hour varnishes' because their greater molecular weight allowed faster drying.

Nitrocellulose lacquers

The application of mass production techniques in the car industry led to the need for a faster method of body painting than the traditional oleo-resinous varnishes. There was a massive post-war surplus of Nitrocellulose production capacity with the run-down of the explosives industry. Nitrocellulose (NC) lacquers had been used in the 19th Century, but their high molecular weight meant that only dilute solutions could be made - allowing only thin films. Use of nitrocellulose as an aircraft fabric dope during the first World War increased supplies and reduced the cost of nitrocellulose and its formerly expensive solvents - amyl acetate, acetone, etc. In the 1920's partial depolymerisation of NC allowed more concentrated solutions at application viscosities to be applied. This went hand in hand with the introduction of the spray gun. NC lacquers were generally adopted first by the car industry, but also by furniture and domestic appliance industries. The car industry has subsequently provided a frequent stimulus for, and site of initial adoption of new paint vehicles and application technologies.

The NC lacquers contained only 20% solids, and thus several coats were needed, and large volumes of expensive solvent were wasted. Drying ovens were used to speed up the process, and their existence in turn facilitated the introduction of baked enamels (based on phenolics and alkyd resins) in the 20's and 30's. The thin films with NC lacquers in turn created a demand for highly opaque pigments (See Chapter 4).

Alkyd Resins

These resins, based on a polyester of a dibasic acid (usually phthalic acid) and a polyfunctional alcohol (e.g.glycerol) were developed in 1912 by researchers looking specifically for surface coating resins. Only after 1917, when oil-modified alkyds, based on the partial ester of the alcohol and drying oil fatty acids, were produced was a successful paint resin developed. Produced commercially in 1928, alkyds rapidly came to dominate the paint market. When baked, drying oil alkyds dried as fast as NC lacquers, but since solutions had application viscosities at 50% solids (rather than 20% for NC) fewer coats were needed. American motor companies and appliance manufacturers switched to alkyds in the 1930's. Despite incursions by some of the more recently developed resins, alkyds still represent over 50% of all paint resins.

Because of the range of acids, alkalis and drying oils, a vast number of different resins are possible and about 400 of these are on the market.[24] In addition, alkyds can be used in combination with other resins, e.g. Melamine/formaldehyde-non-drying oil modified alkyd formulations are used widely for car and appliance baked enamels; the M/f resin improving the hardness of the paint, allowing paler shades (by resisting staining and yellowing) that were in demand after the World War II.

In the 1965 Surface Coatings Resin Index, alkyds represented 35% of all resin types. Of these 17% were non-drying oil types for combination in baked industrial enamels, 53% were drying oil modified for decorative and some industrial use. The remaining 35% were further modifications for specific use (e.g. fast-drying styrenated alkyds).

Alkyds have good viscosity properties and dry quickly (by oxygen absorption) to resilient films with a high gloss. Large volume production has made them cheap. This range of advantages, together with the facility of formulating modifications for specific functions has given alkyds overall domination in the paint market. Later paint innovations have typically been to meet specialised needs. (See table 2.7: reasons for resin introduction).

"Catalysed" Paint Systems

These systems are either 2 components which react when mixed together, or a single material which autopolymerises - but to prevent in-can setting, the reaction must be prevented until application, either by incorporating a volatile blocking material, or by adding a catalyst.

Unsaturated Polyesters

These are similar to alkyds but based on unsaturated acids (maleic rather than phthalic), and are dissolved in styrene. The styrene acts as a thinner and co-polymerises to form the coating in the presence of a catalyst (usually an organic peroxide). This allows thicker coats to be applied, and the "solvent" is not wasted but incorporated in the film. Since oxygen in fact inhibits polymerisation, wax must be incorporated into the paint (which floats to the surface forming an O_2 impermeable layer). This is then polished off to give a deep gloss. Polishing is labour intensive and has restricted use of these materials in the U.S.A., but not Europe, where they comprised about 10% of the auto-paint market and some furniture varnishing.

Epoxy Resins

The typical epoxy resin is based on the additional product of 'Bisphenol A' and epichlorhydrin. (Though a range of different epoxy materials and organic bases can be used).

Epoxies are used as 2 component systems based on partial polymers of epoxy and amine (hardner). The films produced are tough and highly resistant to chemical attack and adhere strongly to metals. They provided equal or better performance that other resins that required baking (Melamine/Alkyds for example) and are used as marine paints, primers for cars, heavy duty paint for plant etc. They are limited from the domestic appliance/auto-finishing market by their poor appearance on weathering (chalking) and use is restricted by the high price of the resin.

Polyurethane Resins

Based on the reaction between a poly-isocyanate and a polyfunctional alcohol (Though other bases can be used, such as amines).

This reaction has been used to make urethane oils, where the alcohol is a drying oil partial glyceride, but the product which dries by the same mechanism as alkyds, has little technical advantage over alkyds.

The most significant use for urethanes is as a 2 component lacquer for spraying. Exceptional abrasion resistance and chemical resistance are achieved. The resins are however costly, (approximately as high as epoxy resins) and stringent controls are required to prevent hazardous exposures to isocyanate vapour and spray (expensive both in terms of resources and technical expertise). Despite widespread applications before the hazards were appreciated, the use of polyurethanes is mainly restricted to high technology industries (aerospace, chemical plant, yacht manufacture) where their special properties are needed and there is sufficient expertise to control user hazards.

Figures for sales of polyurethane surface coatings are available from 1973. These are presented in Table 2.6. There is little evidence of sustained growth in this market.

Urea and Melamine - Formaldehyde based paints

These aminoplast resins, based on various condensation products of Urea or Melamine (or other NH compounds) and formaldehyde have two principal applications.

The first, and predominant application, is in combination with (non-drying) alkyds modified with saturated oils, to make stoving enamels, which set by etherification of hydroxy-groups in the alkyd and aminoplast. These are used to improve the setting time and hardness of the coating and allow paler colours than with ordinary alkyds because i) they don't yellow on drying and ii) they are more resistant to staining. These resins were widely used for domestic appliances since the 1930's though they are currently being displaced by acrylic coatings.

These resins are also used in "acid catalysed" systems, where in the presence of acid, polymerisation continues, to form a hard coating, that has wide applications in the furniture industry.

Other Innovations

A number of new resins for more specialised applications are also noted. Two major innovations in resin systems are emulsion paints and acrylic resins.

Emulsion Paints

Aqueous emulsion of styrene/butadiene resins were developed for emulsion paints after the second World War (stimulated by the excess of these materials that had been produced to supply synthetic rubber). They were

TABLE 2.6 Sales of Polyurethane Surface Coatings 1973-1977

Year	U.K. Sales of Polyurethane Surface Coatings (Thousand tons)
1973	4.7
1974	4.9
1975	5.8
1976	5.5
1977	4.5

Source : G.B.Department of Trade and Industry,
Business Monitor PQ 276.1 Sales of Synthetic Resins.

soon displaced by Polyvinyl Acetate based paints because of their poor durability.

Polyvinyl Acetate (PVA)

Because of the oxygenated groups, these materials can be used in water based paints.

Water based paints are $^2/_3$rds the price of alkyd gloss paints, not only because the resin components are half the price of alkyd resin (1969 figures)[25] but also because they use only minimal amounts of organic solvent - which comprises 10-15% of the cost of a typical paint.[26] Though emulsion paints are less durable than alkyds and only matt finishes are available (though aqueous gloss paints are being developed) they are adequate for indoor paints, and are more convenient to apply (especially for the home "Do-It-Yourself" decorator).

Acrylic Esters

These are increasingly used in water based paints, but are more extensively used to provide the clear, glossy, hard finishes required by the car and domestic appliance industry. These stoved enamels, available as both thermoplastic and thermosetting varieties, are especially popular in the U.S.A. because of their sunlight resistance.

Other Innovations continued

1. Siliconised paints provide special heat resistance.
2. Fluoride based surface coatings (as developed for aerospace and non-stick pans), have low friction properties as well as chemical and heat resistance. (PVDF etc.)
3. Celloidal PVC dispersion (plastisols and organosols) are used to apply very thick coatings to pipes, wire coatings etc. which are highly impervious, though showing poor metal adhesion.

Factors underlying the pattern of innovation/diffusion of resins

Our brief resume of innovations in resin systems achieving significant use in paints reveals a complex web of factors underlying these developments. We have summarised the reasons cited in the literature for their development/adoption in Table 2.7.

Improved durability and weather resistance has been a major objective throughout. Over time there appears to have been a trend from ease of application/speed of drying as major considerations behind the change, towards special resistant properties (in specialised applications) and consumer demands regarding colour and appearance.

Consumption of Different Resins in Paint

The displacement of natural resins by synthetic resins (initially alkyds and phenolics) took place substantially in the U.S.A. during the 1930's.[27] This is demonstrated in Table 2.8.

Though comparable figures for the U.K. are not available, it seems (from industry statements) that this substitution process took place somewhat later in Britain, with alkyds achieving a predominant place in decorative (as opposed to industrial) paints only after the second World War.[28]

Sales of Resins

Though statistics are available for sales of different resins by U.K. manufacturers (Census of Production, Business Monitor etc.) these do not distinguish between sales to the paint industry and to manufacturers of plastic goods. The latter have been increasing much more rapidly than the former.

Figure 2.2(a) charts U.K. sales of major resins for 1958-1964. (Source : F.Armitage The British Paint Industry, Pergamon 1967).

TABLE 2.7 Reasons for successful introduction of Paint Resins cited in paint technology literature.

Resins in Chronological Order of appearance	Ease of application	Faster drying	Better substitute for natural materials	Cheaper	Use excess production	Thicker Coats	Durability	Weathering	Special Resistant Properties	Colour and Appearance	Other Characteristics
N.C.	✓	✓			✓	-		-			Several coats n
Phenolics		✓	✓				✓				
Alkyds		✓	✓				✓	✓		✓	Many modificati for different properties
Urea/formaldehyde		✓						✓			Used mainly with alkyds.
Melamine/formaldehyde		✓						✓		✓	
Butadeine/Styrene	✓				✓						Later withdrawn
PVA	✓			✓							Eliminated solve water dispersed.
Unsaturated Polyesters	-					✓		✓		✓	Requires polishi
Epoxides							✓	✓	✓	-	Metal adhesion good.
Polyurethanes							✓	✓	✓		
Siliconised									✓		
PVC						✓		✓	✓		
PVD F etc.								✓	✓		
Acrylics							✓	✓		✓	

Sources : Various,[23] but chiefly:

F.Armitage, The British Paint Industry, 1967, op.cit.
B.G.Reuben and M.L.Burstall, The Chemical Economy, 1973, op.cit.
American Chemical Society, Chemicals in the Economy, 1973, op.cit.

✓ = reason for successful introduction

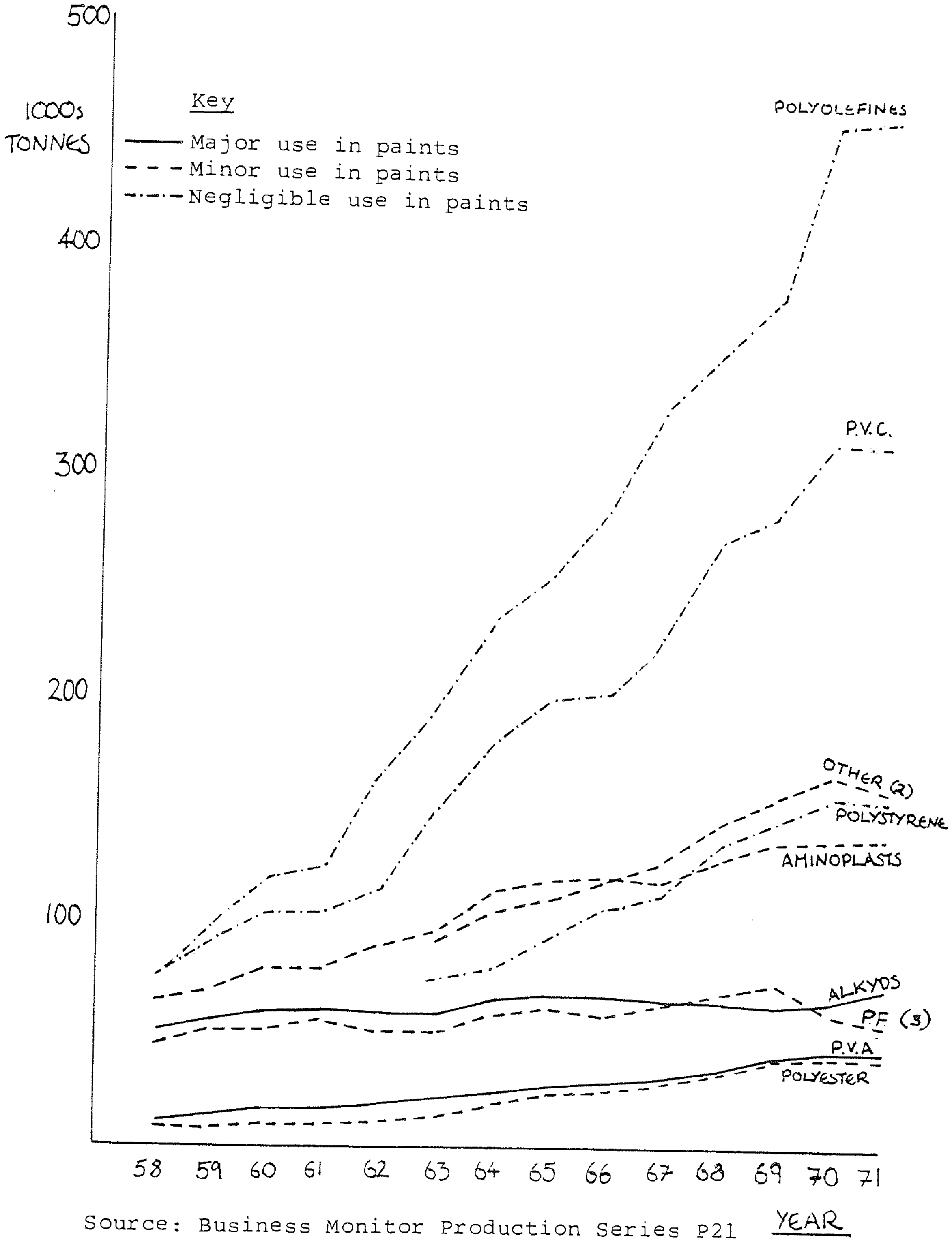
TABLE 2.8 Approximate Share of the Surface Coating Market Held by the Major Resin Types in the U.S.A. 1926-1941.

Year	'Natural Resins'	Alkyds	Phenolics
	Percentage Share by Weight, exclusive of Drying Oil Component		
1926	92	0	8
1936	35	25	40
1941	37½	37½	25

Source: W.von Fisher, Paint and Varnish Technology, 1948, op.cit.

Fig 2-2a) UK PRODUCTION OF SYNTHETIC RESINS 1958 - 1971

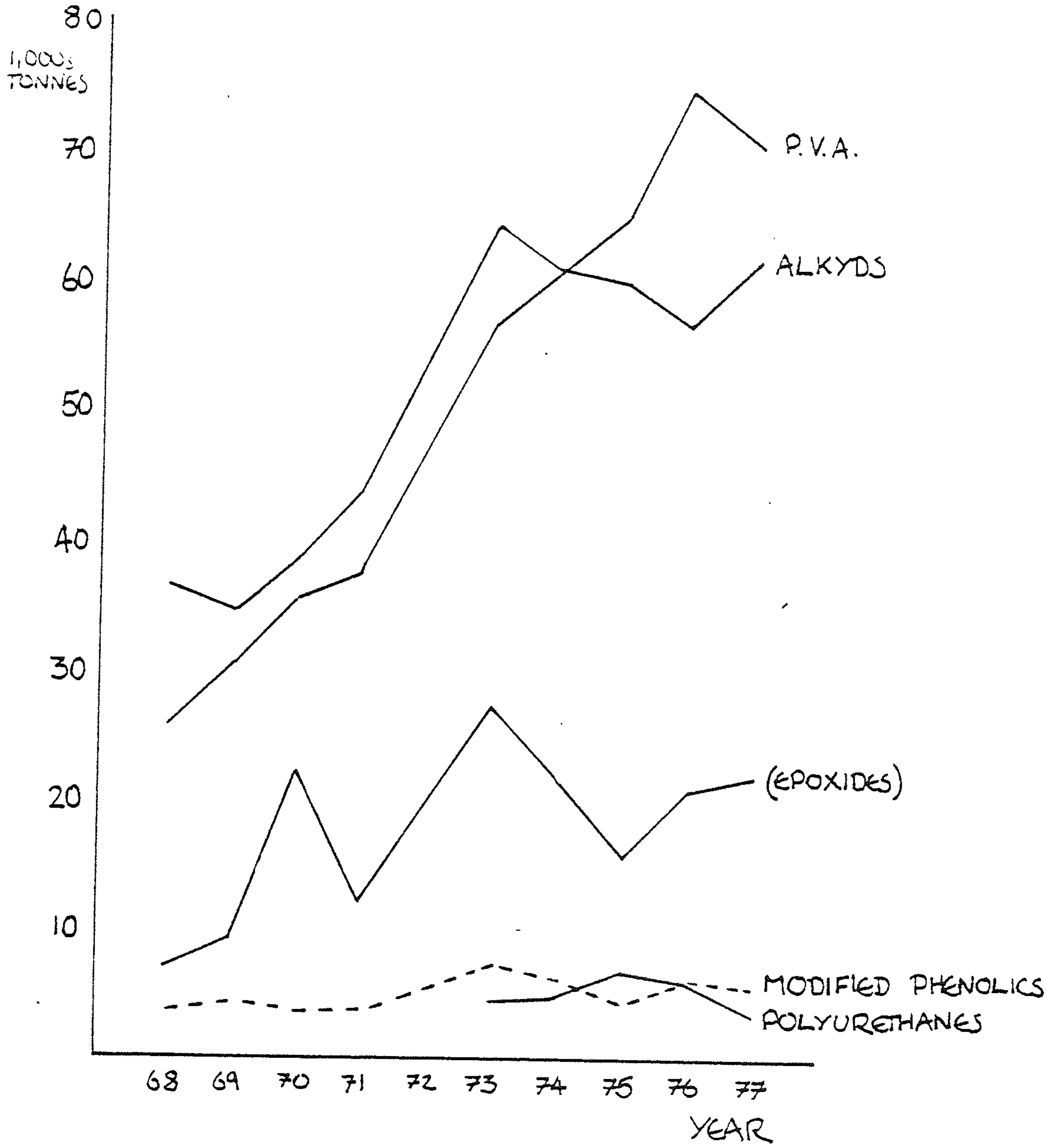
Classed by proportion used in paint industry (1)



Source: Business Monitor Production Series P21

1) Excluding resins used in synthetic fibres
2) 'Other' includes polyurethanes, epoxides, cellulose products.
3) P.F.: Phenol formaldehyde.

Fig. 2-2b) UK PRODUCTION OF SYNTHETIC RESINS WITH SIGNIFICANT USE IN PAINTS 1968 - 1977.



Sources: 1968-72 Business Monitor P21
1973-77 Business Monitor PQ276.1

1) Only a minor proportion of epoxide sales is for paint production.

Figure 2-2(b) charts the same data for 1968-72
(source: G.B.Business Statistics Office Business Monitor P21)
and, with slightly different categorisation for 1973-7
(source: G.B.Business Statistics Office, Business Monitor PQ276.1)
[polyolefins and polyvinyl chloride have been excluded from this list]

Of the resins listed, only alkyds and P.V.A. are predominantly used in paints. A negligible proportion of polyolefins and P.V.C. are used in paint, and only a "small percentage" of the remainder are so used.

The order of importance of the different resins was assessed as follows:

1) oil-modified alkyds
2) polyvinyl acetate and nitrocellulose
3) maleic, phenolic and aminoplast resins
4) epoxies, polyesters, polyurethanes, acrylics.

and the approximate market share in Britain estimated as 50:10:15:15 1967 figures.[29]

We can gain an impression of subsequent development from statistics of sales of major categories of paint.

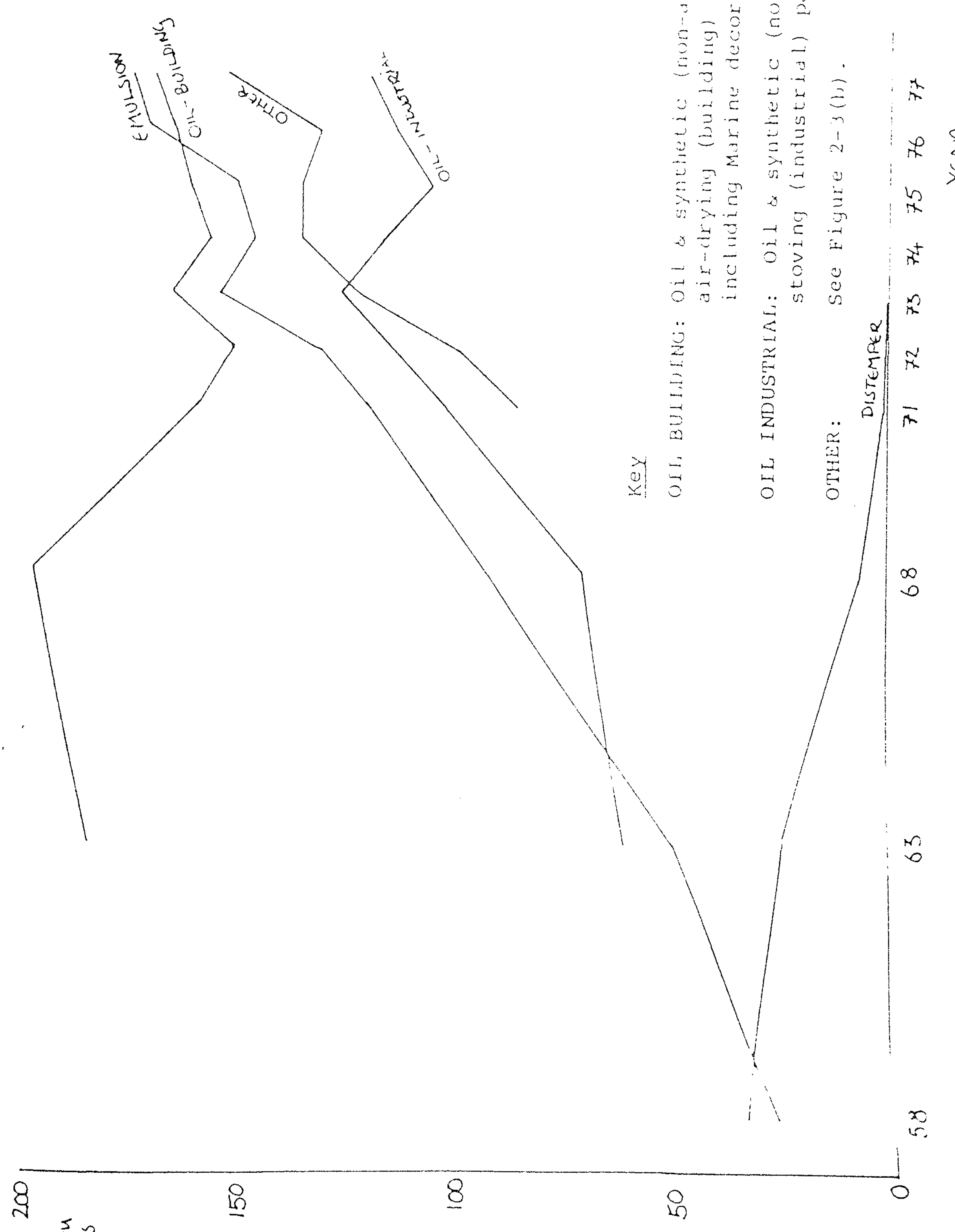
1973-77	Business Monitor PQ276
1971-73	Business Monitor PA276
1963, 1958	Census of Production Pt 31,32

These are charted in Figure 2-3, showing: a) high volume and b) low volume classes of paint.

The three biggest categories of paints listed, are made up broadly as follows:

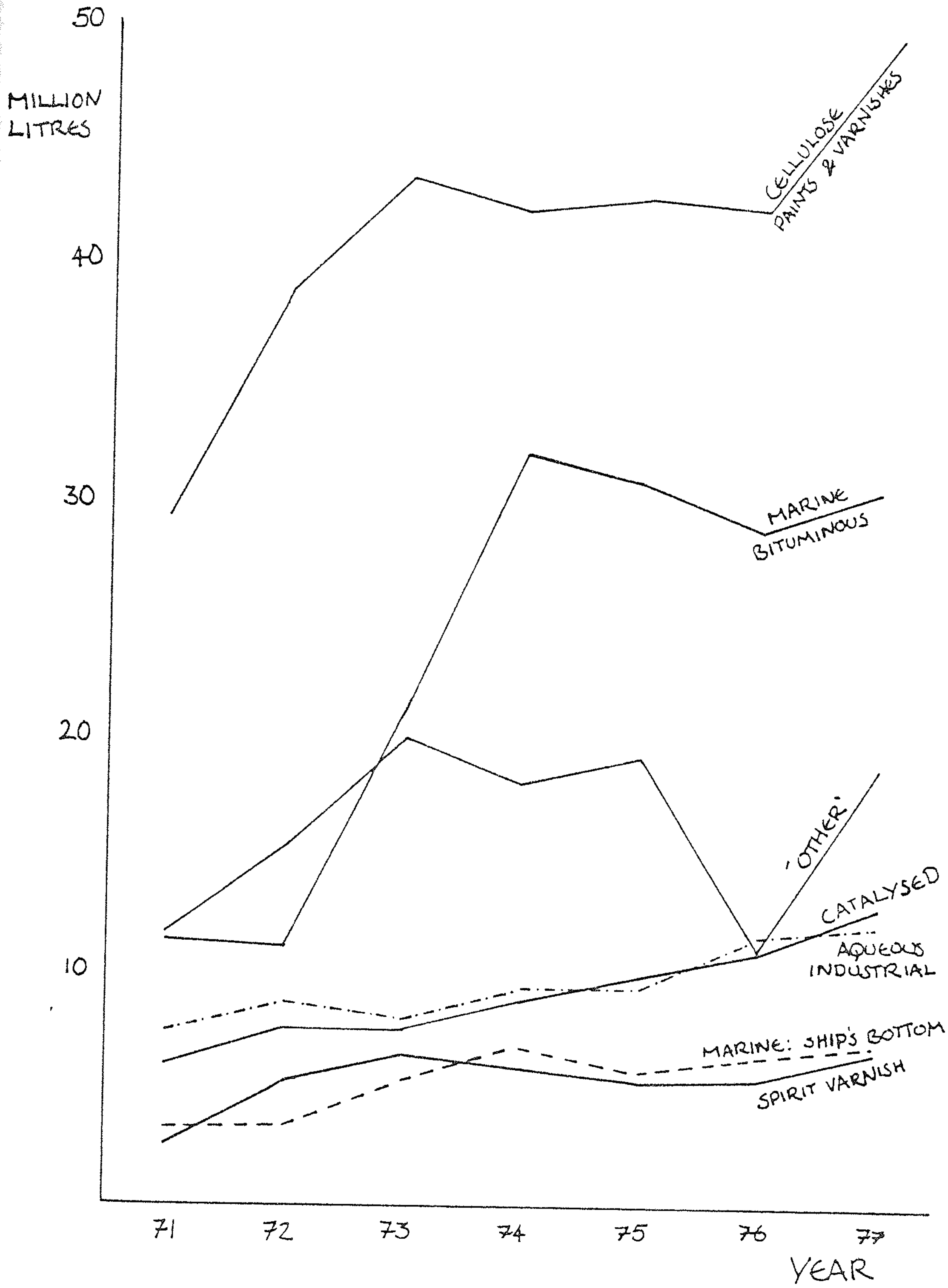
1) Oil and Synthetic, air drying (building) non-aqueous paints consists mainly of drying oil modified alkyds.
2) Industrial (stoving) oil based consists mainly of some alkyds and the condensation resins (i.e. category 3 above)
3) Emulsion paints are predominantly polyvinyl acetate etc. based.

Fig 2-3(a) SALES OF PRINCIPAL CLASSES OF PAINT 1958-1977 BY UK MANUFACTURERS



Sources: Census of Production 1963, 1968
1971-2 Business Monitor PA274, 1973-7 Business Monitor PQ274.

Fig 2-3(b) SALES OF OTHER CLASSES OF PAINT 1971-1977 BY UK MANUFACTURERS



Sources: 1971-2 Business Monitor PA274
1973-7 Business Monitor PQ274

When the proportion of stoving paints based on alkyds is taken into account, it is clear that alkyd resins remain the most widely used in paints. However the use of alkyd based house (+ other building) paints has recently been overtaken by PVA based emulsion paints. On current trends, PVA resins are increasingly threatening the position of alkyd resins and may soon overtake them. Distempers were an early (and total) victim to the challenge of PVA.

Stoving enamels continue to dominate the industrial paint sector. Whilst consumption of nitrocellulose lacquers have remained stable (vehicle refinishing is their biggest area of application) their proportion of industrial paints has fallen. Catalysed paint systems have broadly maintained their market share - which remains small, restricted to specialised application. The sustained growth in 'industrial aqueous paint' (from very small beginnings) is an indicator of the increasing adoption of electrophoretic paint application systems.

Hazard and Technological Change in Resins

The hazard of paint vehicles derives largely from the volatile components (typically the solvent). With the exception of catalysed systems, paint resins have not been found to pose significant health hazards; the large molecular weight, the absence of volatile components and the low content of active groups in the manufactured resin are all found to correlate with reduced biological activity of a resin. The raw materials of resin production are often much more hazardous. Though cases of ill health and even death from the manufacture of these resins have frequently been recorded, it can in principle at least be carried out with sufficient control to minimise hazards. Indeed the high temperature and pressure and extreme reaction conditions required for polymerisation, often necessitate closed systems for production.[30] This also applies to the manufacture of 'two pack' catalysed resin systems. However, these resins as used in paints must contain reactive groups (whether a co-polymer or a catalyst) and tends to include lower molecular weight components.

Table 2.9 charts the main health hazards from catalysed resin systems and the control measures that have been adopted.[31,32,33.] These resin systems have all produced recorded cases of occupational disease amongst paint users (as well as paint makers), and handling precautions are suggested for their use. Where the harm is evident and severe, and where alternatives have been available, there has been a gradual shift to the use of safer materials (either homologues of the material or adducts with a lower vapour pressure, or a lower proportion of reactive groups) without the introduction of specific regulations. Certain materials used in epoxy systems in America (but not Britain) were found to be animal or human carcinogens (e.g. aliphatic diglycidyl ethers and benzidine) and as a consequence were not adopted in Britain. The history of the use of polyurethane lacquers, based on polyisocyanates, was somewhat more stormy. Here industry interpreted workers reactions to isocyanates as being 'irritation' and of minor hazard, and reports of more severe responses were not widely disseminated. Polyurethane lacquers became widely used with little hygiene control.[34] This increasing stringency of hygiene standards was itself a result of the demonstration of bronchospasm and long term lung changes amongst workers exposed to isocyanate vapour at ever lower levels of exposure. During this process there were differences in the assessment of hazards within scientific and industry circles.[35, 36.]

TABLE 2.9 Hazards from Catalysed Resin Systems and Control Measures Adopted

Resin System	Hazardous Component	Nature of Hazard	Control Measures Adopted	
Urea or Melamine/ formaldeyde	Free formaldehyde	Skin sensitisation, Asthma.	Resins available with low formaldehyde content.	
'Acid catalysed' resin.	Mineral Acid Catalyst	Irritant		31
Unsaturated Polyesters	Benzol peroxide Catalyst	Irritant		
	Styrene Copolymer	Narcotic. Cancer risk suggested		32
Epoxy resins	Polyamines. inc. Benzidine.	Irritant Skin sensitisation. Human carcinogen	Use of polyamides, and adducts. Use of other amines/amides	
	Some Epoxy compounds.	Animal carcinogen	Use of different epoxy materials and adducts.	33
Polyurethane lacquers	Free isocyanate	Severe asthma and lung damage in long term.	Use of low vapour pressure isocyanates. Use of isocyanate adducts Systems used with respirators and ventilation.	34, 35,

Source : as referenced.

The Development of Solvents

The solvents used in paints must be capable of dissolving the resin being used, and in the case of a mixture of solvents with different properties, the mixture must continue to be so throughout the evaporation process.

The ability of a solvent (or solvent mixture) to dissolve a given resin depends on two parameters,

- the solubility parameter (a measure of intermolecular attraction)
- hydrogen bonding.

For a given resin it is possible to plot boundary conditions for these two parameters within which solvents can dissolve the resin.[37] In practice this means that solvents can be mixed to get the required properties - and in particular that more expensive solvents can be mixed (within definite limits) with cheaper ones which on their own would not be solvents for the resin in question.

As a result the development of solvents is partly autonomous from the development of resins. Organic solvents for paints are relatively simple organic compounds - small molecules with, in most cases, deliberately low chemical reactivity (the major exception being active solvents which polymerise with the resin to form part of the film e.g. styrene in unsaturated polyesters). Their development has resolved not around identification of new materials but the development of commercial methods of manufacture.

Solvents comprise 20-35% of air drying, brushed paints and 50-80% of sprayed industrial paints. In 1967 they were estimated to account for some 10-15% of the total paint cost.[38] It is not surprising that economy has been a major consideration in the development of solvents. The initial history of solvent development involved a shift to more economical methods of production and cheaper raw materials. This involved increases in scale and technological development of production facilities, along with a shift towards cheaper biological raw materials and to feedstocks from the petrochemical industry which were becoming cheap and plentiful. The achievement of further economies required the development of surface coating technologies that used less solvents (e.g. low viscosity/high solids vehicles, water dispersed paints, powder coating). Post-war efforts in this direction received a massive boost following the escalation of petrochemical costs after the 1973 'oil crisis'.[39] Here, cost pressures interacted with other, mainly environmental, concerns.

The other major factor in the development of solvents has been the need for specialised solvents (e.g. fast drying, with specific, solvency properties) in particular for certain industrial paint systems (e.g. spray painting).

Health considerations have also influenced the use of solvents, although the importance of this factor has varied considerably.

A Brief Chronology of Solvent Development

The traditional solvent in the paint industry was turpentine - a distillation product of pine resins - it was not only toxic, but in limited supply and therefore costly. It is little used nowadays.

The development of the petrochemical industry, with facilities for conversion and separation of hydrocarbons, from 1910 onwards led to the widespread availability of cheap hydrocarbon solvents, with increasing control over composition and properties. These include aliphatics and aromatics (benzene, toluene, xylene, naphthas - a blend of the latter known as white spirit is the major 'thinner' for domestic i.e. drying oil based paints). Large scale production of benzene and toluene was stimulated by the demand for toluene in the first World War for TNT explosives. After the war benzene became more widely used as a solvent (though its use has been curtailed subsequently because of its health hazards).[40]

Thus the wartime use of nitrocellulose lacquer as a dope for aircraft fabric led to the development of production facilities for oxygenated and chlorinated solvents, notably amylacetate, acetone and perchlorethylene.

The widespread use of nitrocellulose lacquers in industry in the 1920's stimulated the development of new methods of producing the solvents they required. The oxygenated solvents were traditionally derived from fermentation processes. U.S. production of butyl alcohol, by fermentation, grew from "a few hundred thousand pounds" in 1923 to 31,000,000 pounds in 1929. However the production of pentyl alcohol, from chlorination and hydrolysis of pentane, on a commercial scale in 1926 heralded a shift of oxygenated solvent production towards the petrochemical industry. This process developed earlier in the U.S.A., partly as a result of the Prohibition of alcohol, which cut off the production of amyl alcohol as a by product of whisky distillation.[41]

Figures for the changing pattern of solvent consumption over time are not available. (Production figures are available for some hydrocarbon solvents but a major use for these is as a feedstock in petrochemical production). The ratio in which the different classes of solvents were used was estimated (1967 figures) at 4 : 2 : 1, aliphatic hydrocarbons, aromatic hydrocarbons and oxygenated solvents, reflecting their relative prices.[42] Chlorinated solvents are used in smaller quantities, because of their high cost (and very fast drying). They have recently been introduced in specialised applications for spray and dip painting.[43]

Water Based Paints

The problem in making water based paints is that the resin must be soluble/emulsifiable in water for application, and yet the resultant coating must be water resistant. This problem can be overcome by baking the product (e.g. thermosetting resins - as used in electrodeposition systems) or using catalysed paint systems (e.g. Polyvinyl Acetate domestic emulsion paints are based on a 'Redox' reaction that generates catalyst to finish the polymerisation process once the paint is applied). Volatile 'coupling solvents' and 'linking agents' have been used to make a resin water compatible without impairing its water resistance. These include glycol esters (used in many water based paints) and volatile bases (such as ethanolamine and triethylamine - which are used to make acidic oil-drying resins compatible with water for use in gloss paints).

Whilst water-based paints have been successfully applied to low-quality finishes, such as electrodeposition of primers and interior matt paints, there have been problems in formulating high-gloss, durable water based paints.[44]

On the basis of the figures for sales of different types of paint (Fig. 2.3) it would seem that the use of emulsion paints (water dispersed building paints) have grown approximately seven-fold between 1958 and 1977 (if the decline in distempers is included, the total increase in water dispersed paints is only three-fold). Water-based industrial paints (electrophoretic paint) increased twenty-four-fold between 1963 and 1977.

Hazard and Technological Change in Solvents

Organic solvents used in paints are intrinsically hazardous because their volatility and the high concentration used make worker exposure, particularly to vapour, inevitable. Their oil-solvency properties makes them narcotic and dermatitic.

The introduction of highly volatile solvents for quick drying dopes and lacquers during and after World War I brought a spate of cases of 'gassing' (and led to the introduction of ventilation plant to control the health and fire hazards of spray painting). Subsequently attention has shifted to the chronic toxicity of some solvents, and finally to possible environmental harm from solvent vapours (particularly in the U.S.A.).

Concern about solvent hazards has not affected solvent innovation (of paint resins) but has affected solvent choice, and more recently encouraged changes in vehicle systems/paint application technologies towards those using lower concentrations of solvent, safer solvents or enabling more effective control of solvent vapours.

Hazards and Solvent Choice

Two examples are described :

Benzene

The use of benzene or a solvent after the first World War resulted in increasing numbers of reported cases of occupational chronic benzene poisoning (destruction of haemopoetic cells leading to anaemia), which became a notifiable disease in 1924 (though not subject to specific regulations).[45] A link between benzene exposure and leukaemia was noted in the 1930's. The Threshold Limit Value set by the American Conference of Government Industrial Hygienists for benzene fell from 100 parts per million in 1946 to 35 ppm in 1948 and 25 ppm in 1957; the U.S. National Institute for Occupational Safety and Health proposed a reduction to 10 ppm in 1974 and to 1 ppm in 1976.

Growing awareness of benzene's hazards led to its gradual replacement by other solvents (e.g. other aromatics such as xylene and toluene).[46]

An agreement between the G.B. Ministry of Health and the Paint Makers Association limited benzene impurities (up to 20% in xylene and toluene) to below 1% in 1965.[47]

A similar pattern of voluntary reduction in use of solvents believed to create specific hazards has been noted in the cases of n Hexane (found industrially and experimentally to impair nerve function) and nitropropane (a hepato-toxin and suspect carcinogen), where the Paint Makers Association recommended its members to minimise use.[48]

In other cases where the possible hazards of paint solvents are causing attention, there has not been notable action by the paint industry. This includes cases where the extent of the hazard is currently uncertain, or where the hazard is not attributable to specific materials which can readily be substituted.[49]

Environmental Pollution Legislation

The biggest area of 'health' concern affecting solvent use has been air pollution, and in particular legislation passed by U.S.A. State Authorities to control emission of organical materials capable of creating 'photochemical smog'.

In 1966, Los Angeles State set strict emission limits on photochemically active solvents, including Isophorone, Aromatic Hydrocarbons, Methyl-Butyl- Ketone and Trichloroethylene. Other solvents were exempt, including Aliphatic Hydrocarbons, Alcohols, Glycol Ethers, Trichloroethane. Permitted emissions from industrial paint stoving ovens were reduced by 85%.[50] By 1974, 21 States had introduced similar legislation. In addition the U.S. Environmental Protection Agency was amending its Ambient Air Quality Standards.

These rules put considerable pressure on manufacturers to reformulate solvents. There was a move towards unbranched oxygenated solvents, (for which demand increased by 72 million gallons, leading to solvent shortages) especially glycol ethers, but also paradoxically nitropropane.[51] Industrial paint users were faced with a choice of installing expensive air emission control equipment or moving to surface coating technologies that used less solvent or totally eliminated them e.g. high solids paints, airless sprays, coil coating, powder coating, etc.,[52] - this involved changes in resins and paint application technology alike.

This relatively rapid change was of major concern to U.S. paintmakers and users. It was stimulated by legislation, rather than concern in the paint industry about hazards.

Whilst for climatic reasons, 'photochemical smog' is unlikely to develop in Europe, air pollution legislation covering paint solvent emissions was introduced in Austria, Germany and Holland during the same period.[53] In addition, moves in the mid-1970's harmonisation of legislation in members states of the European Economic Community, including the discussion of draft directives on the handling of dangerous substances and of paint materials, stimulated attention in the paint industry. These pressures were predicted to affect both solvent formulations and paint application technologies. In contrast to the American situation, legislative pressures in Europe were less intense, slower to build up and comprised a range of concerns as well as atmospheric pollution, including odour, worker hygiene, waste disposal and consideration of e.g. solvent costs.

The Development of Paint Application Technology

Given the slowness and labour intensity of the traditional method of applying paint by brush, it is not surprising that much attention has been paid to the introduction of 'mechanising' paint application.

Here there is a sharp dichotomy between the painting of fixed structures (civil engineering, buildings and particularly houses) and the painting of industrial products which are typically small, uniform and portable (relative to buildings). This partly reflects their different organisation (small size of housepainting firms) and access to technical expertise (which was concentrated in the industrial painting sector), but is mainly a consequence of the very different situation in which painting took place.

The painting of industrial products can usually be carried out on a production line basis, taking the product to be painted to a fixed painting station at which both the paint application equipment and support equipment (primarily environmental control equipment e.g. extraction and cleaning plant for worker and environmental protection, air fed breathing apparatus) can be installed.

In contrast there are immense technical barriers to mechanisation in the painting of buildings etc. The object to be painted is very large, in a fixed position, highly variable in form and the technological infrastructure required for mechanisation may not be available (e.g. space to install equipment, supplies of water/drainage, electric/hydraulic power). As a result the vast bulk of paint application technology has been introduced into the industrial painting sector. The first of these developments, spray painting was introduced to allow more rapid painting (and reduce labour costs). Subsequent developments have also sought to improve speed of painting and labour productivity, but have also had as major features :

1) the application of a uniform coat over the whole product

2) materials savings (controlling solvent loss and paint wastage) to

reduce painting costs

3) environmental protection/regulations have been a significant influence, particularly latterly.

Although attempts were made to introduce spray painting into the painting of buildings, the solvent toxicity/fire hazard was very great and the method did not become established. The exception here is the spray painting of the interior of ships (by workers wearing compressed air-line-fed breathing apparatus), a practice that has remained highly hazardous.[55]

The most significant changes in architectural paint technology affecting ease of application have been changes in paint materials.

1) vehicles that could be applied in thicker coats with more opaque resins - reducing the number of coats of paint to be applied.
2) reduction in paint viscosity to reduce the effort of painting.[56]

A major thrust here has been the reduction of labour costs of painting by allowing it to be carried out by unskilled labour (the introduction of ready mixed paints) and in the house painting sector by the occupiers (towards whom the introduction of emulsion paints, roller painting, and thixotropic paints has been oriented), especially since the second World War.[57]

Paint Application Technology

1) Brushing

This has been the historical method of applying paint, and is still the predominant means in the decorative/building industry. Though faster application is possible by the use of rollers, application is still labour intensive, and has become increasingly expensive relative to paint costs. In 1911 British building contractors estimated that the labour cost of applying paint was approximately equal to the materials cost. By 1967, application costs were held to be three times greater than material costs. Labour costs have continued to rise, with one contractor claiming (1973 prices in Canada) that they were twenty-eight-fold the material costs

2) <u>Spray</u>

This method of application was made necessary and possible by the introduction of fast-drying lacquers in 1920. Much faster application was possible. However the system required large volumes of costly, highly volatile solvents. Local exhaust ventilation (spray booths) had to be introduced to control the fire and toxicity hazards of the solvent and oversprayed paint. Latterly, paint and solvent recycling were introduced to recover some of the cost of the materials. Electrostatic spraying, whereby the paint cloud was given an electrostatic charge to attract it to the oppositely charged object being painted, was introduced in 1953 to reduce the wastage of paint (this made automatic spraying more feasible). The airless spray gun was introduced in 1957 to enable a more concentrated resin solution to be sprayed than possible with air spray, and to reduce the dissipation of paint solvent.

3) <u>Dip Coating</u>

As its name implies, this involves dipping the object to be painted into a tank of liquid paint. The object is then removed, at a controlled, slow rate to allow excess paint to drip off. This method has been used for many years in coating small objects (e.g. lacquering hand tools). The main problem is ensuing an even coating of paint, in addition the process is slow and not very economical of materials. A recent variation of this technique is flow or curtain coating, whereby the object to be painted is passed through a curtain of liquid paint, thereby overcoming some of the above problems.

4) <u>Strip or Coil Coating</u>

A coil of metal strip is fed through paint covered rollers and then through a curing oven before being rewound. A range of high solids resin can be used. This painted sheet metal is then formed into finished products (e.g. domestic appliance bodies). Coil coating allows the painting line to be transferred from the product manufacturer to the sheet meta supplier, (along with environmental protection plant etc.). This centralisation allows capital cost savings, improved quality control and industria hygiene alike.

5) <u>Electrodeposition</u> (Electrophoretic painting)

This method of application, introduced in 1961, involved the immersion of the object to be painted into a tank of aqueous, ionically charged paint A current applied to the object attracts paint particles to coat all expose metal. The process ensures an even coating, even inside bulkheads etc. which could not be reached by spray or brush painting, and is used for the application of primers, especially in the car industry. The method eliminates waste from solvent loss and overspraying. At present negatively charged paint particles are applied (anodic deposition), though cathodic deposition, which would improve coat adhesion, is being investigated. Though initially alkyd resins were used, they have been displaced, first by epoxy then by polybutadiene resins. Current market share is 10 : 50 : 40 respectively.[59] As noted earlier, U.K. sales of electrophoretic paint increased twenty-four-fold between 1963 and 1977 to 12½ million litres per year.

6) <u>Powder Coating</u>

Introduced in the last ten years, powder coating involves the application of a thermoplastic or thermosetting resin/pigment mixture to an object as an aerosol by electrostatic spray or immersion in fluidised bed of resin. The coating is then fused to produce a surface that is less permeable than by conventional solvent based paints. There is no waste since oversprayed powder can be re-used. Colour control is very difficult since the normal method of making a crude mixture and then adding tints as used in liquid paints cannot be applied. Pigment and resin have to be extruded and ground together, but this must be done slowly since heat will cause the resin to set. As a result the cost of powder coating is greater than conventional methods.[60]

90% of powder coat resins are epoxies at present. These coatings discolour on weathering. The crucial car and domestic appliance market is said to be waiting for the introduction of thermoplastic acrylic powder coat resins to be developed, that will have better surface appearance, before transferring to this technology. 25 million pounds of powder coat (equivalent to 6 million gallons) resin was used in 1971 in the U.S.A. and this was expected to quadruple by 1981 if the car market takes up this method. Atmospheric pollution regulations in the U.S.A. were seen as stimulating rapid uptake of this technology. A similar trend was expected to result in Europe from comparable EEC Regulations.[61]

Hazards and Innovation in Paint Application Technology

The paint application technology is the intervening variable between the toxicity of the paint materials and the hazard to workers or the environment, determining (given the physical properties of the paint materials) the exposure that takes place. Consideration of hazard has therefore played an important role in the development of paint application technology. In some cases it has directly determined the possible areas of utilisation of a paint application technology. More generally, it has influenced innovation and diffusion of certain methods of paint application.

For example, the release of solvent in spray painting required it to be used with extract ventilation to control the fire and poisoning risk. The technical obstacles to using ventilation plant prevent the application of spray guns in painting buildings. Certain materials e.g. lead pigments could not be used in spray paints for the same reason. The toxicity of polyurethane sprayed lacquers largely restricts their use to very specialised applications.

Because it is unfeasible to use mechanised painting techniques for buildings, paint application technology has not been a significant factor in architectural painting innovation. The reverse is true in industrial painting. However, here there is a choice in control strategies between installing ventilation (and emission control) plant and utilising less hazardous materials and application technologies. The effects of consideration of hazard on paint application technology choice is thus indirect, determined by the relative technical problems and economic costs of these alternative control strategies. [N.B. these in turn are affected by the degree of control of exposure required. More stringent standards will thus increase the cost of engineering controls required for a given paint application technology, thereby encouraging the adoption of inherently safer application technologies.]

Most of the paint application technologies can be used with a variety of pigments, resins and additives. They do however have a major effect on the nature and quantities of solvents used. Thus the pressures towards 'low solvent' systems described in the previous section (of economy and to conform to environmental standards) have been significant factors in promoting the development and usage of paint application technologies with low or zero solvent usage.[62]

Thus of the 20 major innovations in paint vehicle and application technology (Listed in Table 2.5) introduced since the Second World War, reduction in organic solvent content was the principal or at least a major benefit of at least nine. Four of these were materials innovations (aqueous and non-aqueous dispersions), five were innovations in paint application technology.

It would appear from paint trade literature that economy was the most significant initial factor (increased speed, reduced labour cost as well as materials savings). Latterly, solvent economy emerged as a major factor (following the 1973 oil crisis), coupled with public concern and legislation about the hazards of solvent emissions.

Though figures are not available for the uptake of low solvents paint application technologies (except in the case of electrodeposition which, as noted, is growing rapidly), their use is undoubtedly increasing, but probably remains limited to large scale production in larger firms able to support the capital and technological requirements of such systems.

The Development of Additives

An additive is defined as a material which, when added in small quantities, will ameliorate the physical and or chemical properties of surface coatings to improve film forming characteristics.[63]

In 1911, only one class of additives were commonly used - driers, which were mainly lead soaps (or inorganic lead compounds that would react with the drying oil to produce the same) although manganese linoleate was also used.[64] By 1975, twelve major functions of additives were listed, including :

- Driers and other catalysts to promote polymerisation
- Antioxidants to prevent premature setting or retard the Drying Process.
- Chelating agents to increase the paint body, prevent setting and

reduce paint flow e.g. for thixotropic paint

- Surfactants to aid pigment etc. dispersal and prevent separation
- Surfactants to prevent foaming
- Emulsifiers and coupling agents for water dispersed paints
- Agents to control the evaporation process to aid levelling and gloss in the painted surface
- Biologically active materials to preserve the liquid paint and/or the painted surface from bacteria or fungus and to kill pests (especially antifouling marine paints)
- Penetration and adhesion control agents
- Paint stabilisers e.g. against frost

In addition there is a range of additives to impart specialised properties such as flame retardation, corrosion inhibition, electrical conductivity.[65]

The range of additives available has become highly variegated and specialised. Thus a review of additives available to the British Paint industry in 1977 distinguished over 60 separate categories of additive, with almost 30 different branded formulations in each category.[66] This variety of branded products may include similar or duplicated formulations, and there may be overlap between the categories. However, a massive growth in the uses and range of materials available has clearly taken place.

The growth in additives can be related to a range of factors :

- the growth in ready mixed paints, and the consequent need for greater control over paint performance
- the diversity of paint materials and application to technologies
- pressures to use cheaper materials
- attempts to improve paint performance
- the development of specialised paint applications.

Whilst the small use-concentrations of additives mean that exposure to paint users (if not paint makers) and consequently hazards to users are minimised, health problems have been noted from major classes of additives notably :

1) lead salts - driers

2) ketoximes - antioxidants

3) organomercurial salts - pesticides

4) amines - stabilisers, coupling agents (in emulsions) accelerators (epoxy resins)

5) mineral acid - catalysts in aminoplast paints.

In the case of 2 and 4, the health problems have been controlled (without regulation) by the use of different materials - whether substitute chemicals or homologues with lower volatility or toxicity (e.g. polyamides in place of amines in epoxy systems).

The cases of 1 and 3 have attracted more attention, and we shall briefly discuss developments here.

Lead Driers

Though these were largely unaffected by legislation about lead hazards in the 1920's, because they were used in concentrations of below 1% as metal, more stringent legal controls on the lead composition of paints in advanced industrial countries since the 1950's led to pressures to reduce their use in air drying paints, and their widespread replacement (e.g. by zirconium salts).

One commentator noted that this legislation though irksome, was a 'blessing in disguise' since 'it gives the technologist a chance to review the formulation and the part played in it by driers' and had thereby opened the way to improvements in paint formulation.[68]

Organomercurial Preservatives

We note three major uses of phenyl mercury compounds : for in can preservatives in interdispersed paints, to provide fungicidal properties to exterior paints and as antifouling agents in marine paints (along with other organometal compounds based on copper, arsenic and tin). Concern was expressed about potential hazards to paint mixers and paint users and to the environment, and it was proposed to regulate their use.[69] In the U.S.A. the use of all phenyl mercuric preservatives was banned by the Environmental Protection Agency in 1977 (though this was subsequently reversed for paint preservatives and fungicides following an appeal by manufacturers.)[70] Concern about hazards and the threat to legislation stimulated a 'search for mercury substitutes'.

A wide range of mercury free alternative pesticides was available, though none was suitable for all applications. It was suggested that a solution to this problem would involve a more precise understanding of pesticide mechanisms and their performance in paints.[71] Novel methods of utilising biologically active materials were proposed (e.g. binding pesticides within the paint film).[72]

A similar re-evaluation of organometal antifouling additives also took place.[73]

The development of Pigment Technology

The final component of paints to be examined is the pigment, which imparts decorative properties to the paint (colour, ability to obscure the underlying surface). Unlike many of the other components of paint, pigments were primarily developed for the surface coating industry (in particular for paints, but also printing inks etc.). However, an increasing proportion of pigment consumption is for the newly developing plastic and rubber industries (initially as a filler in linoleum and tyres, but now increasingly to colour a range of plastic products). This creates problems for analysis which will be discussed later.

White pigments comprise over two thirds of the pigments used in paint making, as the sole pigment in white paints, but also as a significant constituent of coloured paints.

At the turn of the century, white lead (basic lead carbonate $PbCO_3 - Pb(OH)_2$) had a near monopoly of white pigments for paint. Subsequently this was displaced by zinc pigments (Zinc Oxide and Lithopone) and by Titanium Dioxide. The regulatory debate, particularly regarding the feasibility of prohibiting the use of white lead, is the main focus of this study. The development and diffusion of white pigment technology, and the role of technical and economic factors and concern about hazards in this process will therefore be examined in detail in the next chapter.

In this section the history of innovation of paint pigments as a whole, and their overall pattern of consumption in paint are briefly examined.

An Overview of the Development of Pigments

The major use of pigments has been in the paint industry (although other applications are now of increasing importance e.g. in plastics, printing etc.), and most of the innovations in pigments have been developed for this application (with the exception of organic dyestuffs developed during the 19th Century). Certain naturally occurring ores have been used in painting throughout human civilisation. The use of manufactured pigments is first recorded by the Greek and Roman civilisations (who also noted the first instances of lead poisoning).[74] A brief chronology of introduction of major pigments is given in Table 2.10. and 2.11.

TABLE 2.10 Chronology of Significant Developments in Pigment Technology prior to the Twentieth Century

Sources: F.Armitage, The British Paint Industry, 1967, op.cit.
Noel Heaton, J.Roy.Soc.Arts. 1932, 80, pp.441.

TABLE 2.11 Chronology of Significant Developments in Pigment Technology Introduced During the Twentieth Century

Source: G.de W.Anderson, - 'Don't waste your money on research' JOCCA, September 1974, p.293-9.

F.Armstrong, 1967, op.cit.

* G.B.Home Department, Report of Departmental Committee into Use of Lead Paints in Coachpainting [Cd.630], HMSO., London, 1920 p.23.

It will be noted that most developments in inorganic pigments had taken place before the end of the 19th Century. The major area of development since that period has been of organic pigments. However, organic pigment are primarily consumed in the manufacture of printing inks. (In 1973 the breakdown of consumption of organic pigments in the U.S.A. was 45% printin ink, 26% paint, 20% plastics.)

This table does not attemptto do full justice to the development of synthetic organic pigments and dyestuffs, but has merely indicated those picked out by paint industry commentators as being of significance.

The complexity of the pattern of development of synthetic organic colours is best indicated by Figure 2.4 which charts significant development in organic colour chemistry between 1856 and 1930.[78] These are mainly 'azo' dyes and pigments, formed by diazotising an aromatic primary amine and coupling this with another aromatic compound (e.g. 2 naphthol). A wide range of colours can thus be prepared. Some are insoluble and can be used in paints. Others can only be used by precipitating their heavy metal salts to overcome water solubility (known as takers and toners). These colours are known as Coal Tar Dyes because of the chemical feedstocks from which they were originally prepared.

'Azo' pigments are the cheapest and most widely used organic pigments in paint. Though a range of bright colours is available, they are very variable in terms of fastness to light, heat, solvents and chemical resistance.

Subsequent development of pigments sought stronger colours and better resistance. A range of 'high performance' organic pigments were achieved (e.g. the quinacridones). These are mainly complex, polycyclic materials and are several times the price of 'classical' organic pigments.

Figure 2-4 SIGNIFICANT DEVELOPMENTS IN ORGANIC COLOUR CHEMISTRY 1856 - 1930

Source: Interchemical Corporation, Three Monographs on Colour No 1 p4, 1935.
Reproduced from J Mattiello 1942 op. cit. (78)

The General Pattern of Consumption of Pigments

The consumption of white pigments will be examined in detail in Chapter 3. However, it is useful to get an overall picture of consumption of all pigments. Data on this are available from the censuses of Production conducted at various periods between 1907 and 1968, and from the Department of Trade Business Monitor annually since 1973.

Unfortunately the categories used in these statistics have varied considerably over the years. Before 1954, certain pigments classified under Dyestuffs and Pigments (Minimum List Heading 277) were grouped under General Chemicals (MLH 271) and Paints (MLH 274). The headings under which pigments were classified vary : before 1930 separate figures are given only for white lead for example.

Figures from the 1948 and 1954 censuses of production show the purchases by larger establishments of various pigments in the Paint and Varnish Industry. The returns only include purchases by establishments employing 25 or more workers. Since the paint industry includes many small firms, the total consumption levels are an underestimate (although the increasing concentration of paint firms will offset this discrepancy).

Current figures for pigment consumption in the Western European paint industry have been provided by ICI, based on a survey by Industrial Aids Ltd., London for 1977.[79]

These data are produced in Table 2.12.

It will be noted that white pigments throughout this period have constituted over $^2/_3$rds of total pigment consumption by the paint industry. Organic pigments have only a small market share (about 2.5%) - due primarily to their high cost (as a result of which, they are usually blended with inorganic pigments to which they confer brightness of colour)[8

TABLE 2.12. Purchases of Pigments by the Paint Industry

Quantities 1000s tons, excluding extenders.

Aston University

Illustration removed for copyright restrictions

Aston University

Illustration removed for copyright restrictions

Source: G.B.Census of Production
Figures provided by ICI Ltd. 1979.[79]

Sales of Dyestuffs and Pigments by U.K. Manufacturers

For recent years it has been possible to use figures of sales of pigments by U.K. manufacturers from the Department of Industry Business Monitor. These have been produced quarterly since 1973. (P.Q.277 Dyestuffs and Pigments)

These figures for total sales are not directly comparable with the earlier statistics - for purchases of pigments by the paint industry.

They are plotted on Figure 2.5.

Titanium Dioxide has been drawn to half scale. Coloured inorganic pigments (from 1973-7) would include both synthetic iron oxides and chrome pigments.

Factors Affecting the Use of Coloured Pigments

As noted earlier, organic pigments have only been consumed in limited quantities in paints. High price is the major factor cited, along with poor durability of pigments - viz:

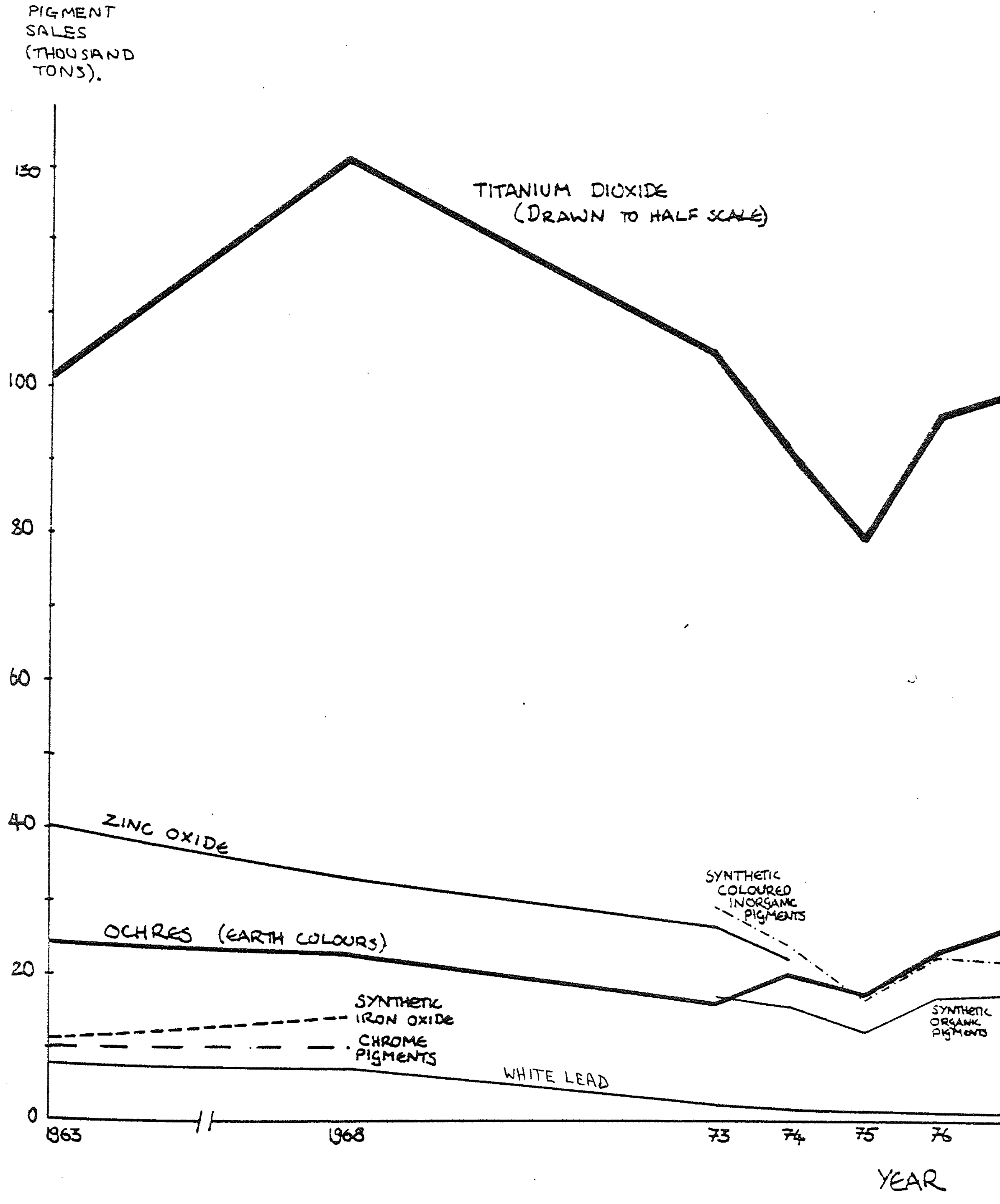
1) lack of heat resistance of some pigments making them unsuitable for stoved (industrial) finishes.
2) lack of light resistance.
3) lack of solvent fastness (loss of pigmentary properties by dis-solution of pigment particles).

Prices of inorganics rose faster than organics following the 1973 oil crisis.[81]

Factors tending to increase the consumption of organic pigments included :

1) technical developments overcoming the poor durability described above.
2) the demand for a greater variety of colours and brighter colours for consumer products. (met in particular by the development of 'high

Fig 2-5 SALES OF PIGMENTS BY UK MANUFACTURERS 1963-1977



Source: Department of Industry Business Monitor performance' organic pigments, which themselves were significantly more expensive than 'classical' organic pigments.)[82]

3) a major factor, emerging during the late 1960's and becoming particularly acute during the 1970's, predicted to lead to increased consumption of organic pigments (and a shift from traditional inorganic colours to new inorganic pigments) has been concern about health hazards and in particular regulation.

Though the first government enquiry into the hazards of lead paint (in 1911) recommended the prohibition of lead colours as well as white lead, this question was largely sidestepped in the subsequent controversy.[83] See Chapters 4 and 5. As will be shown in Chapter 6, it subsequently became necessary to regulate the amounts of lead colours and their coloured pigments based on heavy metals (Cadmium, Chromates, Barium) present in paints in order to protect the consumer, and in particular children. Most of these pigments are in the red to yellow colour range; blue pigments having been obtained with satisfactory price and performance and low toxicity. In addition lead and chromate pigments continued to be used (and cause health problems) for anti-corrosion paints.

The increasing concern regarding health hazards, and in particular increasingly stringent regulations forced paint manufacturers to initially reformulate their products to keep within the limits set for lead, chrome, etc. content, and latterly to consider the abandonment of the use of such pigments (especially for toys, pencils and similar goods for domestic consumption).

A significant body of commentators in the paint and pigment industry predicted substantial, even revolutionary changes in thinking about the formulation of coloured (and protective) paints, (involving use of combinations of pigments to achieve a balance between cost and utility with reduced health hazards) leading to the increasing use of organic pigments and 'low toxicity' inorganic pigments.[84]

Concern about hazards and technological change in paint in paint materials and application technology.

This brief survey of technological change in the paint industry has demonstrated the interacting role of demand from key paint users (especially industrial painting) and the availability of materials from the chemical and related industries in shaping the development and diffusion of paint technology. However, within this broad pattern, concern and legislation about hazards of painting has been a significant influence, promoting modification of materials, substitution of less, for more hazardous constituents, and influencing choice of paint application technologies, in every component of painting technology examined. This state of affairs is not surprising given that painting, both in methods of application and its widespread use, constitutes a highly dispersed use of chemicals, with substantial opportunity for exposure of those materials to the paint maker, paint user, consumer and the general environment.

Significant differences can be noted in both the form and mechanism by which changes have taken place in paint technology as a result of concern about hazards.

The major determinants of the form of this response appear to be the timing of the emergence of knowledge about hazards relative to the adoption of the technology, and the availability of alternative paint technologies and materials. Thus a different pattern of response can be noted where a significant hazard was appreciated when a new paint technology was introduced. (e.g. spray painting not being generally adopted with lead paint or for painting buildings) than when knowledge of the hazard emerged gradually after the technology was already widely adopted (e.g. '2-pack' polyurethane lacquers - continued use of polyurethanes through the application of engineering controls over exposure and changes in materials involved). The direction (and ease) of the response was shaped by the availability of (technically and economically acceptable) alternative materials and application technologies with reduced hazards (c.f.the substitution of benzene by other less toxic hydrocarbons while maintaining the same paint systems, with the adoption of low solvent painting technologies because of concern about atmospheric emissions of solvents).

A distinction can be made between two general mechanisms of response : voluntary control and state regulation.

Voluntary Control

Many of the examples of changes in paint technology cited took place without specific state regulation (although these may have been indirect pressures by the state e.g. through notification of cases of poisoning, by compensation cases from injured workers or informal pressures from the state inspectorates). Voluntary control seems to have been adopted where concern about hazards focused on specific materials/processes which posed major risks. Here a gradual process of technological change had occurred leading to eventual control of the hazard by the paint industry.

Such a 'voluntary control' response was less marked in those instances where the hazard was less severe, or where the nature and extent of harm was less well known or less demonstrated, and the impact was experienced indirectly or diffusely (e.g. hazards arising from long term exposures to materials, consumer and environmental hazards), and where concern focused on groups of materials in widespread use as opposed to specific materials for which substitutes could be found (for example recent concern about potential cancer risks from chlorinated hydrocarbons or neurotoxicity of styrene and of white spirit had not provoked a significant response by the paint industry).

State Regulation

In cases where voluntary control had not been adopted, for some of the abo reasons, state regulation had been developed which forced changes in paint technology. Such state regulation has occurred most frequently since the late 1960's, where it reflected increased knowledge about hazards and reduced willingness to accept levels of risk. In this period, state regulation appears to have been the major stimulus to change, covering a much wider range of materials.

Technical changes as a result of state regulation appear to have taken place rapidly (relative to voluntary control), despite scepticism within the paint industry about the need for such controls. It has been suggested that this regulation has not only accelerated the development of new paint systems, but has also stimulated a re-valuation of paint systems, in which hazard has been a significant consideration.[85]

Concern about hazards (and state regulation to control hazards) has clearly played an important role in changes in paint technology. A study of the pattern of this concern has therefore been undertaken.

The Pattern of Concern about Hazards to Health and Safety of Workers, and the Environment Arising from the Paint Industry.

In order to systematically monitor the pattern of concern about paint industry hazards, an analysis was undertaken of the contents of the paint industry's most authoritative literature abstracting system. World

Surface Coating Abstracts (prior to 1969: the Review of Literature for the Paint, Varnish and Allied Trades) has been publised by the Paint Research Association since 1928.

The abstract appeared bi-monthly until 1950, and subsequently monthly. All paint etc. patents have been abstracted, but non-patent literature has been edited on an increasingly selective basis to keep the publication within manageable proportions (since 1962 these have been kept at 5,300 p.a. while patents have increased from 2174 to 4791 in 1972). References are grouped into categories (primarily by material or area of application). However, 'industrial hazards' has been a separate category since 1933, and environmental pollution since 1970. However, since abstracts are also cross referenced it has been possible to examine all abstracts which deal with 'hazards' and thus minimise the distortions that might arise from changes in categorisation of references.

The number of references cited in the Abstracts is a direct measure of the amount of information on a particular subject going to the paint and allied industries (the Paint Research Establishment provided a lending system for affiliates). It reflects the amount of primary research on a particular subject depending on its dissemination through the trade. It is only an indirect measure of 'concern' in the industry, since it reflects the choice of literature sources, and subsequently editing choices and categorisation decisions of the abstracting staff of the research association. However, since a large proportion of the references are from paint industry journals and literature reviews, which are comprehensively abstracted, the extent of discussion within the industry is well represented. Notwithstanding these limitations, an analysis of W.S.C.A. would appear to provide the most reliable 'objective indicator' available of concern and attention paid to hazards within the paint industry.

The January and July issues of W.S.C.A. have been scanned and the abstracts relating to industrial and environmental hazard categorised as follows:

- Material or Technology Involved,
- Application in Painting/The Paint Industry,
- The hazard involved - fire, electrical, safety, health (distinguishing where possible hazards to paint and raw material producers, painters and the consumer), environmental (distinguishing air, water etc. borne pollutants),
- Type of article - relating to research into the nature of hazards (original paper, literature review), to regulation of hazards (laws, official standards), to control of a hazard (control techniques, patented materials/technologies, measurement and other ancillary technologies for control)
- Country of origin.

All references to hazards were categorised, although in the subsequent analysis references to food hygiene (printing inks for food packaging) and fire-resistant paints have been excluded as these are product characteristics and not relevant to this study. Electrical, Safety and Fire hazards have been grouped together - the overwhelming majority relate to Fire. Where a reference covered more than one category, it was allocated on a proportional basis. This process of categorisation was highly laborious. Looking only at two months in each year (4 months prior to 1950) was expedient but amplified the problems of sampling error. Apparently random intermonth variation in the number of references to hazards within a single year could exceed a factor of two. Caution must therefore be exercised in interpreting the significance of individual observations. No attempt was made to distinguish the length or significance of individual references.

The Abstract was analysed for the years 1928, 1930, 1935, 1941, 1945, 1948, 1953, 1958, 1963, 1966-1976. The results of the analysis are presented in Figures 2.6 to 2.18 below and Table 2.13.

1) Total number of references to hazards

These are presented in Figure 2.6, overlain with a graph showing references to hazards as a percentage of the total number of references to all subjects in those editions of World Surface Coatings Abstracts. Since the Abstracts examined prior to 1950 covered 4 months out of the year (January/February and July/August), as opposed to 2 months thereafter (January and July only), the numbers of references have been plotted to half scale for the 1928-48 period, in this and the next graph. This procedure has been omitted in the subsequent graphs where we are more concerned with internal comparisons.

The total number of references to hazards grows steadily over the 1928-1958 period, although their proportion of references to all subjects falls after 1945 due to the increased size of the abstract.

During the 1960's and early 1970's, references to hazards (total and proportional) are reduced, but rise very sharply in the 1975-6 period.

2) References to hazards by class of hazard

Figure 2.7 plots the total number of references for each major class of hazard : environmental, health and fire and safety.

Initial concern about hazards is overwhelmingly devoted to health hazards (to workers producing and using paint). Safety emerges as a concern only in the 1950's. Environmental hazard

Fig 2-6 WORLD SURFACE COATING ABSTRACTS:
TOTAL NUMBER OF REFERENCES TO HAZARDS 1928-1976
and References to Hazards as % of all Abstracts (estd)

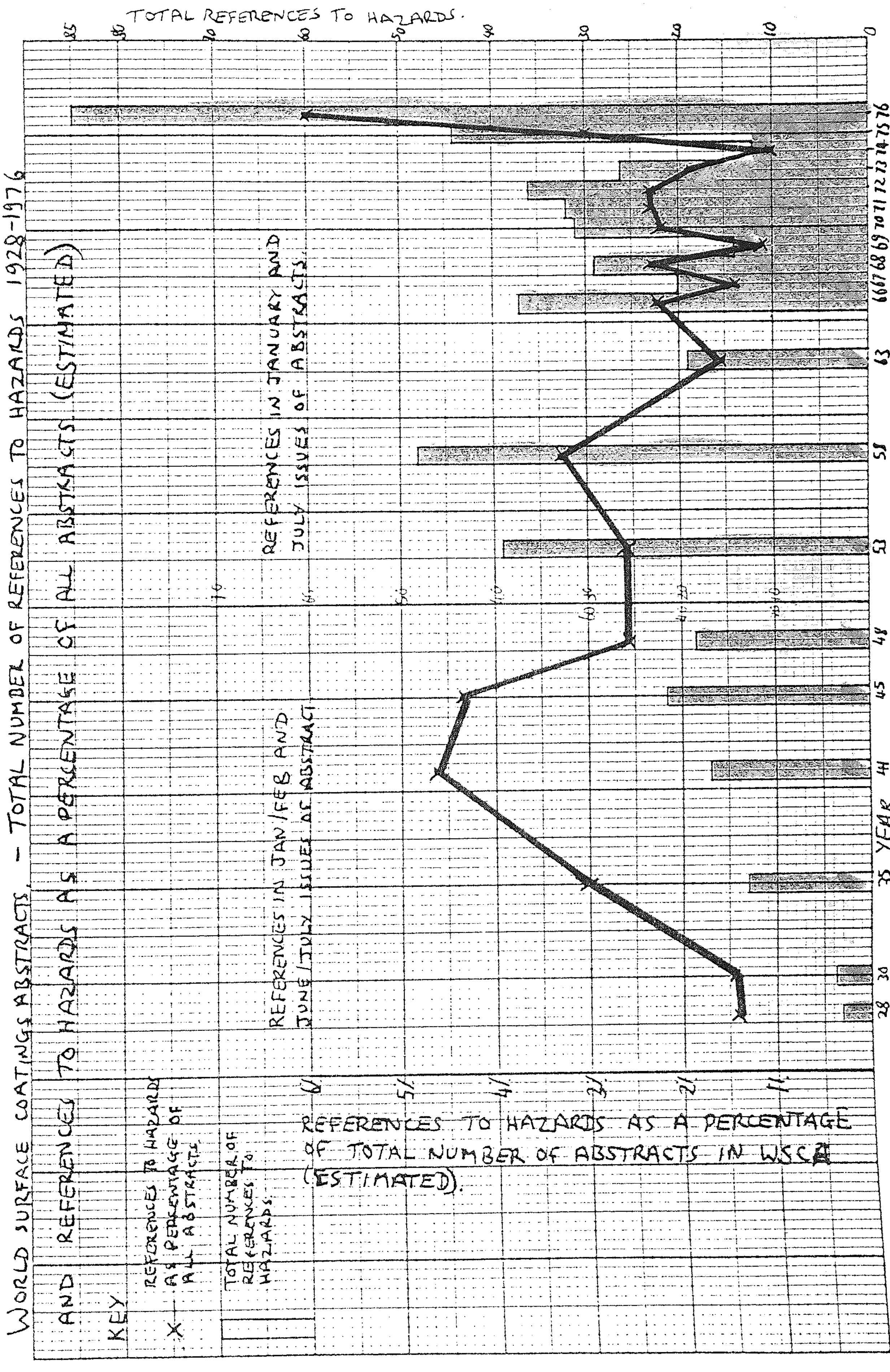
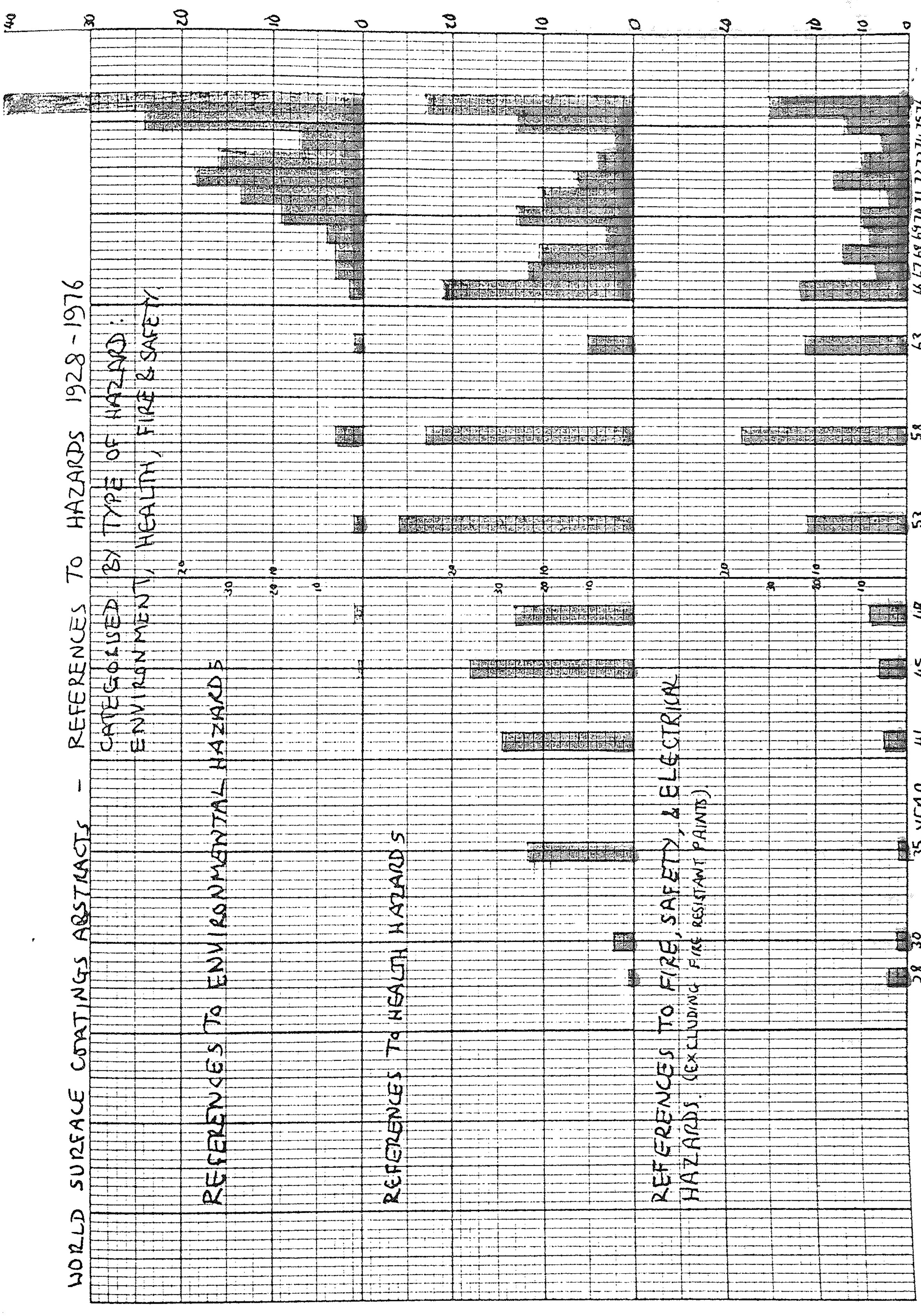


Fig 2-7 WORLD SURFACE COATINGS ABSTRACTS: 1928-1976
REFERENCES TO HAZARDS CATEGORISED BY TYPE OF HAZARD:
Environment, Health, Fire & Safety.



Environmental hazard received no attention prior to 1945, and negligible attention until 1970, when the references to this subject increase exponentially, overtaking all other issues.

While concern about both health and safety hazards seems reduced in the mid 1960's to early 1970's, there is some indication of an escalation of interest in these hazards in 1975 and 1976.

3) <u>Breakdown of references to Environmental Health and Fire etc. Hazards by Country of Origin</u>

Figures 2.8, 2.9 and 2.10 break down the references to Environmental Health and Safety Hazards respectively by country of origin, distinguishing the United Kingdom, the rest of Europe and the United States of America.(a relatively small number of references from other parts of the world - mainly Canada, Australia, USSR and Japan - have been excluded).

This indicates that the changing pattern of concern about hazards is not a simple artefact of shifts in the source of references in W.S.C.A.

The pattern of references to environmental hazard are broadly comparable between the U.K., Europe and the U.S.A. - although there is some indication that sustained attention in the latter country developed slightly earlier (which may be connected with the introduction of "rule 66" type legislation discussed elsewhere - see below).

There is some indication that the early interest in health hazards between 1935 and 1953 reflects discussion/research taking place predominantly outside the U.K., and in particular deriving from the U.S.A. in the 1941-48 period.

Fig 2-8 WORLD SURFACE COATINGS ABSTRACTS: 1928-1976
REFERENCES TO ENVIRONMENTAL HAZARDS
By Country of Origin

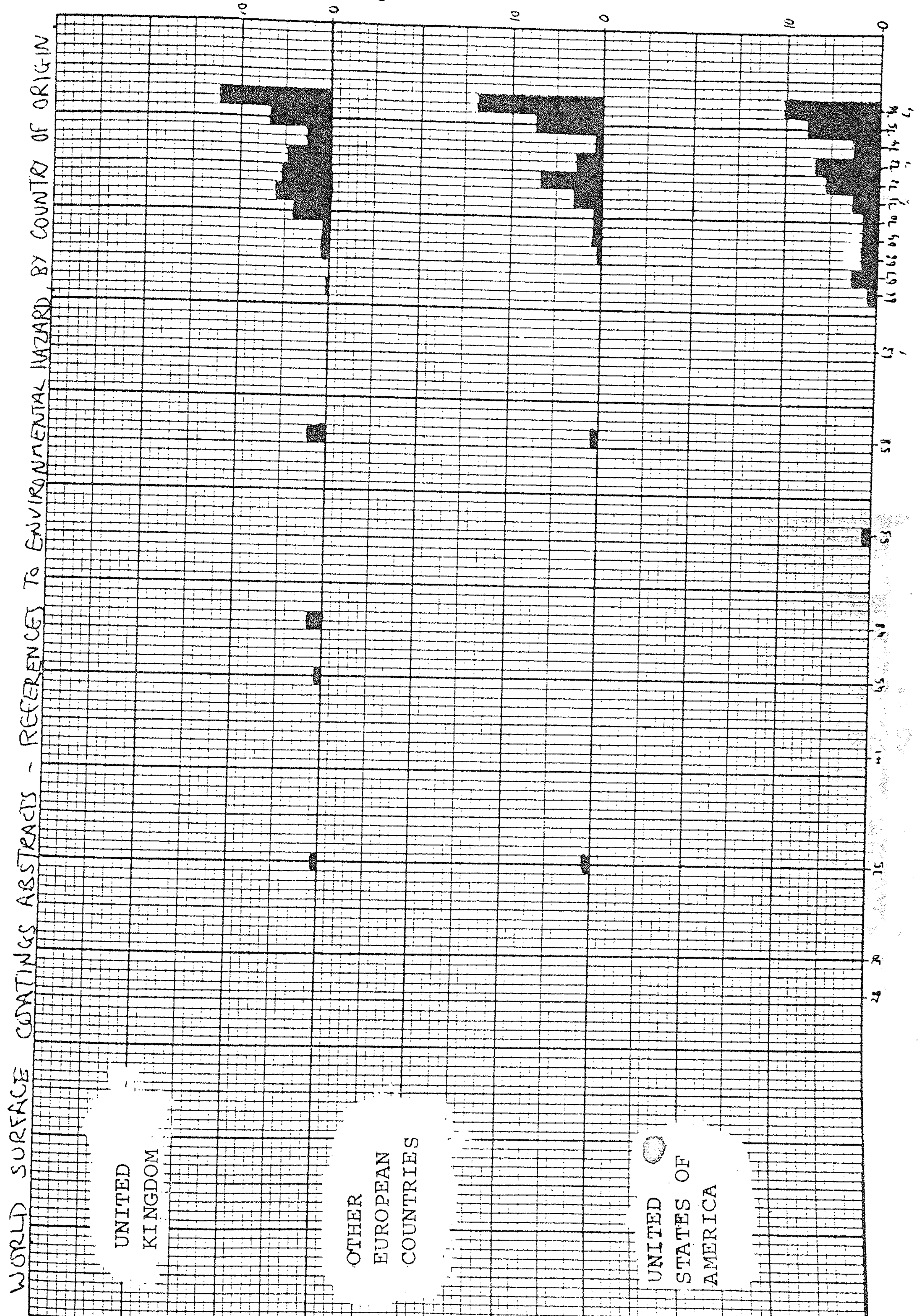


Fig 2-9 WORLD SURFACE COATINGS ABSTRACTS: 1928-1976
REFERENCES TO HEALTH HAZARDS
by Country of Origin

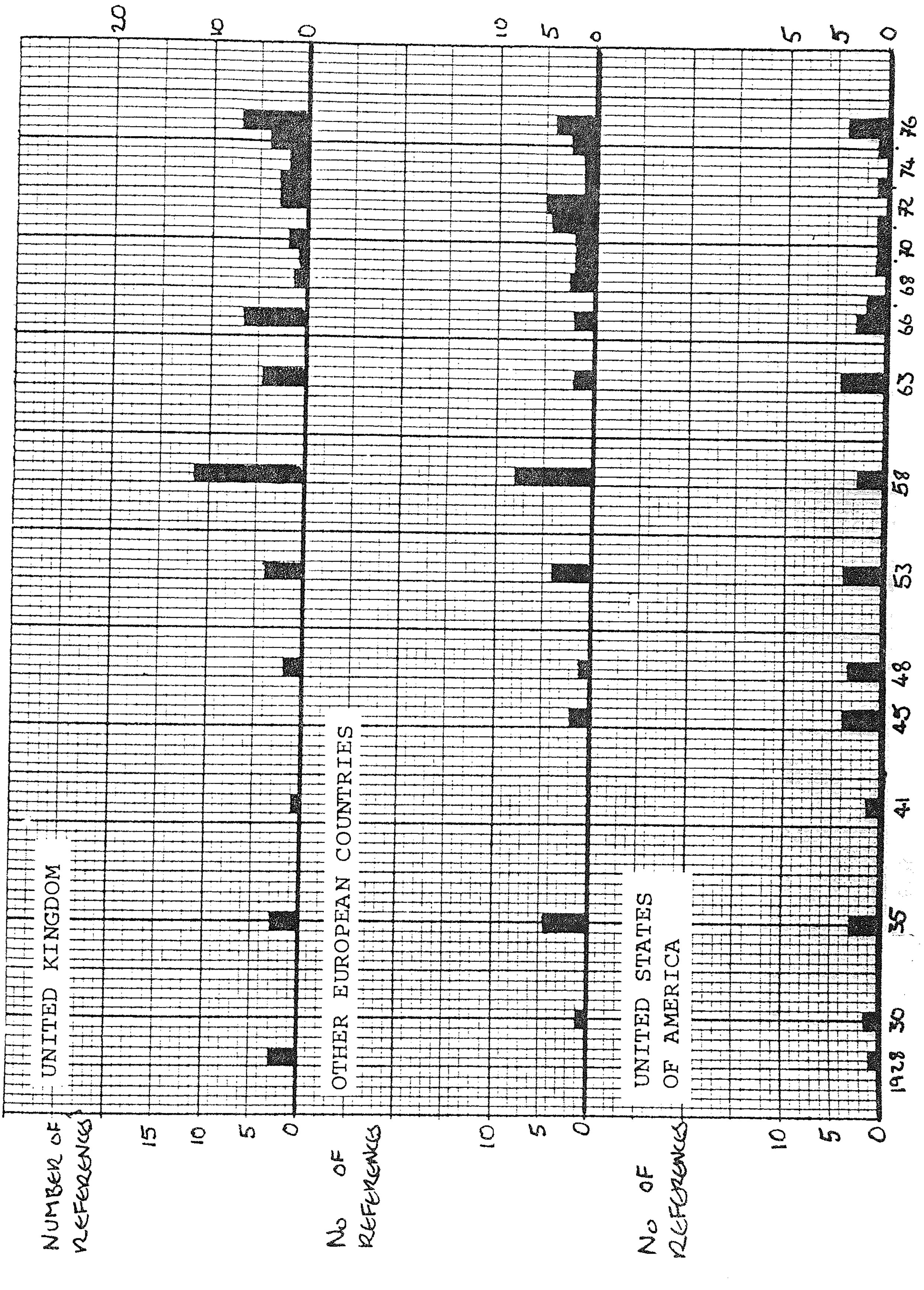
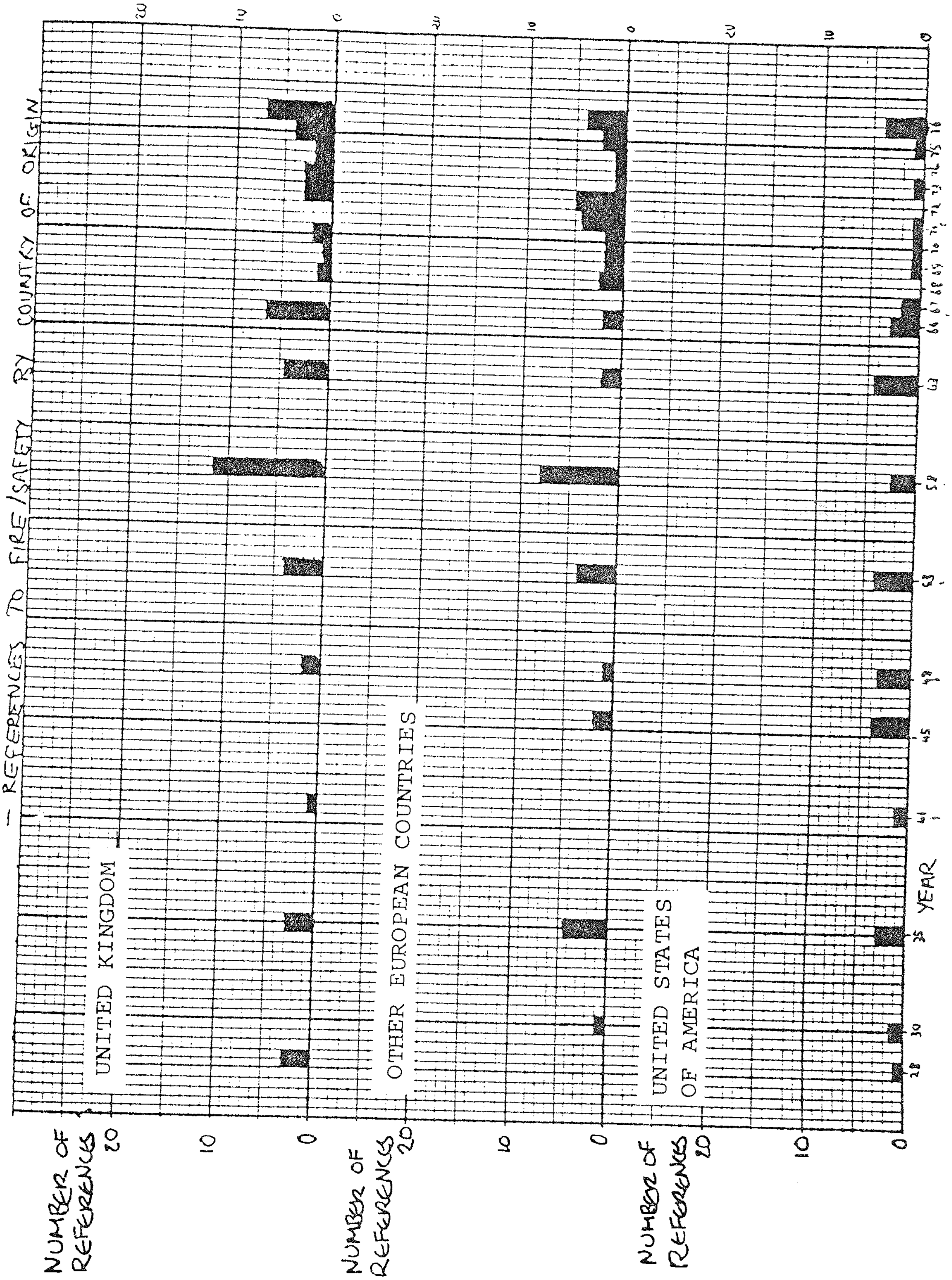


Fig 2-10 WORLD SURFACE COATINGS ABSTRACTS: REFERENCES TO FIRE/SAFETY 1928-1976

by Country of Origin



4. <u>Primary Concern of Papers Dealing with Hazard</u>

The most interesting insight into factors affecting the pattern of concern about hazards is afforded by Figures 2.11, 2.12 and 2.13 which plot the total number of references, to Environmental Hazard, Health Hazard and Fire Hazard respectively, distinguishing between three types of references, to:

a) Papers concerned with the nature of a hazard.

b) Papers concerned with (technical) control over a hazard.

c) Papers concerned with state regulation of hazards.

a) <u>Environmental Hazards</u>.

Sustained interest within the paint industry about the <u>control</u> of environmental hazard seems to have <u>followed</u> concern about state regulation of environmental hazard since 1967, rather than concern about the nature of the hazard. The somewhat earlier interest in environmental hazards in the U.S.A., coinciding with the adoption of state air pollution regulations from 1966 onwards would appear to confirm this relationship.

b) <u>Health Hazards</u>

In the case of health hazards, a very different pattern exists. In the 1935-58 period, it is the nature of the health hazard (i.e. scientific papers and reviews thereof and reports of poisoning in industry) which is most frequently referred to. References to control of health hazards, appearing on a sustained basis from 1941, thus appear to follow concern about the nature of the hazard. In contrast references to regulation receive very little attention over the period.

In the final period studied - the mid 1970's, there is some

Fig 2-11 WORLD SURFACE COATINGS ABSTRACTS: REFERENCES TO ENVIRONMENTAL HAZARDS 1928-19
Categorised by type of paper

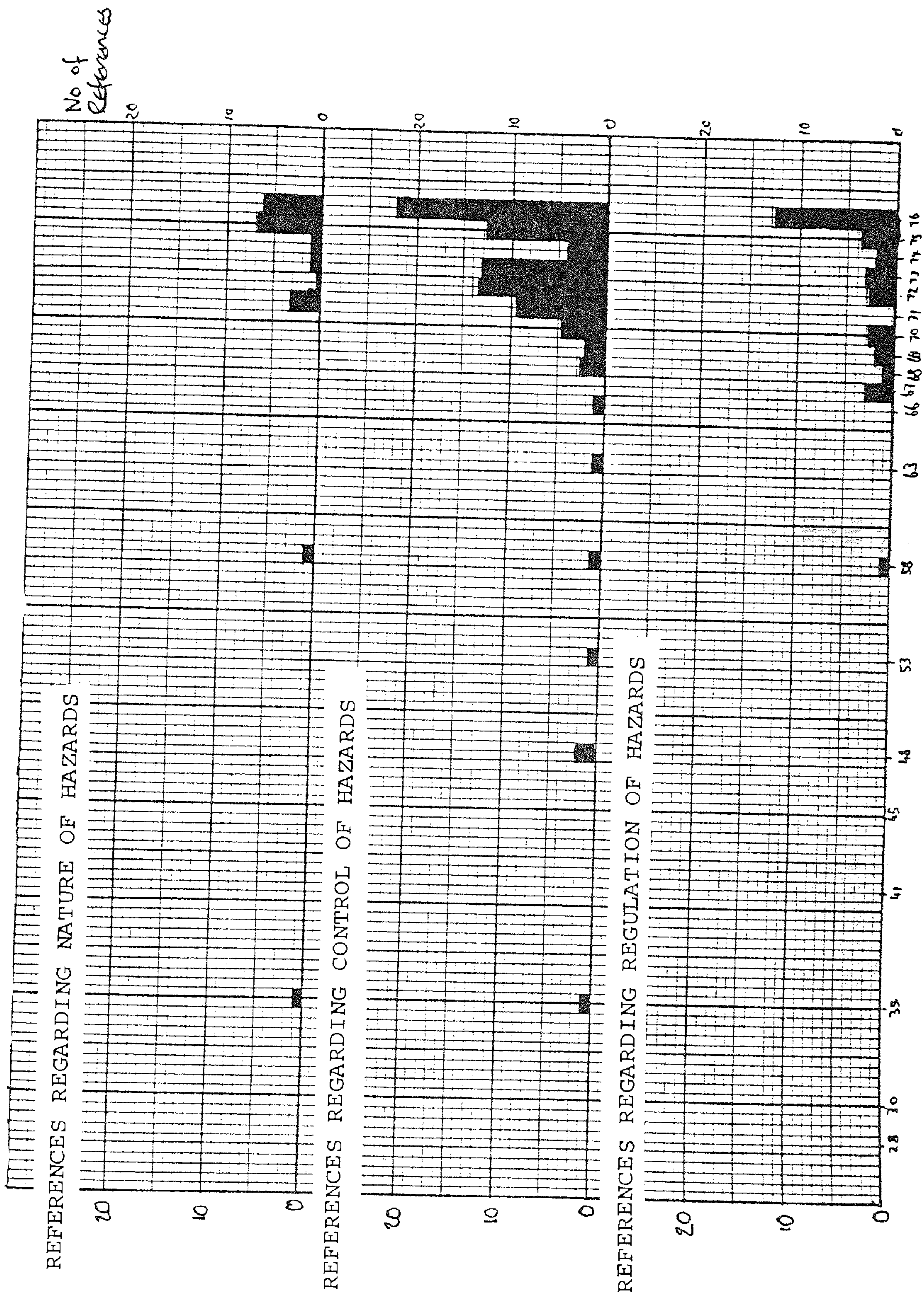


Fig 2-12 WORLD SURFACE COATINGS ABSTRACTS: REFERENCES TO HEALTH HAZARDS 1928-1976

Categorised by Type of Paper

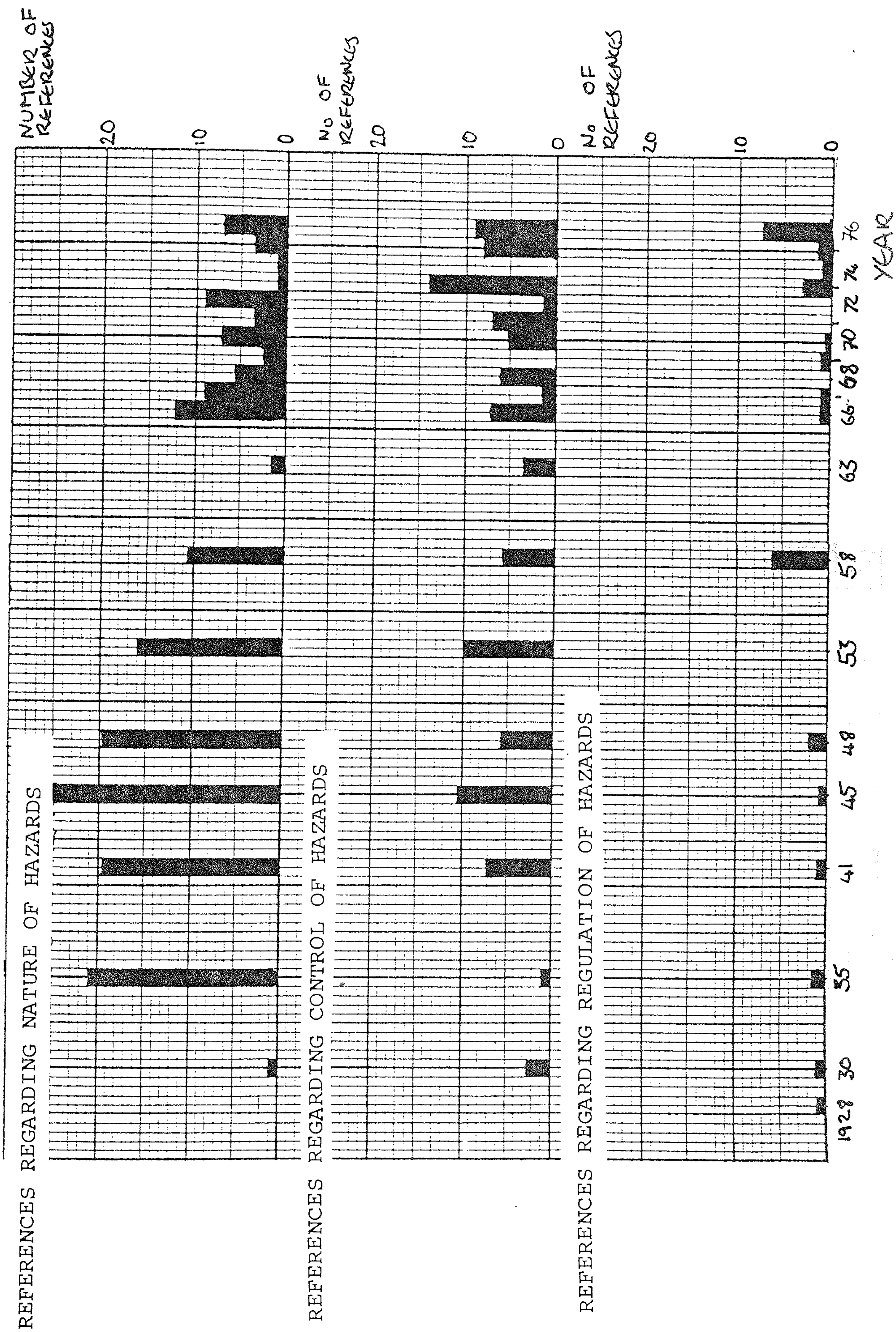
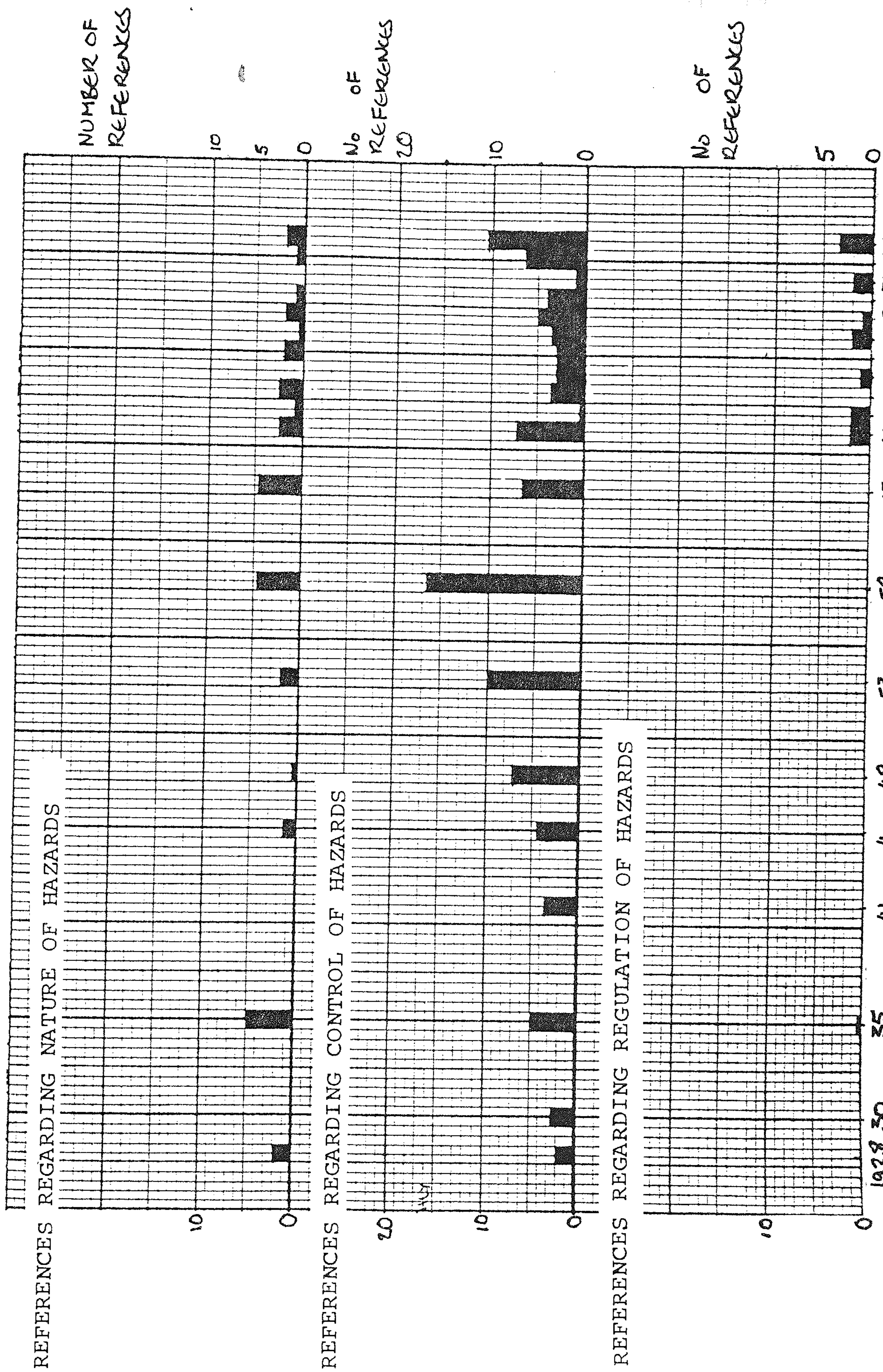


Fig 2-13 WORLD SURFACE COATINGS ABSTRACTS: 1928-1976
REFERENCES TO FIRE AND SAFETY HAZARDS
Categorised by Type of Paper



indication of a shift in the balance of primary concern of references, with 'knowledge' receiving reduced attention, and increased attention to 'regulation'. However, the number of references involved is small, and this relationship may be casual.

The pattern of concern about health hazards would appear to be consistent with the earlier remarks regarding the nature of paint industry's response to health hazards. Concern about the nature and extent of health hazards preceding and apparently stimulating concern about control of hazards during the bulk of the period studied would conform to the model of voluntary control of hazards in this period. Evidence of a shift during the 1960's and 1970's towards regulation-inspired control of hazards is less clear regarding health hazards than it is for environmental hazard.

c) <u>Fire and Safety Hazards</u>

The pattern of concern about fire etc. hazards differ yet again. Here the primary concern throughout the period is with <u>control</u> of hazard. The nature of the hazard receives less attention, concern about regulation is negligible prior to 1966-76 period.

A consideration of the nature of fire and safety risks indicates why this might be the case;

1) the reduced significance of knowledge about (compared to control of) the hazard reflects the fact that fire and safety hazards are immediately experienced. There is little uncertainty regarding their extent. Discovery of new types of fire and safety risk are infrequent.

2) the predominance of concern about fire risks reflects the nature of this hazard, which threatens to damage or

destroy both labour and capital. It is therefore not surprising that concern for control exists irrespective of the development of regulations.

5. Paint Industry Patents mentioning Hazards

Paint industry patents mentioning (the removal of) hazards, uncovered during this analysis, are listed in Table 2.13, distinguishing the year, country of patent, the hazard being controlled (Worker Health, Fire and Worker Safety, Environment - Air and Water), and control technique (less hazardous material, workplace fume control, fire or safety protective device, air and water pollution control).

Figure 2.14 summarises some of the same data, distinguishing the hazard being controlled, and whether the technological change being patented is a change in paint material or in equipment.

Results

1. The number of patents directly related to controlling hazards is small. The greatest number, 5, appearing in the January and July Abstracts of 1971 out of the 700 paint industry patents recorded in those editions. The bulk of these patents derive from the U.S.A. and Germany.

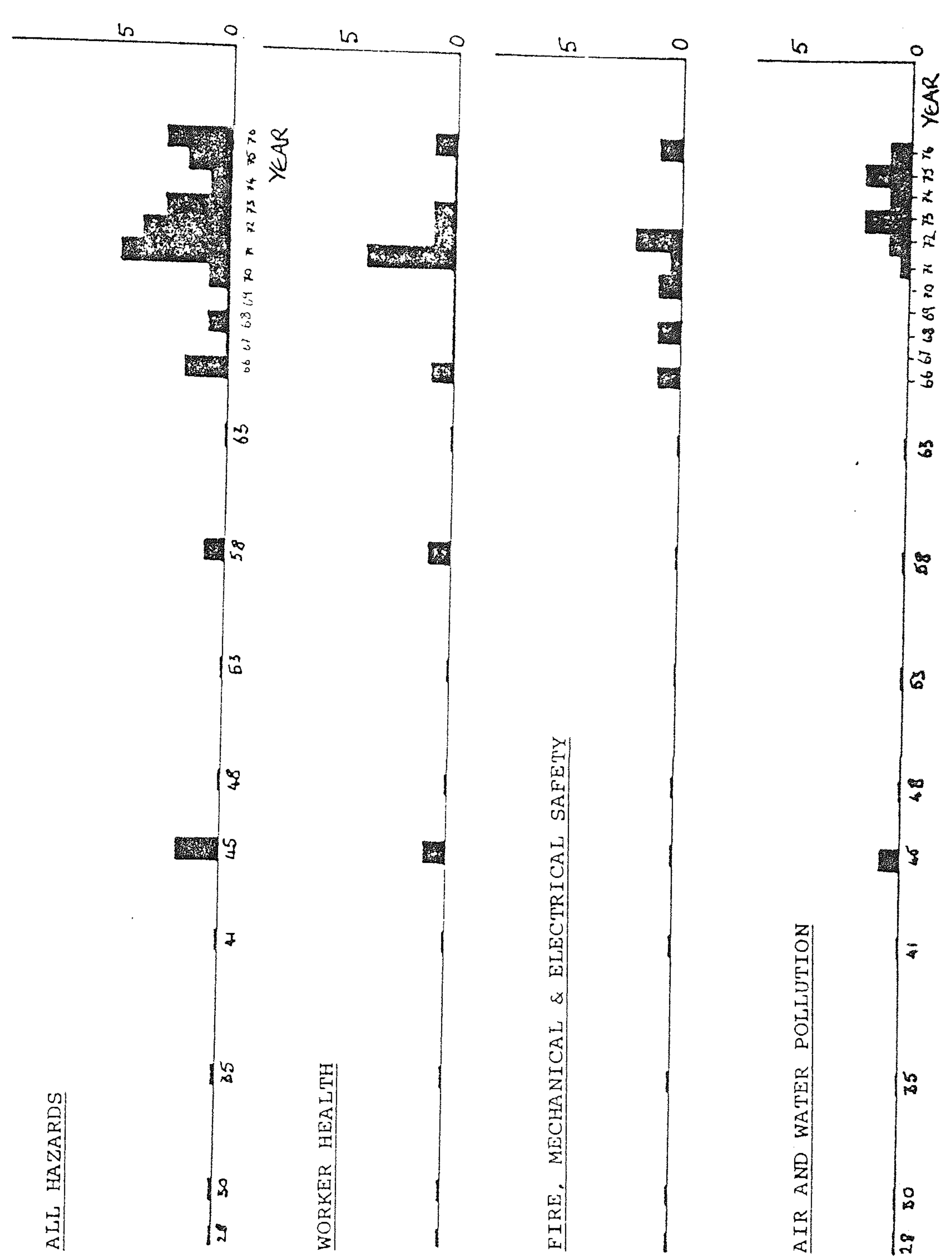
2. The vast majority of these patents appear in the 1971-1976 period. (18 in 6 years, compared to 4 in the preceding 5 years, 3 in the 5 years surveyed between 1945 and 1963 and none discovered prior to 1945). The recent growth in hazard avoidance patents has occurred much faster than the overall growth in paint industry patents.

3. Though the number of patents mentioning each type of hazard is small (10 for health, 6½ for fire and safety, 5 for water pollution, 4½ for air pollution), some

TABLE 2.13 Paint Industry Patents mentioning Hazard
(safety and health risk to workers, including fire, and environmental hazard. Excluding fire resistant paint)

YEAR	HAZARD MENTIONED IN PATENT	OBJECT PATENTED	SAFE MATERIAL (M) OR EQUIPMENT (E)	COUNTRY OF PATENT	LESS HAZARDOUS MATERIAL	FIRE OR SAFETY DEVICE	CONTROL FUMES IN WORK PLACE	ENVIRON-MENTAL AIR POLLUTION CONTROL	WA PO CO
	Worker (Electricity) Fire and Safety	Electrostatic Paint Sprayer	E	USA		1			
1976	Worker Health	Polyurethane Resin	M	Germany	1				
	Environment (Water)	Aldehyde Control Techniques	E	USA					1
1975	Environment (Water)	Control Spray Booth Waste Water	E	USA					1
	Environment (Water)	Control Spray Booth Waste Water	E	UK					1
1974	Environment (Air)	Gas Scrubber	E	USA				1	
	Environment (Water)	Electrodeposition Waste Control	E	UK					1
1973	Worker Health (+ ? Envt.)	Marine Anti-fouling Paint	M	USA	1				
	Environment (Water)	Spray Booth Waste Water	E	USA					1
	Environment (Air)	Spray Booth Exhaust Wet Scrubber	E	Germany				1	
1972	Worker Health	Low Toxicity Cross Linking Agent for Epoxy Resin	M	USA	1				
	Worker Safety	Electrostatic Spray Cut Out	E	Germany		1			
	Worker Safety	Electrostatic Spray Cut Out	E	Germany		1			
	Worker Health	Polyurethane Resin	M	Holland	1				
	Health & Envt.(Air)	Spray Booth Ventilation	E	USSR			1	1	
1971	Worker Health & Safety	Remote Control	E	Germany		1	1		
	Worker Health	Local Exhaust Vent. for Electrostatic Spray Booth	E	Germany			1		
	Worker Health	Local Exhaust Vent. for Spray Booth	E	Germany			1		
1970	Worker Safety	Spray Gun	E	Holland		1			
1969	--	--	-	--					
1968	Worker Safety	Spray Gun	E	USA		1			
1967	--	--	-	--					
1966	Worker Health	Amine Curing Agent for Epoxy Resin	M	Canada	1				
	Worker Fire & Safety	Carbon Black Production	E	USA		1			
1963	--	--	-	--					
1958	Worker Health	Polyurethane Resin	M	USA	1				
1953	--	--	-	--					
1948	--	--	-	--					
1945	Environment (Air)	Spray Booth Exhaust Wet Scrubber	E	UK				1	
	Worker Health	Facemask (Respiratory Protection)	E	USA			1		
1941	--	--	-	--					
1935	--	--	-	--					
1930	--	--	-	--					
1928	--	--	-	--					

Fig 2-14 WORLD SURFACE COATINGS ABSTRACTS: 1928-1976
PAINT INDUSTRY PATENTS CONCERNED WITH HAZARDS
All; and Categorised by Type of Hazard



Patents cited in January and July issues of
WORLD SURFACE COATINGS ABSTRACTS (formerly REVIEW)

differences in distribution over time are discernible. Patents relating to pollution control for example are concentrated in the 1961 - 6 period. In contrast patents relating to fire and health have a more even spread across time.

Observations

There is clearly some correlation between the pattern of concern about different kinds of hazards (and particularly those relating to hazard control) and the pattern of patents about hazards. However it is notable that the grouping of hazard avoidance patents towards the end of the period studied, especially regarding environmental control, follows the recent 'wave' of legislation on industrial hazards.

The issue of a patent reflects the achievement of a significant technical innovation and a decision that the innovation is marketable and requires commercial protection.[86] Thus, mentioning hazard avoidance in a patent involves recognition that this property is both technically and commercially significant. Hazard avoidance patents thereby measure changes in priorities for assessing technology as well as changes in the direction of innovative activity. We cannot distinguish between these two factors in the recent increase in hazard avoidance patents. Either way hazard avoidance appears to have become a more technically/commercially desirable and patentable property in recent years (especially for environmental hazard). It would seem that the increase has been stimulated by legislation against hazards.[87]

If, as suggested earlier, there has been a change in the mechanism of the paint industry's response to hazards, with a slow process of voluntary control being replaced in the late 1960's by more rapid controls based on an element of compulsion by state regulation, our analysis of paint industry hazard avoidance patents would indicate that the shift has led to greater perceived need for hazard avoidance technology.

6. Paint Component Involved in References about Health Hazards

Finally, to supplement the earlier analysis of the role of concern about health etc. hazards in technical development of paint, an analysis has been made of the frequency of reference to different paint constituents in references about health hazards in W.S.C.A. These are plotted in Figure 2-15 which distinguishes references to pigments, resins, solvents and additives. The remainder includes references to paint hazards of paint systems as a whole and those in which the material is not specified.

This shows that pigments and solvents dominated early concern about health hazards (1928-1953). As we shall see below, this was primarily due to two materials alone - lead pigments and benzene solvents. Subsequently, attention has been more evenly spread.

Figures 2-16, 2-17 and 2-18 present a more detailed breakdown of the individual materials or classes of materials involved in references to the health hazards of solvents, resins and pigments respectively.

It is not necessary to comment on the detailed significance of the findings, which will be apparent in the light of the previous section.

a) Solvents

Attention given to different classes of solvents has varied considerably over this period.

Fig 2-15 WSCA: REFERENCES TO HEALTH HAZARDS OF DIFFERENT PAINT CONSTITUENTS 1928-1976

Categorised by use in Paints

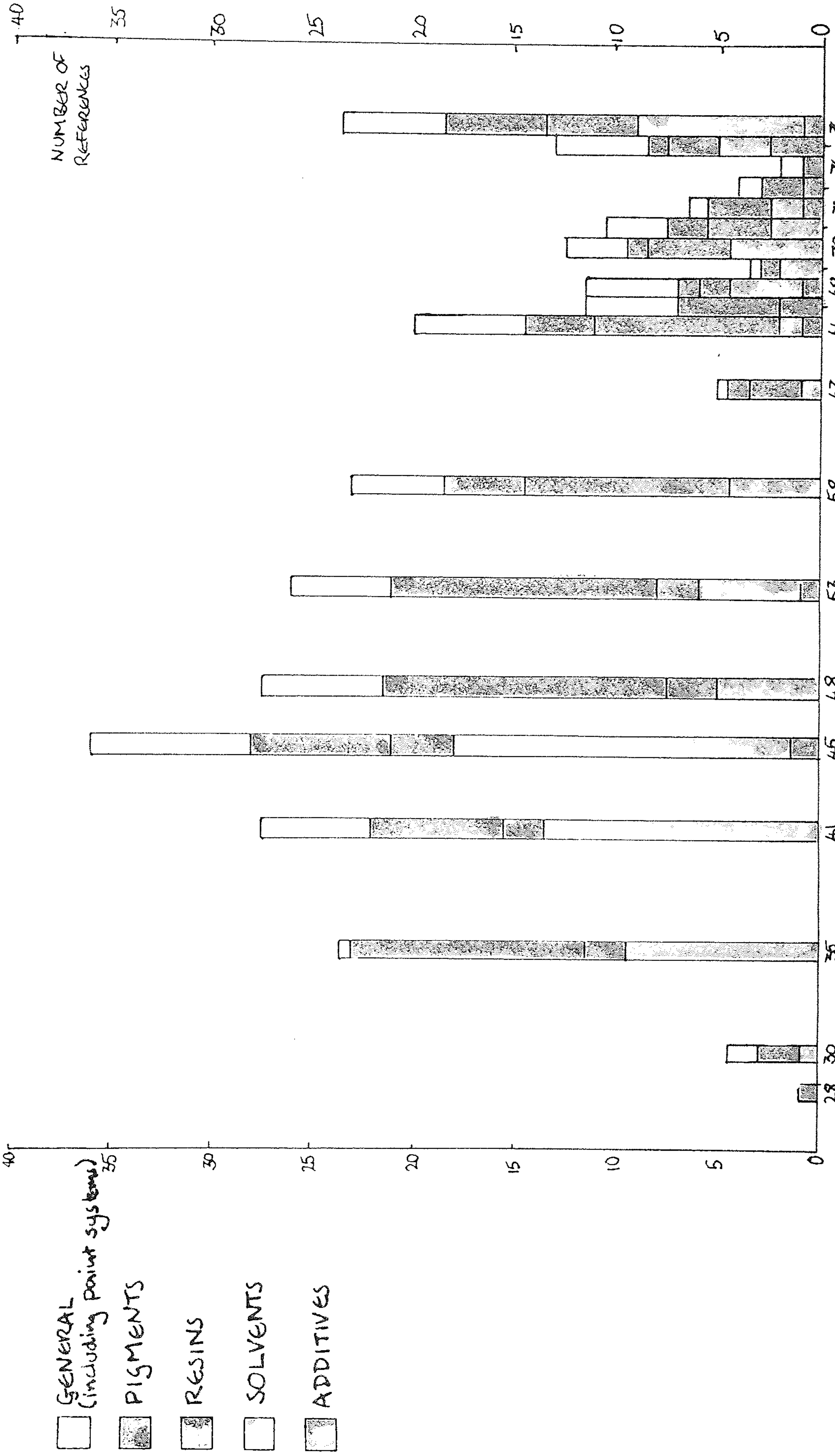


Fig 2-16 WORLD SURFACE COATING ABSTRACTS: 1928-1976
REFERENCES TO SOLVENT HEALTH HAZARD
by Class of Solvent

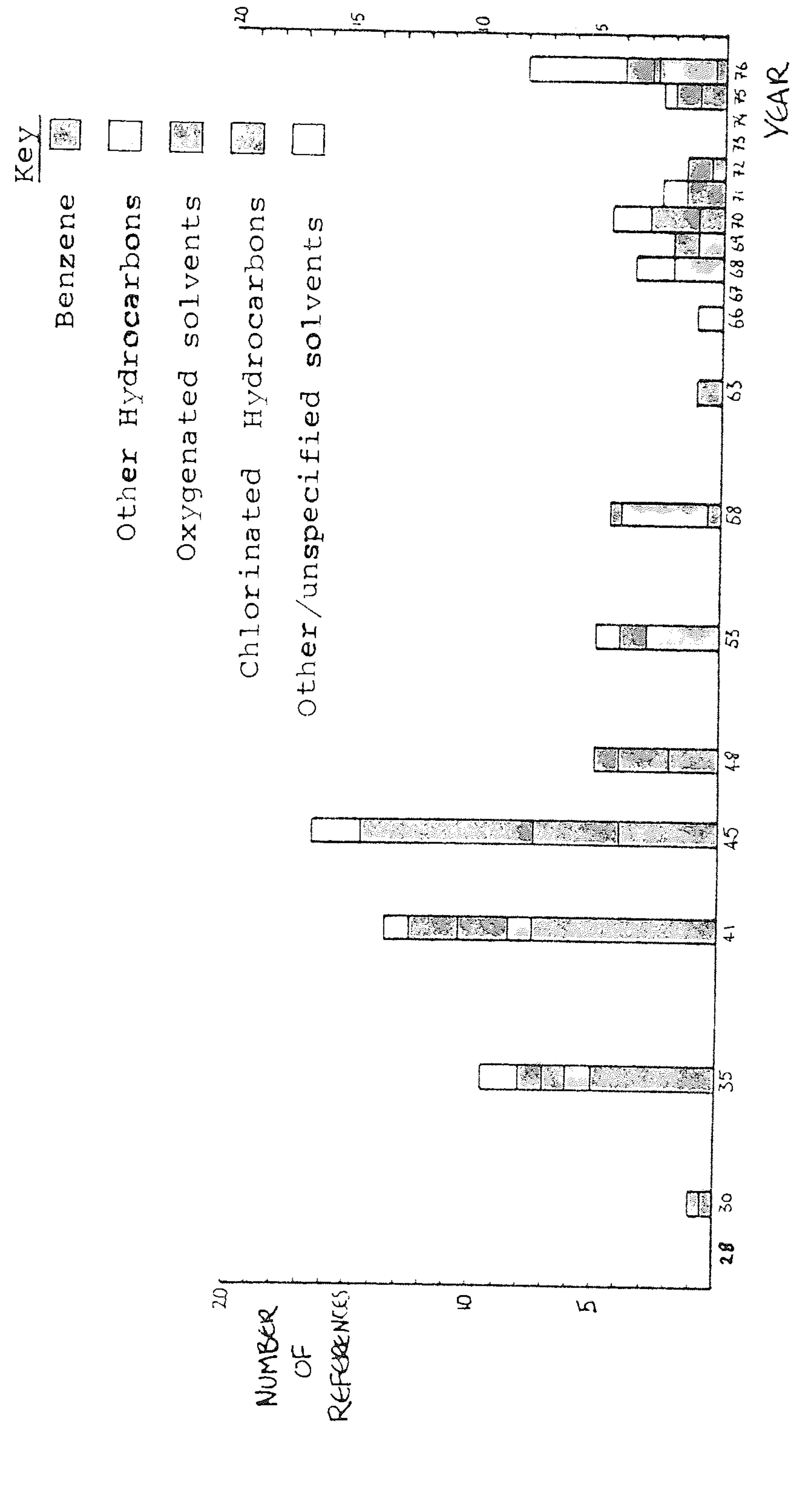
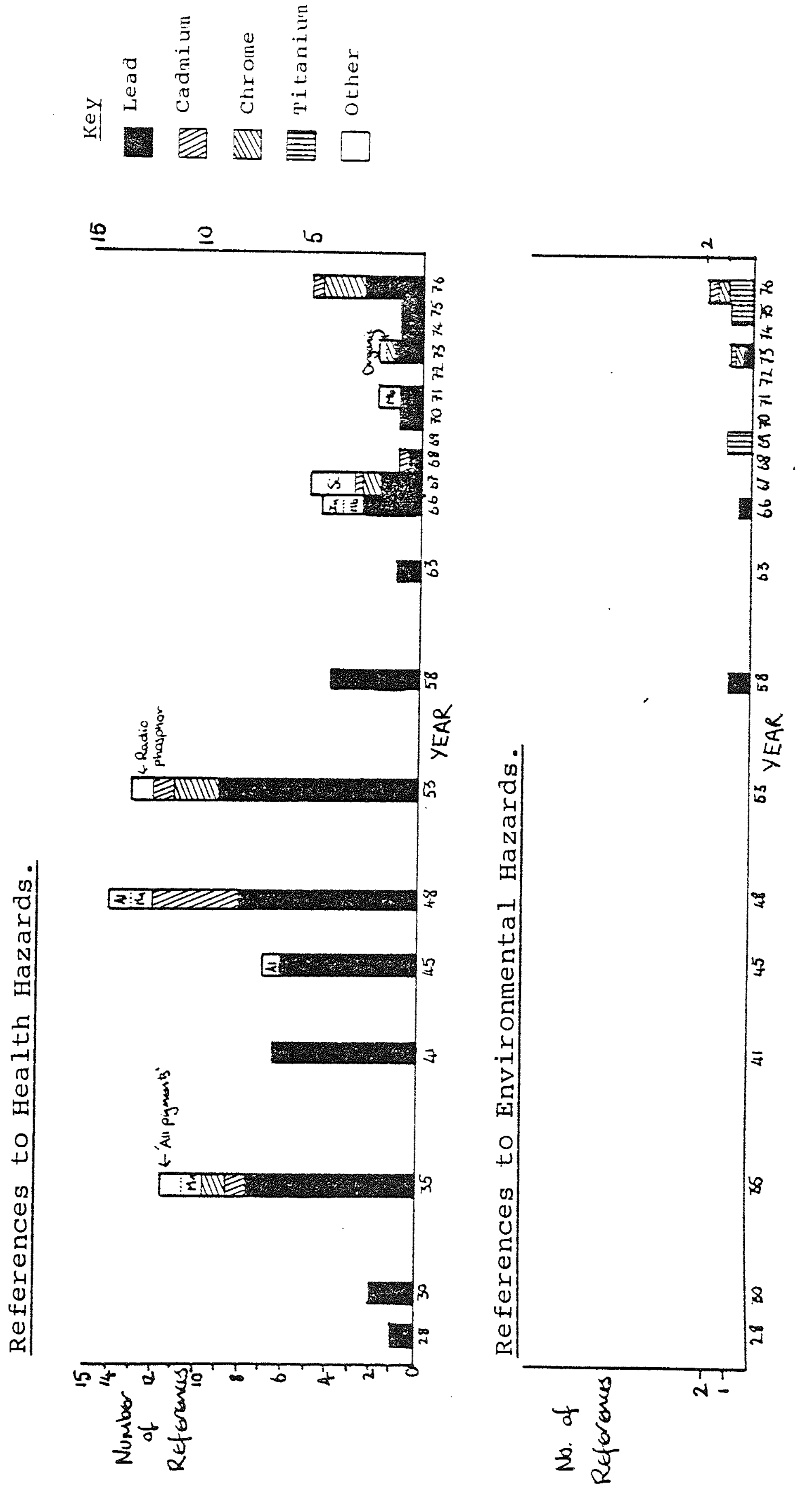


Fig 2-17 WORLD SURFACE COATINGS ABSTRACTS: 1928-1976
REFERENCES TO HEALTH HAZARDS OF PAINT RESINS
(including raw materials/manufacture)

Notes: 1) OTHER - mainly air-drying & stoving
2) OTHER - including drying oil

Fig 2-18 WORLD SURFACE COATINGS ABSTRACTS: 1928-1976
REFERENCES TO HEALTH HAZARDS OF PIGMENT MATERIALS

also showing references to environmental hazards



* To 1958, references taken from Jan/Feb and July/Aug editions
1963 onwards, references taken from January and July editions

The most notable feature is the predominance of concern about the health hazards of a single material, benzene, in the period up to 1948. The subsequent reduction of concern about benzene coincides with its substitution, primarily by other hydrocarbons. It is interesting to note that references to hazards in 1953 and 1958 was in turn directed towards these hydrocarbons (notably xylene and toluene).

b) <u>Resins</u>

Concern about resin health hazards up to 1958 focused almost exclusively on resin manufacture. Subsequently it has been catalysed paint resin systems (polyurethanes, epoxies, unsaturated polyesters) which have received the greatest attention.

c) <u>Pigments</u>

Figure 2-18 shows references to environmental hazards as well as health hazards of pigments.

Pigments are distinguished by their heavy metal component (hazards of organic pigments having been subject to negligible attention).

1. Concern about pigment hazards has predominantly focused on health hazards (the exception here being Titanium Dioxide, which only appears by virtue of recent references to the environmental problems of pigment manufacture).

2. Concern about the health hazards of lead exceeds that directed to all other pigments throughout the period, and is particularly marked in the 1928-1958 period.

3. The only other pigment whose health hazards were subject to consistent attention were based on chrome (mainly

chromates-yellow and anticorrosive pigments) and cadmium (yellow-red pigments).

The sustained attention to lead health hazards in the 1935-58 period coincides with declining levels of consumption of lead pigments and a rapidly falling incidence of frank lead poisoning in the U.K. (See Chapter 6).

A major portion of the references to the health hazards of lead related to monitoring the levels of lead absorption amongst workers exposed to health and its affects on health and metabolism (e.g. the measurement of blood and urinary levels of lead, and resultant changes in blood cytology, and levels of metabolites).

It will be argued below that this sustained attention to lead hazards reflects two factors.

i) development of an infrastructure of medical monitoring of lead absorption as a means of using lead pigments etc. without causing frank lead poisoning.

ii) increased sensitivity of diagnosis of the health effects of lead.

CHAPTER THREE

THE DEVELOPMENT OF WHITE PIGMENTS

AND THEIR DIFFUSION INTO PAINTS

THE DEVELOPMENT OF WHITE PIGMENTS AND THEIR DIFFUSION INTO PAINTS

Introduction and Overview

The development of white pigments and their diffusion into paints will be analysed in detail since they set the scene for the remainder of this study of the development of state regulation over the health hazards of making and using lead pigments. The debate about regulation focused on the use of white lead (basic lead carbonate) pigment since this was held to be responsible for most of the lead poisoning amongst painters. It was used in greater amounts than any other pigments in Britain in the Nineteenth and early Twentieth Century - as a major component of coloured paints and as the sole pigment in white paints (which comprised the bulk of paints used, especially in housepainting). The major controversy of the regulatory debate surrounded the technical feasibility and economic costs of prohibiting the use of white lead paint and its replacement by 'lead free' substitutes (based on certain white pigments, chiefly zinc oxide, lithopone, antimony oxide and latterly titanium dioxide). This analysis therefore concentrates on these white pigments which comprised over two-thirds of the pigments used in paint making.

A group of white pigments known as extenders, which includes Barytes (BaSO4), Blanc Fixe ($CaCO_3$), China Clay and Asbestene, have been excluded from this account. Their low refractive index and hence very low covering power in oil paints makes them unsuitable for use on their own as a paint pigment. In the Nineteenth Century they were considered as adulterants. However the development of high refractive index pigments (in particular Titanium Dioxide) which could be used in low concentrations allowed the use of extenders to increase the bulk of a paint without impairing its decorative properties.[1] However, since extenders were naturally occurring materials (or materials of obvious manufacture) their technical/industrial development is of little interest.

The development of pigment technology and the diffusion of pigments into paints played a significant role in conditioning the debate about state regulation of lead paint hazards. Equally, the British pigment industry (dominated in the early Twentieth Century by the white lead manufacturers) was one of the major and most powerful interest groups involved in the regulatory process. Conversely, the development of pigment technology was affected not only by economic and technical factors, but also explicit by concern about the hazards of lead pigments.

This process of economic and technological development is highly complex, and spans the pigment production, paint making and paint using industries. For example, the industrial development of pigment production (and thus the costs and availability of pigments) stimulates and is stimulated by the consumption of pigments in paints. The output of pigment production is thus bound up with the diffusion of pigments into paints. For the purposes of this study, a distinction (which at times may be blurred or arbitrary) has been made between two important phases in the development and diffusion of pigment technology for paint - termed innovation and diffusion.

Innovation of pigments is used in its broadest sense to describe those technical (and industrial) developments which make up the background to decisions to change paint technology/formulation. Since the white pigments were all inorganic materials whose existence as chemical entities had been known for many years by 1900, this account does not focus on the first preparation of these compounds. The key stages in innovation include :

1) the proposal of a material as a paint pigment, its testing in paints, development of methods of paint formulation,

2) development of improved material properties,

3) development of techniques for commercial production.

Diffusion of paint pigments comprises the market introduction of a pigment, the establishment of significant use (consumption - particularly in paint) and the economic development of production. This diffusion of pigments constitutes a major component of changes in the technology of painting (which includes composition of paints, methods of painting). The hazards and regulation of this technology of painting are the principal objects of this study. Changes in pigment composition were linked to other changes in paint formulation and application discussed elsewhere.

Table 3.1. gives a brief chronology of the first stages in the development of the major white pigments, distinguishing innovation and diffusion.[2,3,4,5,6,7,8,9,10].

The Diffusion of Pigments - a review of possible determinants

The major concern of this chapter is to document the changing pattern of consumption of the major white pigments and to analyse and explain this process. The relevance of existing research into technological diffusion/substitution will be addressed.

Comments on the process of substitution of paint pigments during the Twentieth Century would indicate that both price and non-price factors did play a significant role. It is useful to summarise the (sporadic) observations that have been made on this matter, which provide an

TABLE 3.1. Chronology of Development (Innovation and Diffusion) of Major White Pigments

	Innovation	Diffusion
	Innovation and Technical Development.	Market Introduction and Significant Use.
White Lead. $PbCO_3.Pb(OH)_2$	Antiquity	17th Century UK Us 18th Century UK Ma fact
Zinc White ZnO (also hydrated zinc oxide).	1786 Atkinson-UK patent on use of ZnO. (2)	1835 French Manufa of ZnO for pa 1893. UK use "less 5% of white l consumption".
Lithopone. $BaSO_4 . ZnS$.	1874 Orr-UK patent on Lithopone(4) "Orr's Zinc White".	
Basic Lead Sulphate	1855-1876 USA. (5) 1881 UK patent (6) development.	1911 UK introduction.
Antimony Oxide Sb_2O_3/Sb_3O_4	approx. 1890 USA. (8)	1911 UK introduction (
Titanium Dioxide TiO_2 Anatase form.	1910 Research and Development 1917 Commercial Introduction 1918 Marketing (10)	1928 UK produc (
Rutile form.	1941	1945 U.K.Produ
Chloride Process.	1950	

impression of the factors perceived as being important at various times, and set the scene for the subsequent analysis.

Pigment Price

This was the factor most frequently commented upon. Dunn (1975) argued that (in the U.S.A. at least), "over the years the use of lead pigments has risen and fallen with the price of lead. When lead was 4 cents 1lb a large tonnage of lead pigments was used. When lead went to 20 cents 1lb the use of lead began to subside as a matter of economy".[12]

Similar processes were observed in the U.S. paint industry (it will be shown below that the U.S. paint industry exhibited the same developments as the U.K. industry, although the timing and extent of these processes differed - typically starting earlier than in Britain). For example, Dunn (1975) noted that "in the early 1930s, Titanium pigments began to replace lead pigments in interior wall paints as they are more economical to use".[13]

McCleary (1975) noted the steady growth in the use of zinc oxide in paints in the U.S. (at the expense of lead) until it too began to be displaced in the 1920s as 'the competitive effects of Lithopone and Titanium dioxide pigments began to be felt'.[14]

Several commentators pointed out that what was important was the price in relation to pigment properties. Thus Lawrence (1921) stressed that lead substitutes were more economical because they yielded a greater volume of paint, weight for weight, than white lead.[15]

The decline in lithopone consumption (and eventual demise of the industry) since the late 1950s was attributed by Cocks (1968) to the increased demand for titanium dioxide which had technical and price advantages over lithopone.[16]

M.Pisart (1911) noted that the demand for lithopone had increased because the price of white lead was very high (as a result of the lead cartel raising its prices).[17]

J.Lawrence (1921) pointed to a reversal of this trend since in the post-war period the price of substitutes for white lead "have not dropped to the same extent as white lead"; "this fact has modified the extent to which leadless paints are used in place of lead".[18]

The failure of the U.K. lead sulphate pigment industry in the same period was attributed inter alia to the paint market being flooded by imports of cheap continental white lead.[19]

Ziegfield (1964) explained the reduced use of white lead over the previous 40 years because it cost more than other pigments. However it was still felt to be necessary for external paints, and paint manufacturers continued to use a (reduced) proportion of white lead in such paints, although it was no longer used in indoor paint.[20]

Falla (1980) argued that the higher cost of lead restricted its use to "high quality" paints in the interwar years, whereas after 1945, the availability of high quality grades of titanium dioxide and the escalating price of lead " tended to limit the use of lead pigments to wood and metal primers".[21]

Conservatism and Prejudice

Pisart (1911) explained the limited use of zinc pigments in Britain (compared to their widespread adoption in Sweden) because "the painters in Sweden are more advanced and less conservative than those in England".[22] Prejudice against zinc oxide was noted in the same period by Oliver (1911).[23]

Remington (1954) explained the continued preference for white lead (and prejudice against zinc oxide) for exterior paints because "old ideas and stolid conservatism die hard" in an old country like Britain (sic).[24] Whereas Falla (1980) attributed this preference to the association "in people's minds" of lead paint with high quality.[25]

Hazards, Regulation

Concern about health hazards of white lead, while frequently mentioned, was not suggested as a major direct factor behind the displacement of white lead from paint until the 1950s. Concern about hazards, was seen as playing a role in the development of new pigments; however, in the choice of available pigments for paints, it was seen at the most as being an additional influence to the major determinants of price and pigment performance.[26, 27] Increasing awareness of the hazards of lead paint to the consumer (in particular children) led to the 1955 American National Standards Institute recommendation that the lead content of paint for household use and for toys should not exceed 1% of the weight of the paint film.[28] In Britain this resulted in a voluntary agreement between the Paintmakers' Association of G.B. and the Ministry of Health in 1963 for warning labels to be attached to cans of paint with more than 1% lead in the dry film.[29] As a result, almost all decorative paints were formulated so as not to require the precautionary label, though wood and metal primers with high lead content continued to be used. In 1972 the Paintmakers' Association recommended that their members discontinue the production of proprietary lead based primers for sale to the general public. Whilst such paints cannot be obtained through retail outlets, they are available for the use of the building trade.[30]

Subsequent U.K. legislation on the lead content of paint for toys and pencils also affected the composition of paint used in these specialised applications.[31] State and Federal legislation in America covered interior domestic paints as well.[32]

This brief review of opinions regarding the substitution of pigments suggests that whilst pigment price appears to have been a major determinant, 'non-price' factors may have played a significant role, including pigment performance and health hazards/regulation. The concepts of 'conservatism' and 'prejudice' lack analytical sharpness. However, as will be shown below, lack of knowledge regarding the assessment of pigment and paint performance may have played a role. This study highlights the importance of knowledge about the formulation of pigments into effective and durable paints. These factors would appear to have been important elements behind 'prejudice'.

To investigate the role of these different factors, data on the price, and pattern of U.K. consumption of the major white pigments have been collected. The relationship between market share and pigment price will be examined, drawing where relevant, on previous studies of technological diffusion, and in particular the 'Fisher-Pry' and related models of competitive 'technological substitution'. The form of the price/consumption relationship, and deviations from the expected relationship indicate the role of non-price factors in the substitution process and in particular pigment properties, and knowledge about paint formulation and performance.

Overview of this Chapter

This chapter involves the handling of large amounts of empirical data and the production of detailed calculations and models. Where possible, these have been extracted and are contained in a set of technical appendices (Technical Appendix A). These appendices are constructed to be read in conjunction with the sections they derive from, and are referenced as part of this chapter.

The contents of this chapter are as follows:

i) The innovation of major white pigments.

ii) U.K. production and consumption of major white pigments, and pigment price.

iii) The development of the U.K. pigment industry.

iv) Analysis of the market share of major white pigments.

v) Review of studies of technological diffusion and application to the pattern of pigment consumption.

vi) Pigment properties, knowledge about pigment performance and paint formulation in paint performance.

vii) The Pattern of consumption of pigments in different sections of the Paint Industry.

viii) Assessment of role of non-price factors in the pattern of pigment consumption/substitution.

Innovation of Major White Pigments

The innovation of major white pigments for use in paint will be described. This includes the proposal and testing of a material as a paint pigment in the development of improved material properties and techniques for commercial production.

White Lead

White lead was known from antiquity, as a decorative pigment in paints. In Britain, its use in paints was recorded in the Seventeenth Century and its manufacture in the Eighteenth Century.[33]

The nature of the pigment itself has altered only marginally over time. The major developments were in methods of manufacture which were directed to increasing the speed of preparation (but also allowed greater control over particle size and purity.).

In practice, manufacturers attempted to standardise the composition of white lead to ensure uniform performance when mixed into paint, though in the Twentieth Century, grades were produced with finer particle size and lower lead carbonate content, resulting in greater hiding power and paint thickening properties (through reaction in the acid groups in the resin).

The traditional method of manufacture developed in Holland in the Seventeenth Century and known as the Dutch process, began to be replaced at the end of the Nineteenth Century by more rapid processes of preparation.[34]

The Dutch Process involved the preparation of white lead from lead metal by reaction with carbon dioxide and water vapour in the presence of an acetic acid catalyst. In the Dutch Process, strips of metal were suspended over bowls of vinegar, standing on rotting bark (which fermented to produce the carbon dioxide). The reaction was allowed to proceed for 100-120 days after which time most of the metal had been converted to white lead.

A modification of this method, known as the chamber process had been developed in Newcastle by 1890. In this, carbon dioxide was passed through a chamber containing thin sheets of lead metal; acetic acid and water vapour were blown in periodically. The greater surface area of lead allowed the reaction to proceed in 50-60 days. (There was also a saving in labour from 13 to 5 from the Dutch method).[35]

The Carter process, developed in America in 1885 reduced the time for this reaction to 10-12 days by using a higher concentration of carbon dioxide and by removing the white lead from the surface of the lead metal.

A different route of manufacture - passing carbon dioxide gas through basic lead acetate solution - was identified in 1801 by a French Chemist Thenard, and put into commercial use in 1935. Various developments in the method of preparing the basic lead acetate were made. The composition of white lead could vary depending on the reaction conditions which needed careful control, however the preparation time was reduced to some 6 days.

Several electrolytic processes were developed in the early Twentieth Century in America which, in effect, were means of further speeding up the dissolution of metallic lead.[36]

Basic Lead Sulphate

One pigment suggested as a substitute for white lead was basic lead sulphate. It was first produced on an experimental basis by a zinc oxide manufacturer using lead sulphide in place of zinc ores in the 'direct' process (described below). This produced a pigment of lead sulphate with 'impurities' of lead oxide (20%) and zinc oxide (5%) which gave the material its basic properties. Commercial production began in

America in 1876, and the pigment achieved a small but steady market share.[37]

The material had less success in Britain. The process was patented in Britain in 1881. In 1884 plant was opened in Glasgow but only operated for nine years.

The next attempt of manufacture occurred in 1908 with the establishing of the Purex Company which manufactured basic lead sulphate for sale as a 'non-poisonous white lead'. Uses of lead sulphate paints in house and coach painting were recorded by the 1911 Departmental Committees.[38] The material made little headway and the Purex Company closed in 1925. This failure has been attributed to the conservatism of the paint trade, opposition by the white lead makers and the flooding of the market by cheap imported white lead.[39] However, basic lead sulphate has poor hiding power (inferior even to white lead). Its claims to 'non-toxicity' rest on its lower solubility in dilute hydrochloric acid than white lead. Its only significant U.K. application has been in conjunction with other pigments (and in particular as a component of 'leaded zinc oxides'.).

Zinc Oxide

Zinc White or Zinc Oxide (ZnO).

The innovation of zinc oxide as a pigment is of particular interest because its espousal was frequently linked to concern about the hazards (in particular of manufacture) of white lead. The material was well known as a waste product of brass foundries (and in the Nineteenth Century of zinc furnaces and galvanising plant). Its preparation from burning metallic zinc was described in 1739 by Cramer.[40] Courtois, at the Laboratory of the Academy of Dijon in France first proposed the use of zinc oxide as a pigment, in substitution for white lead in 1770, noting that it (unlike white lead) was not blackened by hydrogen sulphide. His experiments were confirmed by a co-worker, Guyton de Morveau, who published results of various experiments with 'lead substitutes' in 1780. The French Navy conducted trials with zinc oxide paints for the interior of one of their ships, with favourable results reported (1786).[41]

Meanwhile, in 1783 the British Royal Society of Arts offered a prize for the inventor of a 'harmless method of preparing white lead paint, or alternatively, for a base which would be equally durable and not substantially dearer than white lead'.[42] After 10 years the prize was withdrawn when this offer was judged to have produced nothing of value.

During this period, Atkinson took out a British patent for the use of zinc oxide in paints. However, at that time there were no facilities for the commercial production of zinc oxide, which was four times the cost of white lead, and these various experiments failed.

Only in 1835 did zinc oxide paints become commercially feasible when John Leclaire built a factory in Paris to produce zinc oxide paint 'at a modest price'. Leclaire was a master painter and paint maker, whose interest in zinc oxide was stimulated by its non-toxic properties. The process of manufacture was developed in partnership with Sorel, the chemist who invented the process of galvanising iron. The non-poisonous properties of zinc oxide were brought to the attention of the French government and resulted in zinc oxide being specified for all government work.

The method of manufacture they developed is known as the indirect process since it starts by the smelting of zinc metal. This is then vapourised and oxidised, and the pigment particles are collected in a filter.[43] Consumption of zinc oxide (primarily for paints) increased from this point

In 1851-6, Burrows and Wetherill in America developed the 'direct process for manufacturing zinc oxide directly from the ore in an attempt to utilise low grade zinc ores. Air is then blown through a mixture of burning anthracite and ore - and zinc is volatilised and oxidised in a single process.

Zinc oxide produced by the direct process contains approximately 1% of lead (mainly as sulphate), which was held to improve durability of the paint.

In America, in 1891, leaded zinc oxides were produced by the inclusion of lead sulphide (galena) in the ore, which was oxidised to lead sulphate, during the 'direct process'. Leaded zinc oxides were produced containing between 5% and 35% lead sulphate. Some leaded zinc oxides were simple mixtures of zinc oxide and lead sulphate (as opposed to the confirmed grades.).

Leaded zinc oxides were introduced in Britain after World War I.[44]

Lithopone

Lithopone is the foremost example of a family of pigments incorporating zinc sulphide, and its development stems from the promotion of the latter. Guyton de Morveau recorded the preparation of zinc sulphide (from zinc oxide) in 1783. The successful use of zinc sulphide in paints was mentioned by Certeau in 1862. However interest switched to lithopone, which was becoming commercially significant around 1900, despite its lower hiding power (50% of zinc sulphide), because of its low cost and ease of preparation.

In the 1920s in America, there was increased interest in zinc sulphide because of its relatively high hiding power (needed because new vehicles required more opaque pigments, especially nitrocellulose lacquers). In

Britain, increased interest does not appear to have developed until after the war when zinc sulphide was considered as a rival to Titanium Dioxide (without the latter's chalking tendencies). However, zinc sulphide on its own did not become a major white pigment in Britain. 'High strength lithopones' with a 50% zinc sulphide content had a significant use. In addition blends of zinc sulphide and magnesium silicate were marketed.[45]

Lithopone is a co-precipitate of Zinc-Sulphide and Barium Sulphate. Its preparation by double-decomposition of Barium Sulphide and Zinc Sulphate was recorded in 1842 by De Douhet. Lithopone so produced contains 28-30% Zinc Sulphide.

J.B.Orr (a Scottish chemist) claimed to have 'invented' lithopone as a pigment, and patented a method of production (identical to De Douhet's but with a final roasting step to improve whiteness and compactness) in 1874. However patents and production facilities were also being develope in Belgium and Germany, in the latter quarter of the Nineteenth Century. Orr was seeking a non-poisonous pigment with greater opacity than zinc oxide the only available substitute for white lead. However Orr's Zinc White factory was initially not very successful and lithopone was little used in Britain. In 1911 there were only 2 lithopone factories in Britain and the Departmental Enquiries into lead paints paid very little attention to lithopone as a possible substitute for white lead.[46]

Lithopone had the greatest refractive index/covering power of the commercially available white pigments prior to the development of titanium dioxide. The slow uptake of this pigment was attributed not only to people's unwillingness to change, but to the fact that it darkened on exposure to light - limiting its application to interior uses. After 1920, marked improvements in light fastness were achieved allowing more widespread use.[47]

Antimony Oxide

The first suggestion of using antimony oxide (Sb_2O_3) pigment was made in the U.S.A. in the 1890s. Attempts to manufacture antimony oxide with suitable properties for paint continued for many years. Preparation is similar to that of zinc oxide, by vapourising antimony metal (or sulphide) in an oxidising atmosphere. Early grades had a yellowish hue because of the presence of (orange) antimony sulphide impurities.[48]

At the time of the 1911 Departmental Committees, its use in paint was being launched in Britain. A decade later, the 1921 Departmental Committee heard evidence from a major paint company which was marketing a paint based on antimony oxide (III and IV) with a barytes extender, at a similar price to lead paint.

Interest in antimony oxide focused on its high hiding power (which exceeded lithopone and was only surpassed by Titanium Dioxide) and its low systemic toxicity. (though its use in paints was held to cause dermatitis)[49] However the price of antimony oxide remained high and as a result its use was limited to specialised applications, typically in combination with other pigments to impart special properties (e.g. fire resistance) rather than as the sole pigment in a paint.

Titanium Dioxide

Titanium dioxide (TiO_2) was first prepared in 1791 in England by the Reverend William Gregor. However, the development as a pigment (like Antimony Oxide) appears to have been stimulated by the controversy over the hazards (and possible prohibition) of white lead, and the increasing application of science to the paint industry since the turn of the century.[50] In 1908, Barton and Ross, in America, began investigating its extraction from the mineral rutile (mainly Titanium Dioxide).

Meanwhile Farup and Jebsen in Norway had independently begun to investigate its extraction with Sulphuric Acid from Ilmenite (mainly Ferrous Titanate). In 1916 they joined forces to set up the first factory to produce titanium dioxide. Their company, the Titan Co., set up works in the U.S.A. and Norway based on a sulphuric acid extraction process.

Titanium dioxide was marketed in the U.S.A. in 1917/18 precipitated on to Barium Sulphate (known as Titanox) with a hiding power double that of white lead. In 1926, pure titanium dioxide was marketed with a hiding power 5 times greater than white lead (especially for applications where a high opacity or low volume of pigment was required - primarily in nitrocellulose lacquers).[51]

Titanium dioxide had dramatic advantages over other pigments especially regarding covering power/refractive index. It also had low toxicity and was chemically inert, (it was resistant to acids and alkalis and did not discolour or react with the medium).

However, the first titanium dioxide produced was in the anatase crystallin form, and promoted 'chalking' (breakdown of the resin, stimulated in particular by ultra violet light leading to release of pigment particles from paint film). As a result, the Titanium/Barium co-precipitate pigment had to be used in conjunction with other (e.g. zinc) pigments to make a hard film and prevent chalking. This drawback was suggested as retarding the widespread application of titanium pigments.[52]

Another obstacle to the rapid introduction of titanium dioxide was the sheer difficulty of extracting the material which involved many stages, often at extreme temperature and pressure, and required precise control. Thus the (ilmenite) ore was dissolved by heating with strong sulphuric acid, producing mixed Titanic, and Iron II and III Sulphates. The selective precipitation of the titanium component was at first achieved by adding alkali (which produced a pigment of 'poor quality'). In the 1940s, this method was replaced by a process of boiling or autoclaving more concentrated solutions, which improved pigment quality. To reduce the requirements for high temperatures and pressures, seeding techniques were developed to enhance the rate of precipitation. Finally the hydrous titanium oxide precipitate is filtered and washed before calcining under controlled conditions to convert the amorphous Titanium dioxide to crystalline form.[53]

Initially, growth in titanium dioxide production was constrained by the massive capital investment required. It was necessary to produce a chemical with the purity of fine chemicals in the quantities and price of gross industrial chemicals (for example a minute trace of iron impurities at concentration of parts per million tended to give early titanium dioxide a pink/brown tint).[54]

Careful control of the process was needed, and the plant needed to be sited near the sea, with ample water supply, to dispose of the massive quantities of sulphate, sulphuric acid and other wastes, [about 4 tons of sulphuric acid and 2½ tons of Ilmenite ore are required to produce 1 ton of titanium dioxide].[54]

In 1948 it was estimated that the cost of plant (in the U.S.A.) for titanium dioxide production was $200,000 for each ton of daily production, (equivalent then to £75,000).

In comparison the white lead industry, in 1911 claimed a capital value of £1,334,000 to produce around 55,000 tons per year,[55] equivalent to £4.1 million in 1948 values, or £22,000 for each ton of daily white lead production (based on a notional 300 working days per year). Whilst this conversion can only be considered approximate, it does indicate that the capital cost of producing one ton of titanium dioxide was in the order of three times that of white lead.

A striking aspect of the development of titanium dioxide is the continuing improvement not only of production techniques, but also of pigment performance.

Titanium dioxide produced by the sulphuric acid extraction process spontaneously produced the material in its anatase crystalline form.

In 1941 it was discovered that by 'seeding' the solution with crystals, it was possible to produce titanium dioxide in its rutile crystalline form. Rutile titanium dioxide had an even higher refractive index, and a covering power eight times that of white lead. In addition, rutile titanium dioxide had the advantage of being resistant to chalking. (unlike anatase, whose tendency to promote chalking tended to require its use in a mixture with Barium Carbonate extender, Barytes, Blanc fixe or antimony oxide pigments).

A further development was the introduction in the early 1950s of the 'Chloride Process' for making titanium dioxide, which avoided the large volumes of sulphuric acid needed in the sulphate process. Mineral rutile is heated with chlorine in the presence of carbon, to produce Titanium Tetrachloride, which is purified and hydrolised or oxidised to form titanium dioxide. If oxidation is used, the chlorine can be recycled.[56] Chloride rutile titanium had an even higher refractive index/covering power (ten fold that of white lead.). However the Chloride Process was slow to be introduced. Widespread successful application of the chloride process has been very uneven - Laporte's 'Chloride' plant did not come 'on-stream' till 1970.

In the 1950s and 1960s, further developments in pigment technology allowed development of titanium dioxide with a surface coating of alumina, silicon and titania to further reduce the interaction between the pigment and resin.[59]

Commentary on the Process of Pigment Innovation

The pigment innovation process is notable insofar as a major concern behind the promulgation of new pigments was the elimination of lead poisoning hazards associated with white lead. This was expressed most strongly in the Nineteenth Century. However, the alternatives identified at that time made little headway, particularly because the methods of commercial manufacture had not been developed that could produce lead substitutes at a competitive price to white lead.

Whilst the pigments that were 'launched' during the Twentieth Century (antimony and titanium oxide and, arguably lithopone) were also lead substitutes and conferred health benefits, this aspect seems to have received less emphasis. A major characteristic of these pigments is the substantial improvements they offered over white lead in opacity/hiding power, thereby allowing a lower pigment concentration or fewer/thinner coats of paint to be used. This factor was particularly important in the case of nitrocellulose lacquers applied by spray, developed at the turn of the century and gaining significant use after the First World War. Thus the development of these high opacity pigments would appear to have been promoted by demand from industrial users of paint, and particularly the vehicle industry (See Chapter 2).

U.K. Production and Consumption and Price of Major White Pigments

In order to analyse the process of substitution of major white pigments, a set of figures for pigment consumption is needed over an extended period. Ideally figures for pigment consumption by the paint industry would be sought. However these are only available for a few years and there is uncertainty about their validity. A series of figures for total U.K. pigment production and consumption by all industries has therefore been developed. This task has been extremely laborious. Official statistics are sporadic, inconsistent, and incomplete, particularly before the Second World War.

The core of information on production and consumption of pigments are provided by an internal report by British Titan Products Ltd. (the major U.K. producer of Titanium Dioxide) which covers the years 1935-1955.[60] These data have been corroborated, and where necessary adjusted/corrected to reconcile them with figures from other industry sources, published data and official statistics.

The reports of the various Home Office Deparmental Committees concerning the regulation of lead pigment hazards, official statistics and a wide range of published sources (mainly trade literature) have been searched to produce figures for pigment production for earlier years, dating back to 1907-10. On occasions this has involved the use of estimates to overcome gaps or inadequacies in the data base.

Official statistics for production (sales by U.K. manufacturers) of individual pigments are obtained from the reports of the Censuses of Production of 1907, 1924, 1930, 1935, 1948, 1951, 1954, 1963, 1968. Surveys in 1912 and 1937 were not fully reported but some data is contained in subsequent census reports.[61] Since 1973 this information has been published in the Department of Trade and Industry Business Minutes.[62]

Figures on Imports and Exports are available on an annual basis from the Customs and Excise (Annual Statement of Trade).[63]

Problems in the use of these official statistics include:

i) the form of presentation of statistics on the pigments,

   a) a high degree of aggregation makes it impossible to isolate trade in individual pigments,

   b) the definition of pigment may be arbitrary e.g. the 1935-1951 Census of Production gives production figures for dry white lead, but excludes lead produced in a paste with oil (about half the total in 1951). Similarly Titanium dioxide figures sometimes refer to weights of pure Titanium dioxide, but at other times refer to pigments containing Titanium (the majority of which could be an extender or zinc pigment.).[64]

   c) inconsistency between different sets of statistics in the above figures.

ii) industrial classification - the white pigment industry has an ambiguous position being linked to the metal extraction, chemical and paint industries. This ambiguity is reflected in the statistics on pigment production. Thus, for example, the 1907 Census of Production placed white lead production under 'Lead, Tin, Zinc etc. Factories' (non ferrous metals excluding copper and precious metals). The 1954 Census places pigments production under general chemicals, whilst in 1968 it appears under Dyes and Pigments. With these changes in classification have come changes in the availability and form of presentation of statistics.

iii) the statistic being presented - the definition of the statistics of production etc. vary in their precision especially in the early period. Thus the 1907 Census of Production includes figures for Gross Sales of Pigments, but notes that this may include the value/weight of partially processed products twice (estimated as up to 25% of the total). Where possible, figures for Net Sales have been used. The simple determination of domestic consumption by the formula:

Domestic Consumption = Domestic Production + Imports − Exports

is not always possible. In particular Domestic Sales of a material are often presented which include partially processed imports. Lack of precision in the definition of statistics (and lack of availability of information on for example the levels of partially processed imports) in some cases prevent an exact determination of the statistic being sought (domestic consumption), especially in the early years.

iv) validity of statistics - the census of production is based on returns from companies under various legislation, and its administration has varied over time.[65] The completeness of returns varies (in particular in the early censuses) as did the size of firms covered. The lower limit of 25 employees (adopted since 1958)[66] probably makes little difference in the statistics of output in a concentrated industry such as chemicals or pigment production, but may make a significant difference in the figures for purchases of materials by paint making firms (due to the large number of small establishments in the industry.). As a result, the significance of the statistics may be variable.

Because of these problems in using the Census of Production and related statistics, priority has been given to informed sources of information deriving from the paint/pigment industry.

Information on pigment prices has been derived from 'spot prices' published in trade journals[67] and from the relationship between value and tonnages recorded in official statistics of trade and production.

The data on U.K. production, trade, consumption, and price, and consumption by the U.K. paint industry of the major white pigments are presented in Appendix A-1 which also details the handling of contradictory data, estimates etc.[68, 69, 70, 71, 72, 73, 74, 75, 76]

These data will be analysed in subsequent sections. However this same investigation has facilitated an account of the development of the U.K. pigment industry. This will be briefly described.

The Development of the U.K. Pigment Industry

The development of the U.K. pigment industry was of particular significance in the regulatory debate about lead paint hazards. The opponents of prohibition of white lead paint focused on the impacts of this regulatory strategy on British industries and the balance of payment As will be seen in Chapter 5, the eventual resolution of this regulatory debate and the rejection of prohibition appears to be related to the uneven strength of the industrial lobbies concerned, and in particular the predominance of the white lead manufacturers over the U.K. pigment industry.

The development of the pigment industry is also of interest insofar as it was a factor in, and throws light on, the process of pigment substitution. This development reflects both the innovation (as described in the previous section) and diffusion of pigment technology (the incorporation of pigments into paints and other products); it is therefore a product of the interaction between pigment producers and pigment users (paint makers/paint users). This interaction has a national and a global dimension, though only the former has been documented.

The increasing differentiation of the U.K. paint making industry from the U.K. pigment producers since the turn of the century gives it a degree of autonomy regarding pigment choice (by allowing the import of pigments with preferred characteristics). U.K. consumption of zinc pigments for example developed in advance of U.K. production in the early Twentieth Century. The relationship between production and consumption (or balance of trade and production or consumption) gives some indication of the role played by industrial demand for pigments in the development of the U.K. pigment industry. Caution must be exercised in drawing conclusions from these figures since there was a high degree of integration between extractors and processors of these materials. Shif in location of production facilities by a U.K. multinational company to the U.K. would for example show up as an increase in the ratio of production to net imports without any change in the size of the U.K. owned pigment industry.

At the same time the U.K. pigment making industry must be seen as exercising a significant influence over pigment choice despite the availability of imports, due to the costs of importing and the benefits of using domestic products (e.g. access to the manufacturer).

The respective roles of the paint and pigment industries in the development of the latter are discussed for each pigment in turn in the light of the pattern of U.K. production, trade and consumption of pigments.

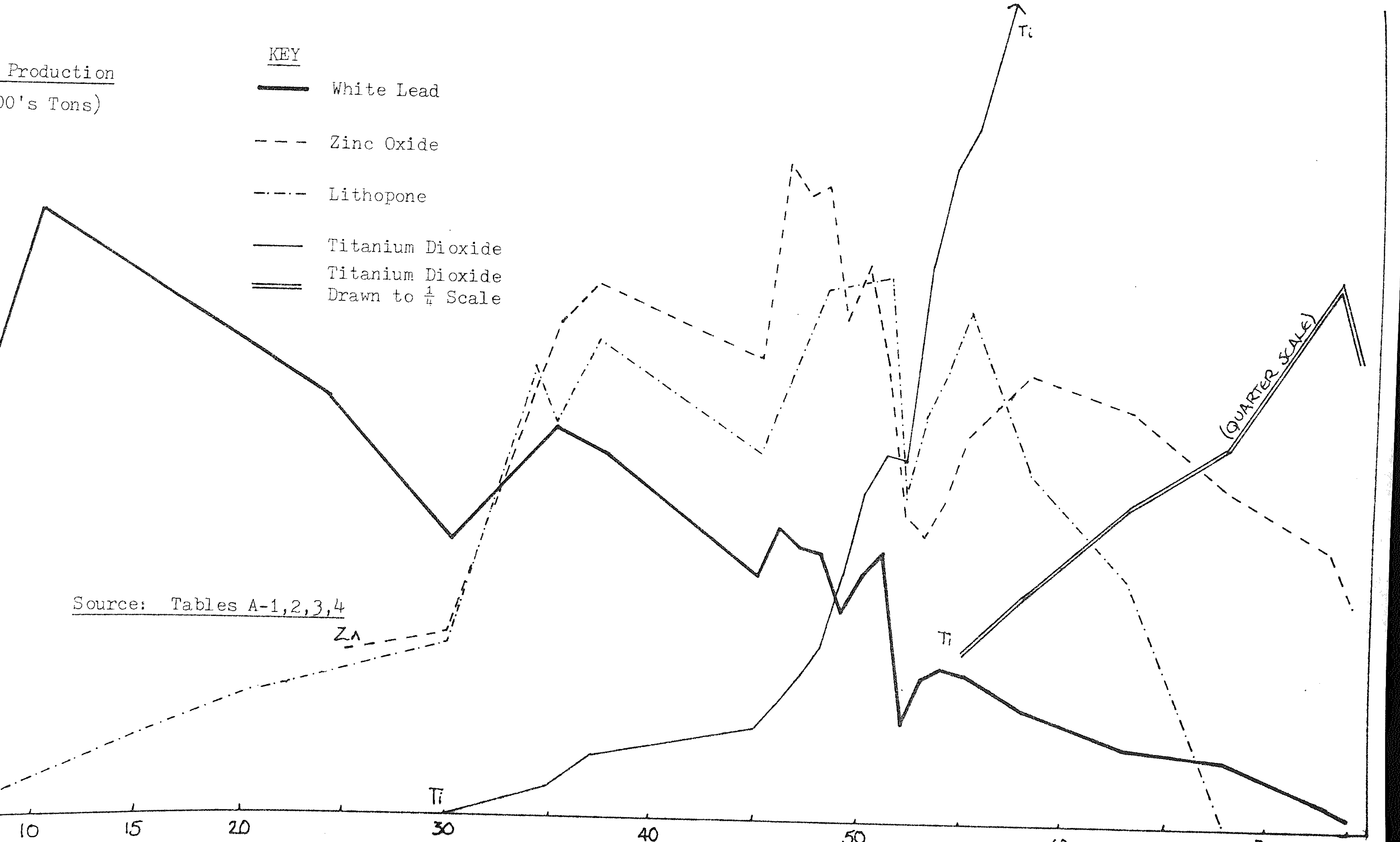
Figure 3-1 shows U.K. production of the major white pigments, 1907-74. Figures 3-2,-3,-4 and-5 show the production, consumption and balance of trade for each of these pigments in turn; white lead, zinc oxide, lithopone and titanium dioxide. Antimony oxide has not been included in this analysis because of its very low consumption.

The White Lead Industry

The white lead industry at the turn of the century was Britain's major pigment industry, comprising at least 27 plants.[77]

In 1910 it produced 57,000 tons of white lead, of which net exports were about 10%, and employed 2500 workers.[78] From this peak U.K. production falls steadily, largely in line with U.K. consumption (although between 1910 and 1925 exports are increasing. The curtailment of exports after 1925 would appear to be associated with the effects of the International Labour Convention, which came into force in 1927, on the world market for white lead.).

Fig 3 - 1 U.K. PRODUCTION OF MAJOR WHITE PIGMENTS 1905 - 1974



Source: Tables A-1,2,3,4

Fig 3 - 2 UK PRODUCTION, CONSUMPTION AND BALANCE OF TRADE IN WHITE LEAD 1907 - 1974
Balance of Trade Measured as Imports minus Exports

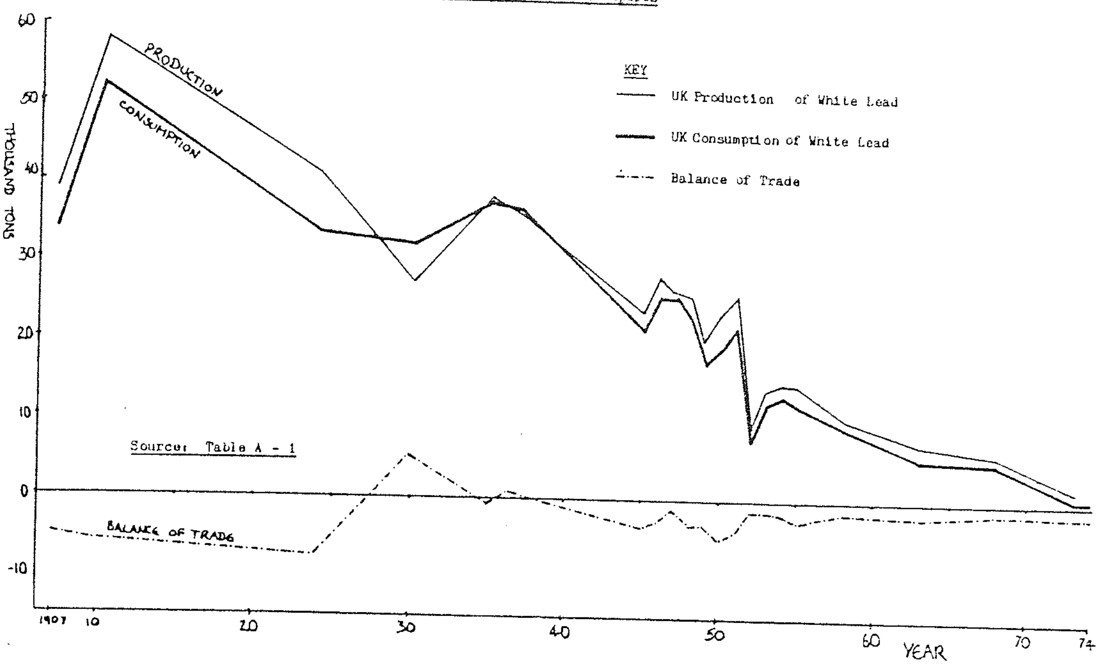


Fig 3 - 3 UK PRODUCTION, CONSUMPTION & BALANCE OF TRADE IN ZINC OXIDE 1907 - 1974
Balance of Trade Measured as Imports - Exports

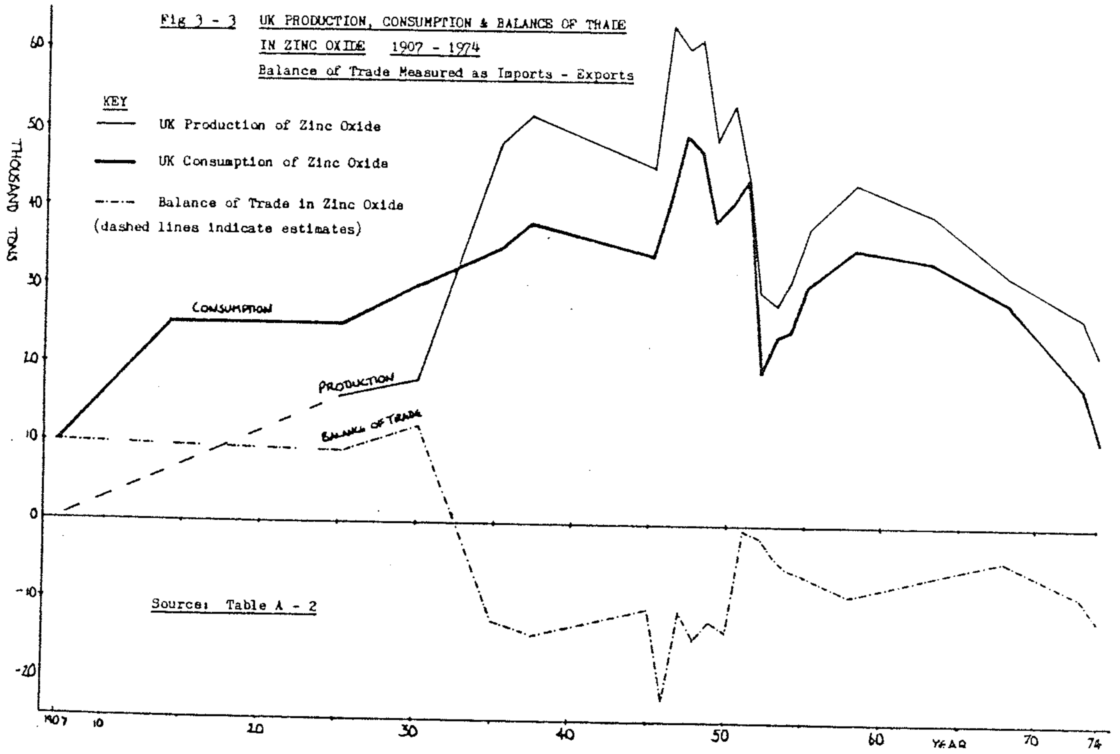


Fig 3 - 4 UK PRODUCTION, CONSUMPTION AND BALANCE OF TRADE IN LITHOPONE 1907 - 1974
Balance of Trade Measured as Imports minus Exports

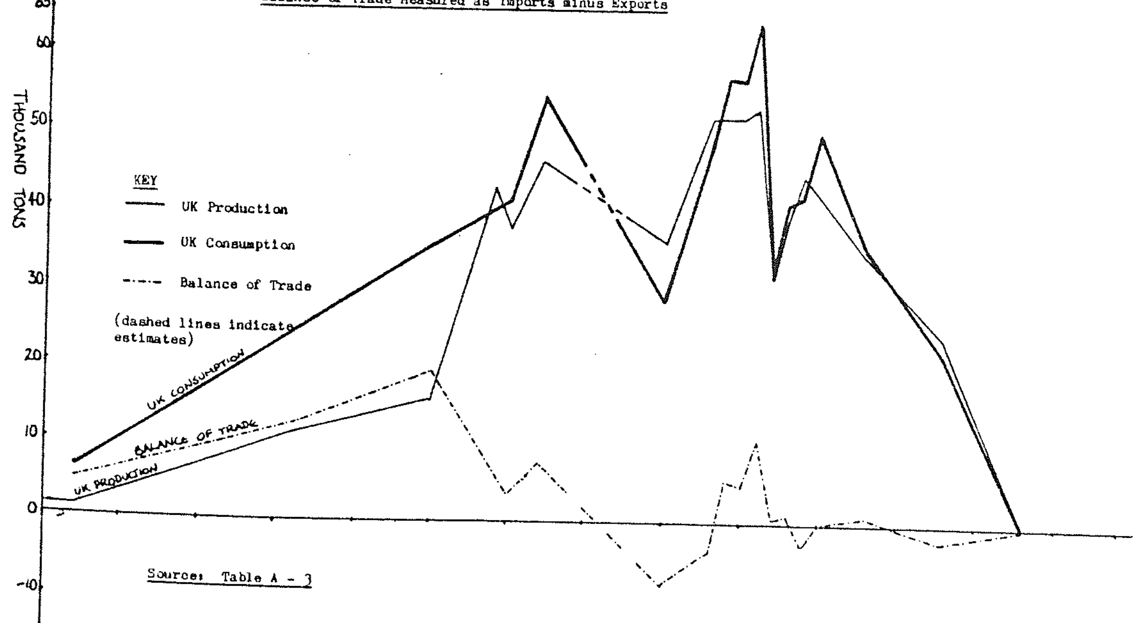
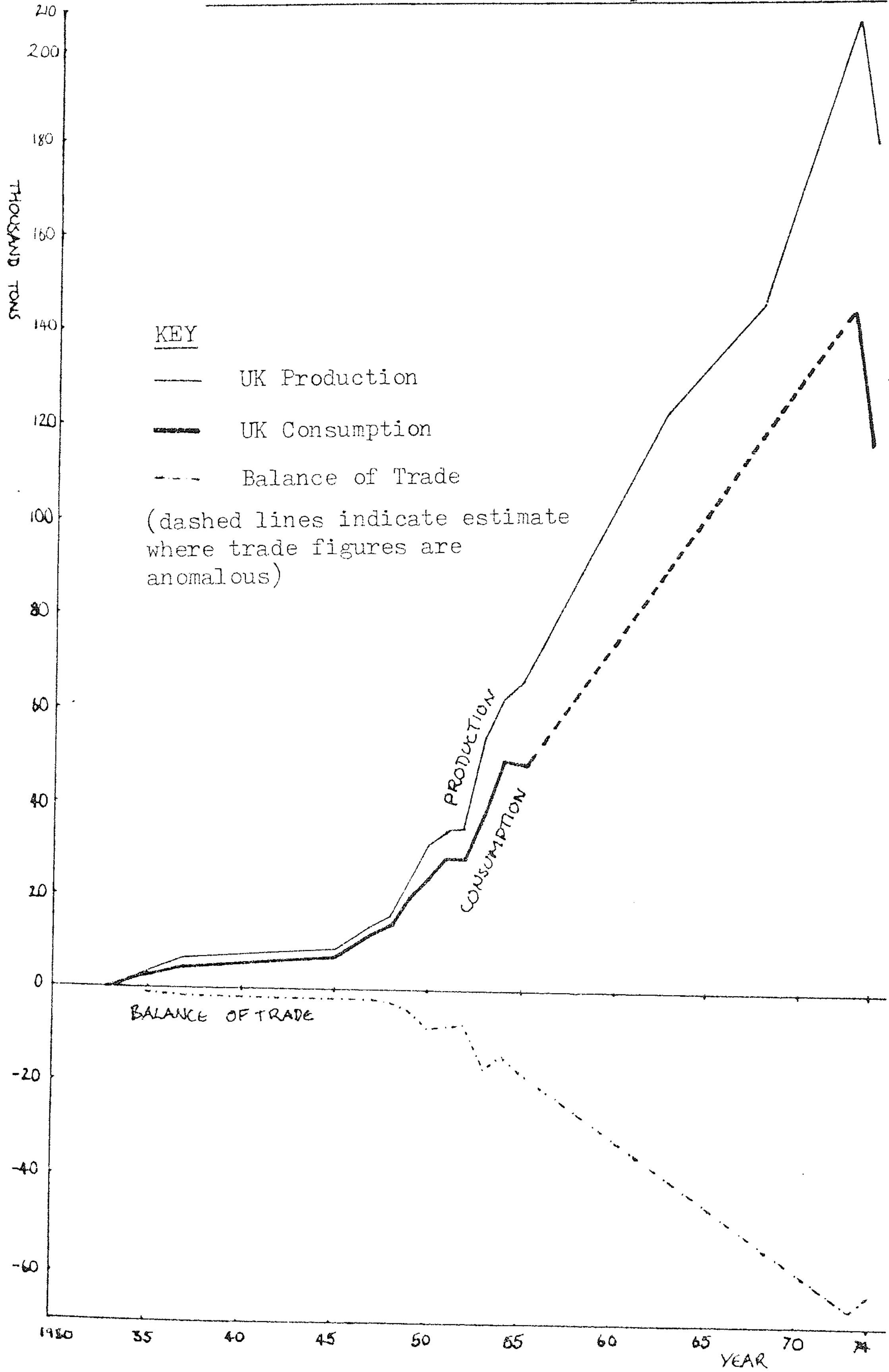


Fig 3 - 5 UK PRODUCTION, CONSUMPTION AND BALANCE OF TRADE IN TITANIUM DIOXIDE 1933 - 1974

Balance of Trade Measured as Imports minus Exports



Source: Table A - 5

White lead production/consumption shows a particularly sharp fall in 1952 after which it gradually disappears. This was a period of increased concentration and rationalisation of the white lead industry. By 1948 the number of plants producing dry white lead had fallen to 16 and this had fallen to 9 by 1951. Though we cannot follow this in subsequent years as dry white lead manufacture is not recorded separately, the number of plants producing lead compounds of all types (white lead, red lead, lead chromate and other inorganic lead compounds) falls from 23 to 11 between 1958 and 1963.[79] The concentration of ownership was equally marked, and one firm, Associated Lead, came to dominate the white lead industry.[80]

The Zinc Oxide Industry

Until 1908, practically all the zinc oxide consumed in Britain was imported. The Balance of Trade comprises net imports of around 10,000 tons per year until 1930. During this period, U.K. manufacture of zinc oxide develops steadily, matched by steady growth in consumption. Initially, production was by the indirect process (from the oxidation of zinc metal).

The first plant to manufacture zinc oxide by the direct process was opened by Fricker's Metal and Chemical Co. in the early 1920s. In 1928 Fricker was taken over by Imperial Metal who had made a strategic decision to produce zinc in Britain from Australian reserves after the First World War. They identified pigments as a profitable outlet for zinc. Fricker's output of zinc oxide was 5,800 in 1928 and 6,900 in 1929 rising to 11,000 in 1934.[81] Imperial Metal's production of zinc oxide is shown on Table 3.2.

Imperial Metal's move into the area was matched by equally dramatic

TABLE 3.2. Production of Zinc Oxide 1925-65 Output by Imperial Metal and Total U.K. Production

Thousand Tons.

Year	Imperial Metal Production	Total U.K Production
1925		16
1928	5.8	
1929	6.9	
1930		
1931		18
1932	7.2	
1933	9.8	
1934	11.0	
1935	10.3	48
1936	11.0	
1937	12.2	52
1938	11.6	
1939	10.3	
1940	16.5	
1941	11.2	
1942	8.9	
1943	8.6	
1944	11.9	
1945	13.6	45
1946	19.1	63.9
1947	16.8	60.9
1948	16.8	61.8
1949	12.5	49
1950	14.0	54.3
1951	9.0	44.6
1952	6.7	29.9
1953	8.6	27.9
1954	8.3	31.5
1955	9.3	37.7
1956	8.1	
1957	9.7	
1958	8.8	44.2
1959	7.7	
1960	7.8	
1961	6.2	
1962	6.0	
1963	6.6	40.2
1964	6.7	
1965	7.0	
	(1)	(2)

Source: (1) E.J.Cocks and B.Walters - A History of the zinc smelting industry in Britain. G.Co., Harrop London 1968.
(2) Table A-2.

growth in output by other firms. Between 1930 and 1935, U.K. production rises from 18,000 to 48,000 tons. This is only partly taken up by increased consumption, and the balance of trade shifts sharply, from net imports of 12,000 tons to net exports of 12,500 tons. Production continues to rise, peaking immediately after the Second World War. In 1948 15 plants are recorded as producing zinc oxide, and this rose to 17 in 1951. However this was the zenith of U.K. production and consumption of zinc oxide and, after a sudden, temporary fall in the mid 1950s, production falls steadily, matched by a reduction in the number of companies and plants involved in zinc oxide manufacture.[82] See Table 3.3.

The Lithopone Industry

Between 1905 and 1935, U.K. consumption of lithopone grows steadily (doubling every 7½ years). Only half of this was met by U.K. production. Britain's only lithopone producer until 1930 was Orr's Zinc White Ltd., established by the 'inventor' of the pigment in 1874. In the first decade of the century output stood at 1500 tons p.a. but by 1921 this had reached 12,000 tons.

In 1930 this Company was taken over by Imperial Metal, as part of their strategy to develop zinc processing facilities in this country - expecially in pigment manufacture, along with the acquisition of a Barytes mine to establish a base for lithopone production. U.K. production of lithopone grows dramatically, more than doubling between 1930 and 1934 (despite an initial limit being placed on Imperial's output by a cartel - the International Lithopone Union, of 17,000 tons in 1931).[83] Production comes to match consumption, and the substantial trade deficit in lithopone prior to 1930 is replaced by a balance of trade fluctuating around zero.

Imperial Metal dominated U.K. production of lithopone between 1930 and

TABLE 3.3. Number of Plants and Enterprises involved in Zinc Oxide Manufacture 1946-1968.

Year	1948	1951	1958	1963	1968
Number of Zinc Oxide Plants recorded	15	17	15	11	8
Number of Enterprises producing Zinc Oxide			11	8	6

Source: Census of Production for the year 1948, 1951, 1958, 1963, 1968. [81]

1950 during which time it accounts for 70-85% of U.K. production. Figures for Imperial and total U.K. production of lithopone are shown in Table A.7 and Figure 3.6. Imperial's near monopoly position is all the more surprising given the simplicity of manufacture of this pigment. The number of the U.K. lithopone producers is not known - they are not published in the Census of Production because of the small numbers involved.

U.K. lithopone consumption reaches a peak of over 60,000 tons in 1951, after which consumption and production fall very rapidly. Imperial's share of production fell below 50% of the total in this period and its factory closed in 1963. By 1968 production and consumption of lithopone cease.

The Titanium Dioxide Industry

In 1923 an unsuccessful attempt was made to develop a United Kingdom and British Empire manufacturing and marketing base for Titanium Dioxide. A small company, National Titanium Pigments began to develop the process of preparing titanium dioxide from Australian ores (with support from the Mineral Resources Department of the Imperial Institute).

Laporte, a Barytes manufacturer who, since 1920 had been selling a mixture of Barytes and Titanium Dioxide imported from the U.S., had been conducting trials with a view to making Titanium Dioxide itself. In 1927, Laporte bought N.T.P. and in 1932 a substantial production facility came on stream, producing initially 1 ton of Titanium Dioxide per day.[84]

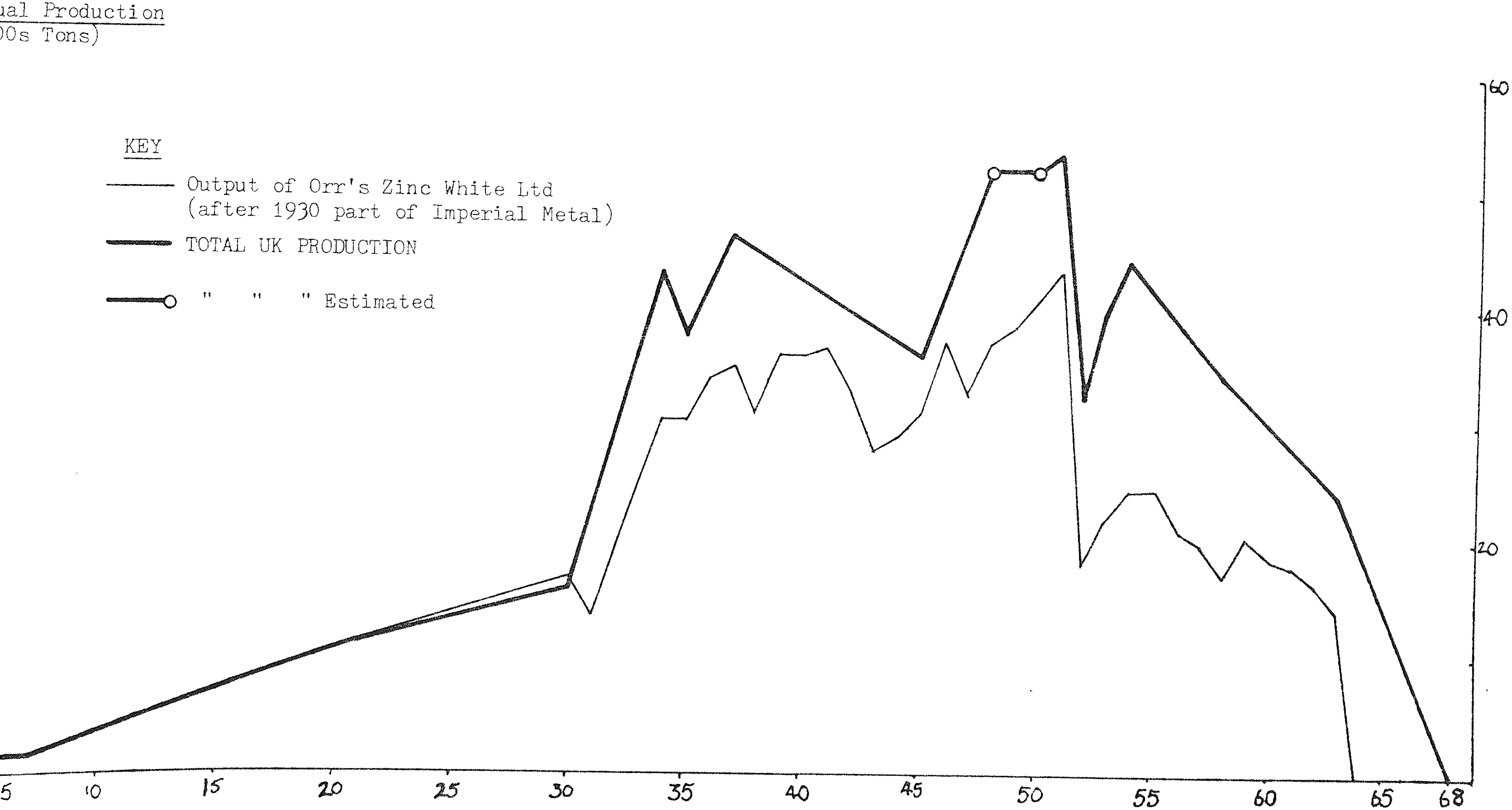
Meanwhile, different sectors were also becoming concerned to be involved in producing this pigment, which had obvious advantages in terms of its hiding power and chemical inertness.

The American Corporation, National Lead, in 1927 acquired the rights to produce Titanium Dioxide, based on the U.S./Norwegian development work.

Fig 3 - 6

PRODUCTION OF LITHOPONE 1905 - 1968

Showing Output of Lithopone by 'Orr's Zinc White Co'(after 1930 Imperial Metal) and Total UK Production



Source: Tables A-3 and A-7. (Estimated)

The only major European producer was I.G.Farben, operating under licence to National Lead. National Lead sought a European manufacturing base. The zinc and lead pigment makers were worried about possible competition from the new pigment, whilst the paint mixers were worried that a single firm should have a monopoly of U.K. production.

Thus in 1932 a joint venture to produce Titanium Dioxide was established in Britain. National Lead, Imperial Smelting (with interests in zinc and zinc pigments), I.C.I. (with paint interests) and Goodlass Wall Ltd. (a white lead manufacturer - now part of Lead Industries Ltd.) formed a new Company - British Titan Products (BTP) Ltd. which came on stream in 1934.

These two firms have remained the sole U.K. producers of Titanium Dioxide (although National Lead was forced to divest its share in BTP because of anti-trust legislation, and other changes in the ownership of BTP have taken place).[85]

The British Titanium Dioxide Industry has sustained massive growth. For example BTP Ltd. had a capital value of £125,000 in 1932 which had risen to £32,000,000 in 1968. Profits of £74,000 in 1938 were £2,500,000 in 1968. U.K. output of Titanium Dioxide has grown almost exponentially as is shown in Table 3.4.[86]

In the 1935-1951 period the price of Titanium Dioxide has fallen in real terms and relative to other pigments fell by over 60% to bring it in line with other white pigments.

There are no figures for Titanium Dioxide imports prior to 1935, but these must have been negligible. Since this time Britain has been a net exporter of Titanium Dioxide amounting to around a quarter of production in 1950 to about one third by 1974.

TABLE 3.4. U.K.Production of Titanium Dioxide 1932-76.

The output of the two British Titanium Dioxide producers was as follows. (Thousand Tons).

Year	Laporte Industries[1]	British Titan Products[2]	Total
1932/3	0.3		
1935	0.6	2.7	3.3
1937		5.2	
1940	1.5		
1945	1.7	7.3	9.0
1946		9.5	
1947		11.0	
1948		11.3	
1949		19.4	
1950	4.2	28.0	32.2
1951		28.0	
1952		25.5	
1953		42.8	
1954		50.4	
1955	13.3	54.0	67.3
1960	32		
1965	42		
1970	65		
1975	89		
1976	68.3		

Sources:

1. Personal Communication R.J.Wiggington, Administration Section Manager, Laporte Industries, 17.1.79
2. G.E.Watts. The Consumption of White Pigments in the U.K. Statistical Report No.2., Records and Market Research Dept., British Titan Products Co. Unpublished Report May 1956, courtesy of Titanox International Ltd.

<u>Observations on the Development of the U.K. Pigment Industry</u>

1. The white lead industry would appear to have been in continual decline and rationalisation which dates back to 1910.

2. The development of the U.K. zinc oxide and lithopone industry show a broadly similar pattern.

   Domestic production develops slowly in the first quarter of the Twentieth Century. U.K. production is exceeded by U.K. consumption. This would indicate a surplus demand by the U.K. paint industry (and other pigment users) resulting in a significant level of net imports of zinc pigments. This in turn provokes a strategic decision by (U.K. based, multinational) zinc interests to establish a U.K. manufacturing base for zinc pigments in the 1930s (aided by tariff barriers and protectionism). U.K. production of zinc pigments grows rapidly after 1930 to meet increasing consumption and to displace imports.

3. In the case of Titanium Dioxide the pattern is rather different. This pigment is identified as being of strategic importance by manufacturers of other pigments, in advance of the development of significant U.K. consumption (i.e. through imports). Its potential threat to all sections of the white pigment industry is expressed in their involvement in establishing U.K. production facilities. Growth in pre-war production of Titanium Dioxide is relatively slow, but subsequently it increases at a nearly exponential rate (even exceeding the rapidly growing levels of U.K. consumption).

Analysis of the Market Share Held by the Major White Pigments

The Pattern of Consumption of Major White Pigments

The consumption of the major white pigments (white lead, zinc oxide, lithopone and latterly titanium dioxide) by all U.K. industries is charted in Figure 3-7. (Source Appendix A-1).

This charts the gradual decline in consumption of white lead, overtaken initially by lithopone and zinc oxide (between 1924-30 and 1935-7 respectively) and latterly by titanium dioxide, which overtakes white lead in 1949, and eventually largely displaces the other white pigments from the market.

Relative Consumption of Major White Pigments

The total consumption of white pigments varies from year to year. Over the period under examination pigment consumption grows substantially.

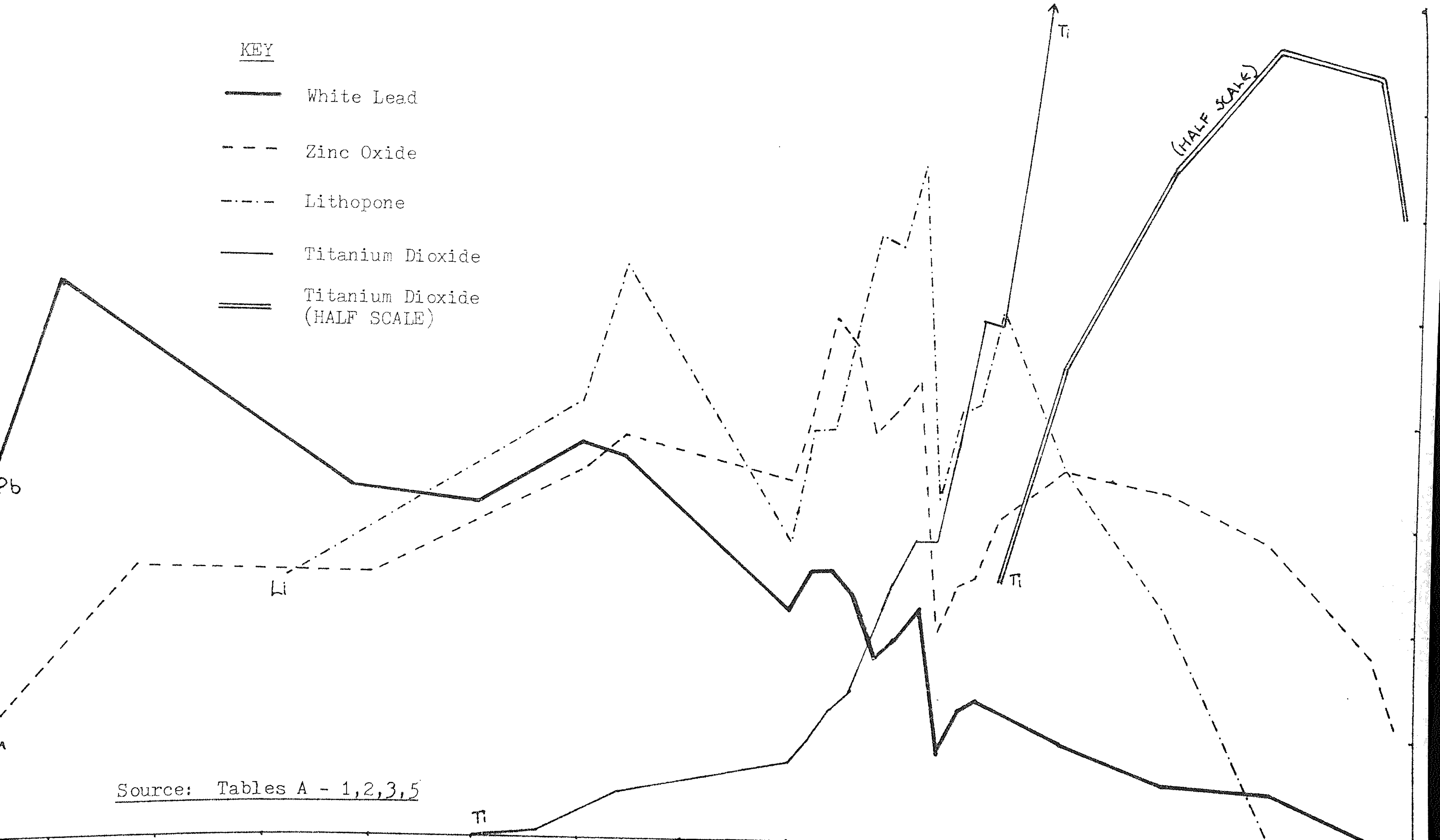
In order to offset the effects of these changes we have calculated the relative consumption of the major white pigments. (consumption of pigment [tons] divided by the combined consumption of major white pigments - i.e. white lead, zinc oxide, lithopone, titanium dioxide). Unless otherwise stated, relative consumption will be used to describe consumption of pigments by all U.K. industries.

The relative consumption of the major white pigments for 1924-1974 are shown in Table 3.5 and Figure 3-8.

Pigment Consumption by the Paint and Non-Paint Industries

A consistent set of figures for pigment consumption by all U.K. industries has been obtained for twenty years between 1924 and 1974. In the same period, information on consumption of pigments by the U.K. paint industry has only been obtainable for five years (1924, 1948, 1954, 1963, 1968).

Fig 3 - 7   CONSUMPTION BY ALL UK INDUSTRIES OF MAJOR WHITE PIGMENTS   1907 - 1974



Source: Tables A - 1,2,3,5

TABLE 3.5. 'Relative Consumption' of Major White Pigments All Industries 1924-74

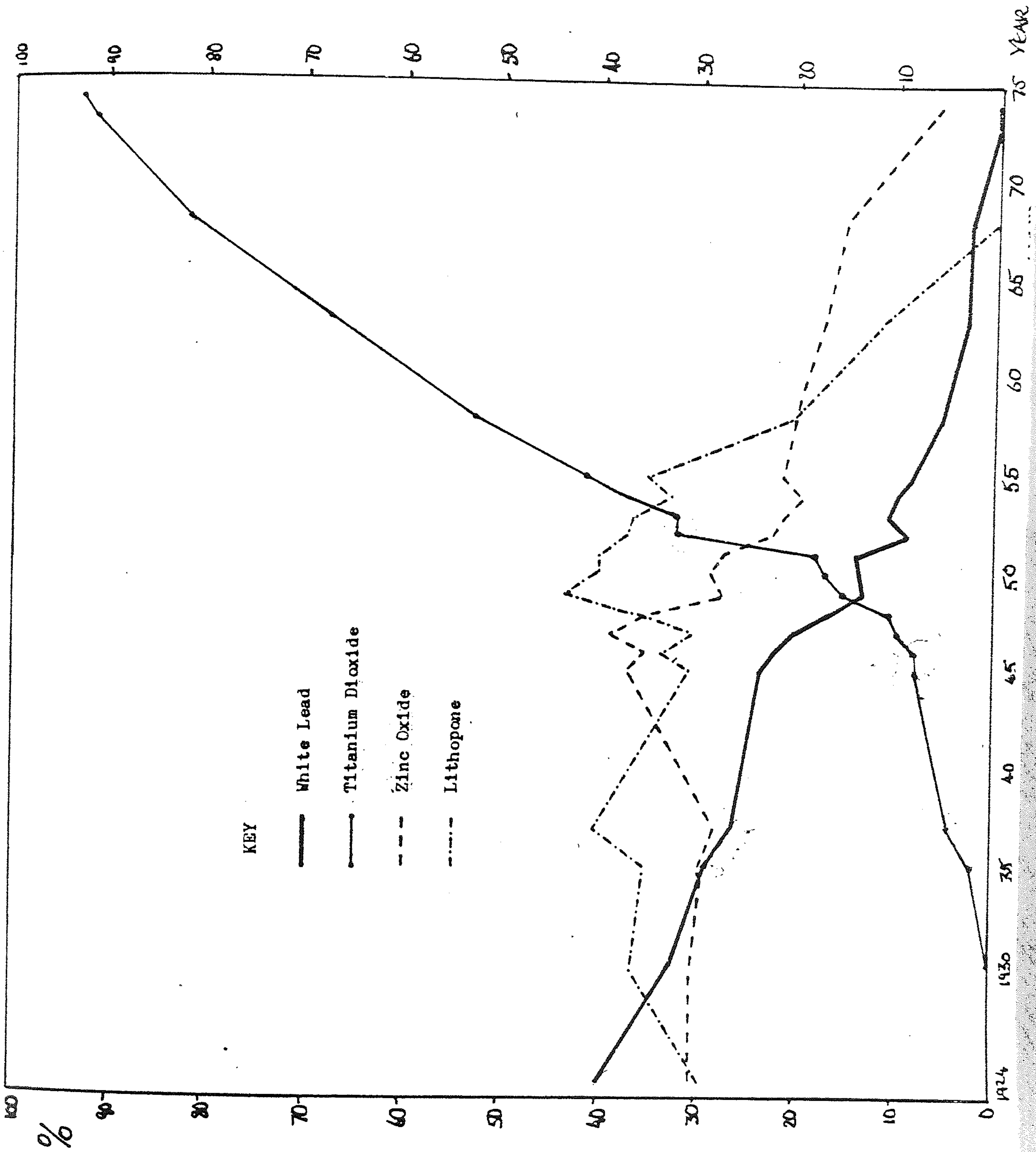
Pigment Consumption as a Percentage of the Combined Consumption of Major White Pigments in All U:K. Industries.

Year	White Lead %	Zinc Oxide %	Lithopone %	Titanium Dioxide %
1924	40.0	30.3	29.7	0
1930	32.5	30.5	37.0	0
1935	29.1	29.8	35.7	2.0
1937	26.5	28.3	40.7	4.5
1945	23.8	37.2	31.1	7.9
1946	22.3	35.7	33.9	8.1
1947	20.2	39.1	30.9	9.8
1948	17.0	35.8	36.5	10.6
1949	13.3	27.8	43.6	15.3
1950	13.6	28.8	40.3	17.3
1951	14.0	27.6	40.2	18.2
1952	9.2	22.5	37.5	32.4
1953	10.8	21.4	36.7	32.3
1954	10.1	19.5	33.1	38.0
1955	8.6	21.3	35.3	34.8
1958	5.6	20.6	20.7	53.1
1963	3.1	17.6	11.5	67.8
1968	2.9	15.3	0	81.9
1973	0.3	7.6	0	92.0
1974	0.5	6.0	0	93.5

Numbers may not add up to 100% due to rounding errors.

Source: Tables A-1, 2, 3, 5.

Figure 3-8: 'Relative Consumption' of Major White Pigments 1924 - 1974. Consumption by All U.K. Industries.



Pigment Consumption as a Percentage of the combined consumption of major white pigments in All UK Industries.

Source: Tables A-1,2,3,5

These data, their calculation and validity are discussed in Appendix A-2.[87, 88, 89, 90] They probably underestimate the paint industry consumption.

Figure 3-9 shows the combined U.K. consumption of the major white pigments by the paint industry and by all U.K. industries. It can be seen that consumption of pigments by the paint industry is relatively static (in tonnage terms) whilst 'non-paint' consumption of pigments has been increasing steadily. In 1924, the latter only accounted for 35.9% of total pigment consumption, but by 1968 this had risen to 57.1%.

Figure 3-10 shows the consumption by the U.K. paint industry of each of the major white pigments (plotted on the same axes as Figure 3-7 - consumption by all U.K. industries). Though the scarcity of observations in the former make detailed comparison difficult, there are marked differences between the pattern of pigment consumption by the paint industry and other industries. These differences become more obvious from a comparison of Figures 3-11 a) to d). These show the 'relative consumption' of major white pigments by the paint and non-paint industries (pigment consumption as a percentage of combined pigment consumption). In particular this shows :

i) that white lead is displaced more slowly from the paint than non-paint industries,

ii) that zinc oxide retains a larger market share outside the paint industry (largely attributable to its use in the rubber industry - see Appendix A-2),

iii) the reverse is true of lithopone,

iv) titanium dioxide displaces other pigments more rapidly from the paint industry than non-paint industries.

Figure 3 - 9: Combined U.K. Consumption of All Major White Pigments, 1924 - 1974, by the U.K. Paint Industry and by All U.K. Industries. (Thousand tons)

source: Appendix A-2, Table A-12.

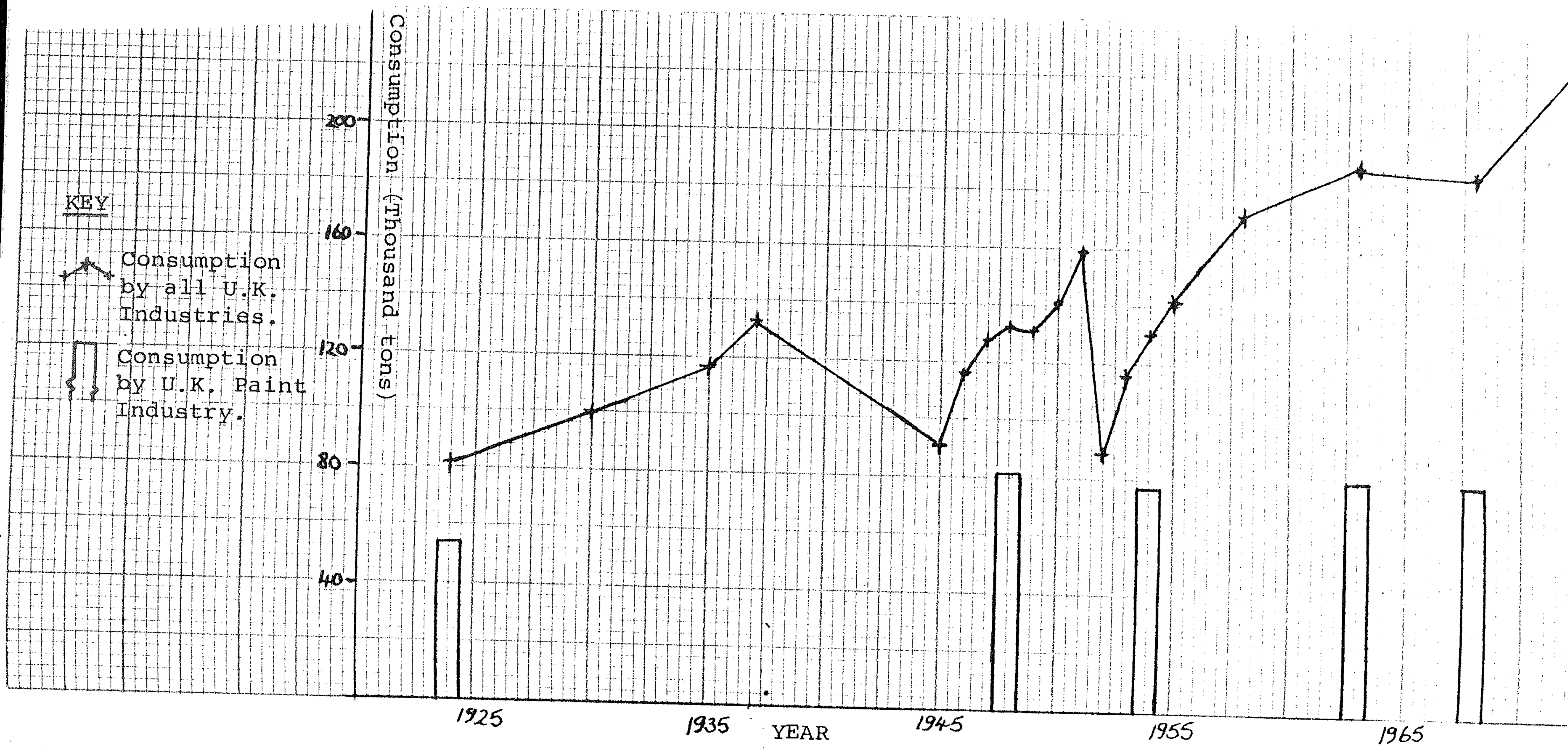


Fig 3 - 10 CONSUMPTION OF MAJOR WHITE PIGMENTS BY UK PAINT INDUSTRY 1910 - 1968

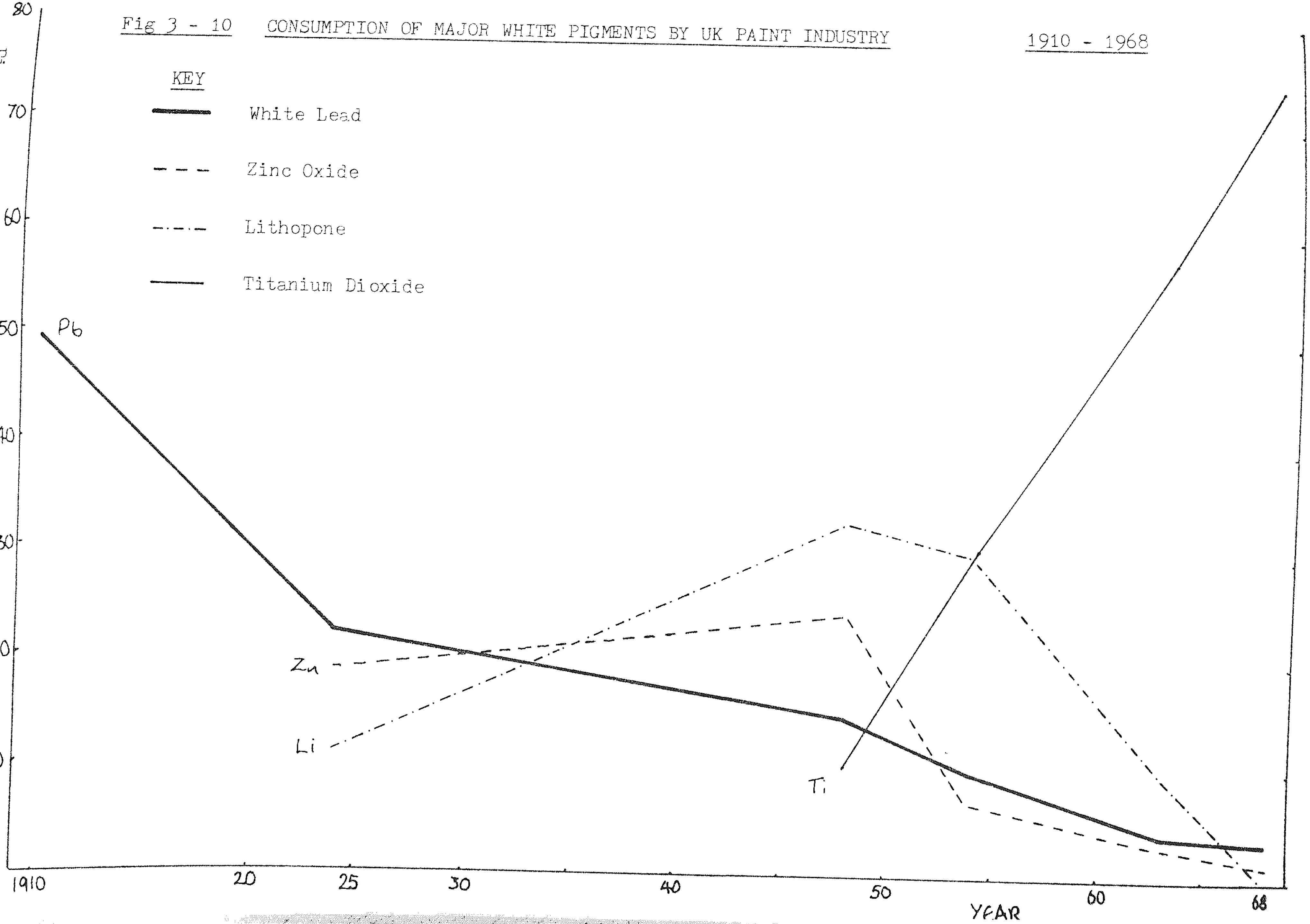
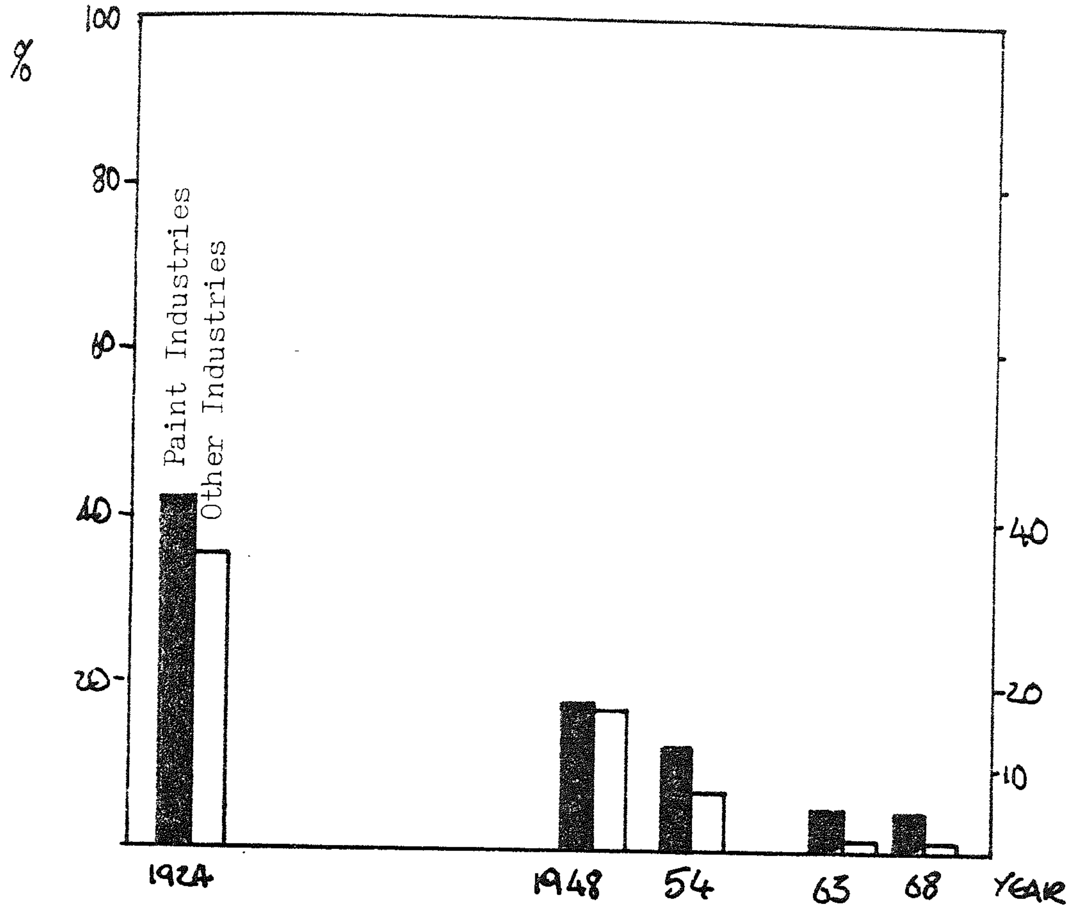
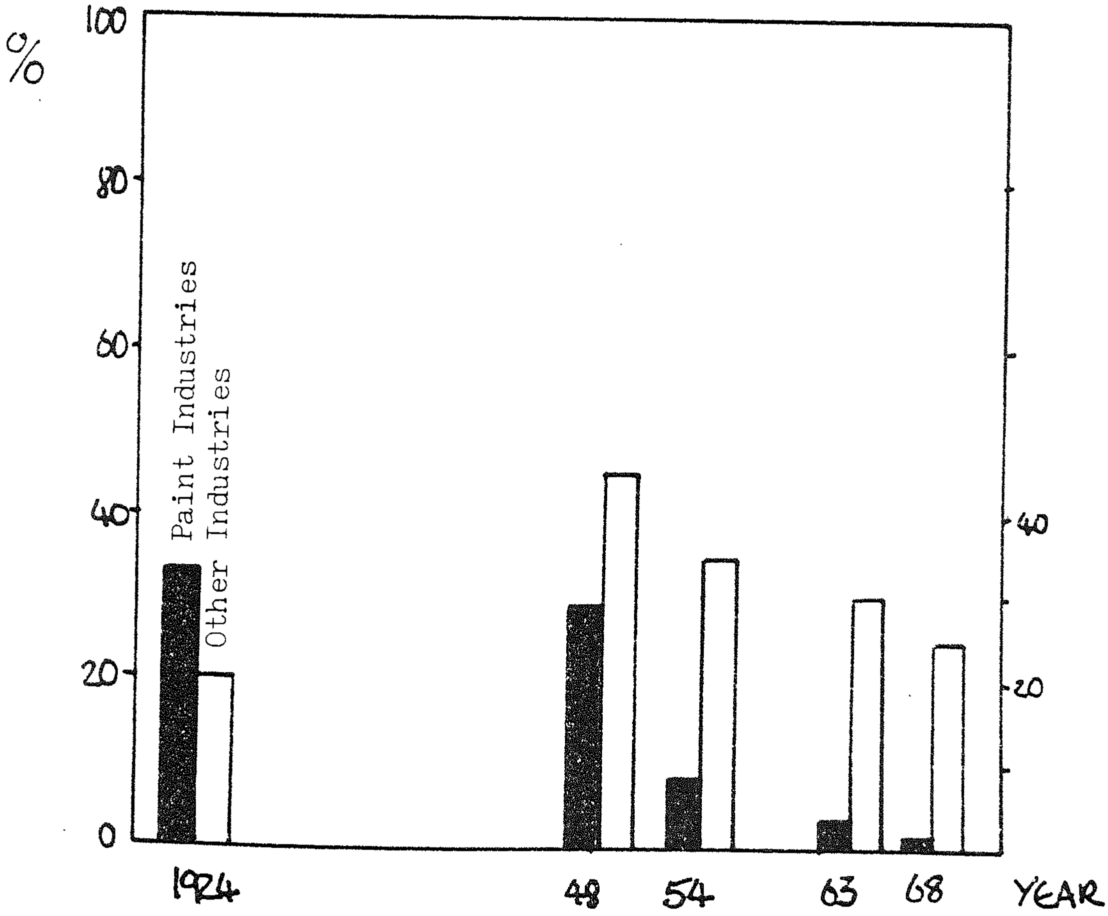


Fig 3-11 RELATIVE CONSUMPTION OF MAJOR WHITE PIGMENTS BY THE UK PAINT AND 'OTHER' INDUSTRIES 1924 - 1968

a) White Lead



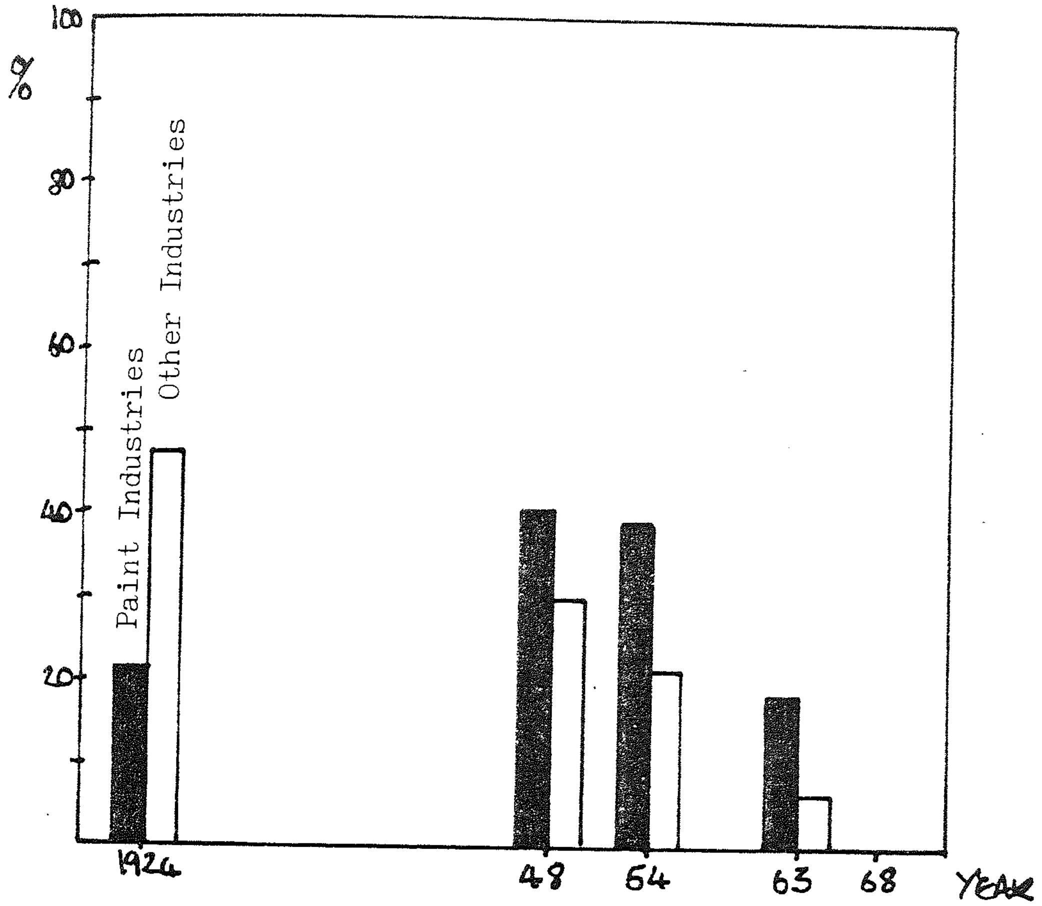
b) Zinc Oxide



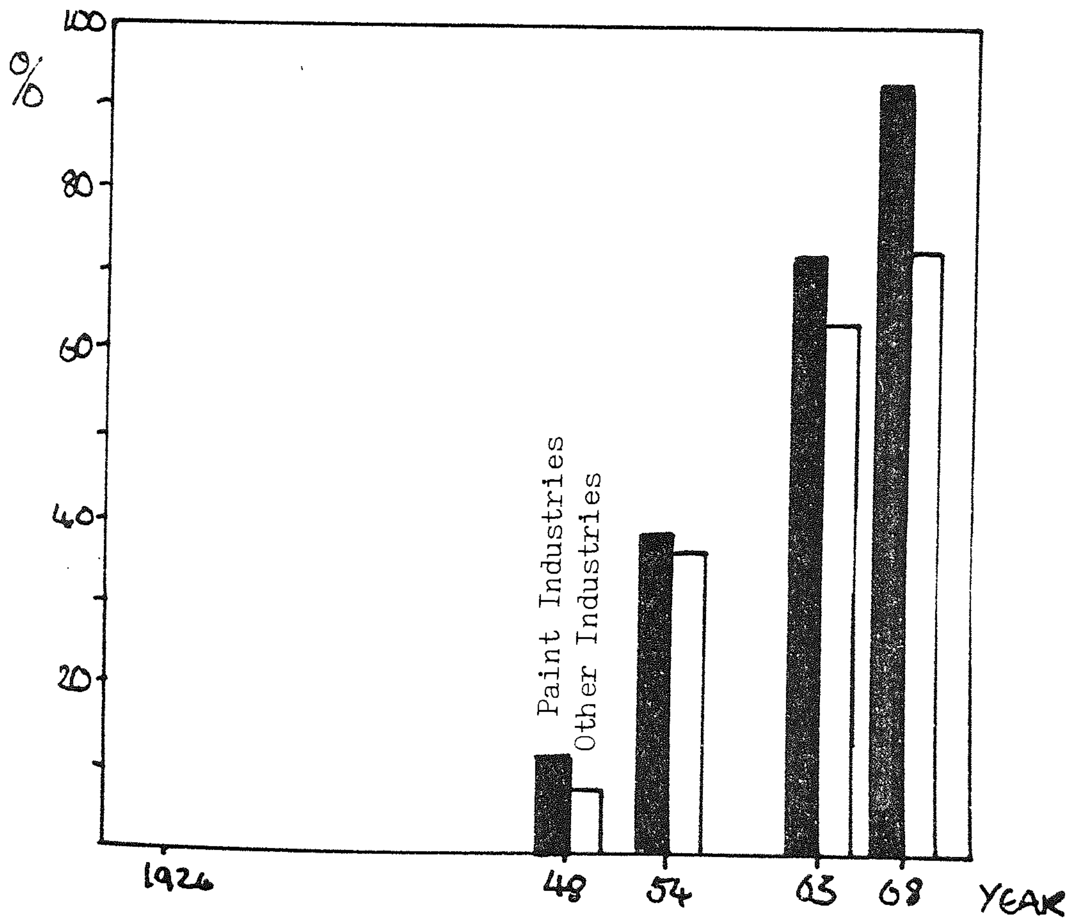
source: Appendix A-2. Paint Industry Relative Consumption from Table A-11. 'Other Industry' Relative Consumption calculated from Table A-10.

Fig 3-11 Contd

c) Lithopone



d) Titanium Dioxide



These differences can be explained in terms of the price and physical and chemical properties of the pigments as will be seen below.

The occasional nature of the figures for paint industry consumption of the major white pigments obscures the complex pattern of the pigment substitution process evident from the data on pigment consumption by all industries. Rather than attempting to deduce the determinants of pigment substitution from the figures for paint industry consumption, an attempt will be made to analyse the pattern of consumption of pigments by all U.K. industries. The differences between the trends in paint and 'non-paint' consumption will then be explained in terms of the different pigment properties, applications and markets involved. In this way a larger volume of data can be used which are more reliable and cover a longer time-span.

Market Share and Pigment Price

Pigment price was the most frequently cited explanation for the substitution of one pigment by another. Data was therefore collected on the price of the major white pigments (see Appendix A-1) to determine what relationship this had to the market share of each pigment.

Over the 1924-74 period inflation has resulted in a tenfold increase in the price of pigments. Two methods have been used to adjust for inflation yielding two sets of indices for pigment price:

i) Relative Price

The total value of white pigments consumed was divided by their total weight yielding an average price for each year. The relative price of each pigment is given by the cost of the pigment per ton divided by the average price. This method has the advantage that it eliminates the effect of inflation altogether and shows only changes in price differentials. The disadvantages are that it can only be calculated for years in which consumption figures are available for all pigments, and that the price of the dominant pigment tends towards unity.

ii) Weighted Price

Here historical pigment prices were adjusted by means of an 'index of the Internal Purchasing Price of the Pound'[91] to yield their equivalent prices at 1963 values (per 1/100th ton to yield weighted prices varying around i).

'Weighted' price is not affected by pigment consumption, but has the disadvantage that it does not simply measure changes in price differentials of pigments but is affected by differential inflation rates between pigments and the commodities used to construct price indices.

The methods of calculating these two price indices and the results are presented in Appendix A-3.[91, 92, 93] Both sets of inflation adjusted prices have been used in the subsequent analysis. Both sets of price indices yield broadly similar results (the major difference between the two indices being of scale). 'Weighted price' proved a more convenient measure, and only the results on analyses based on this price index will be presented. Where use of weighted price would produce a different result, this is noted. The validity of these two price indices is discussed in Appendix A-3.

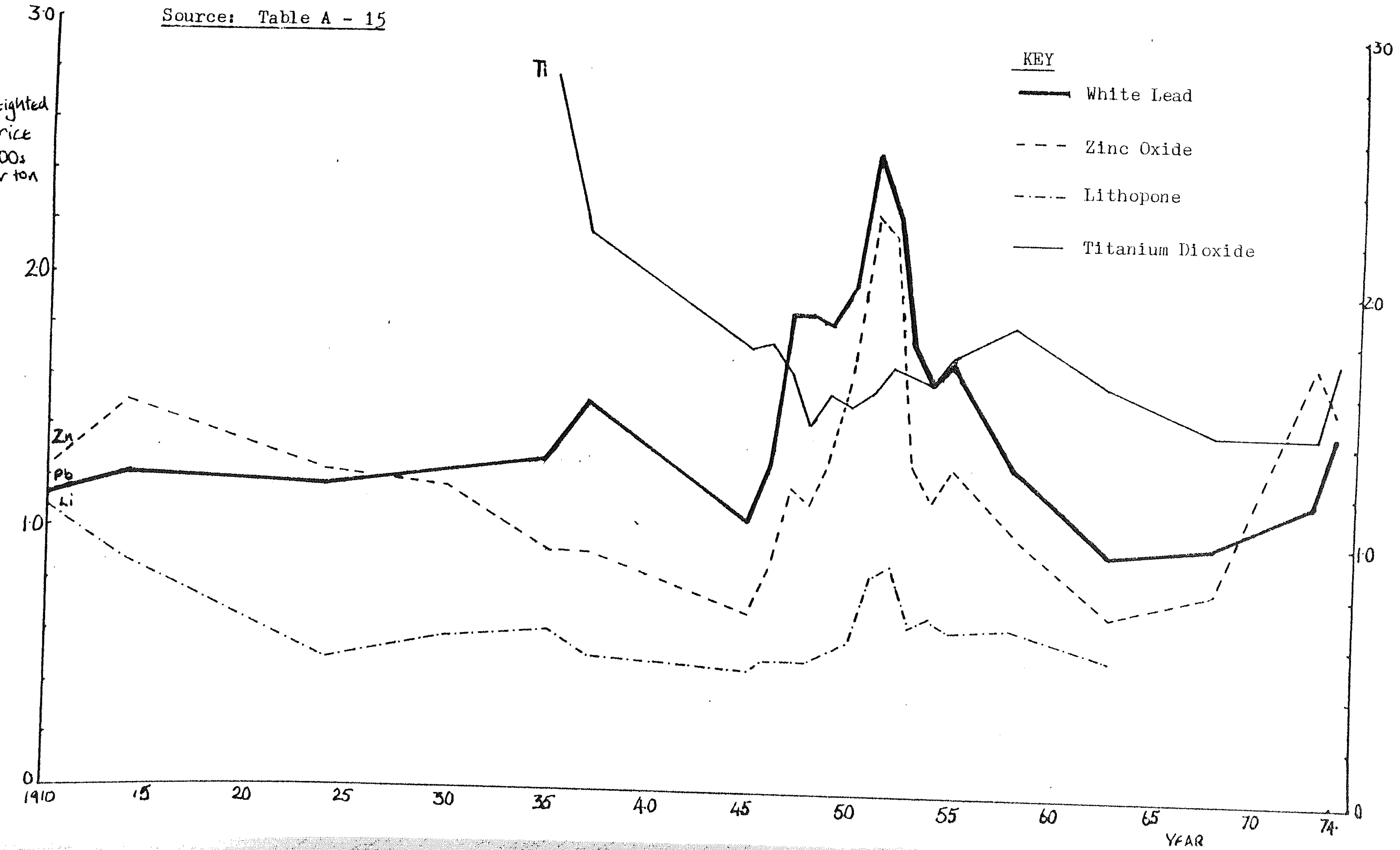
The Relationship between Market Share and Pigment Price

Comparison between Figure 3-8 'Relative Consumption' (i.e. market share) and Figure 3-12 'Weighted Price' of the major white pigments shows a very clear overall relationship between these two factors. For example, the rank order of pigments in terms of price is matched by the reverse rank

Fig 3 -12 'WEIGHTED' PRICE OF MAJOR WHITE PIGMENTS 1910 - 1974

At 1963 Prices, £100s per Ton

Source: Table A - 15



order of pigments in terms of market share in the same or successive time period. The exception here is titanium dioxide which from the mid-1950s combines highest price with market domination. However, as will be seen below, the hiding power of titanium dioxide is substantially greater than the other white pigments and smaller quantities were therefore needed to make a given quantity of paint. If cost per unit of hiding power, rather than weight, were plotted, titanium dioxide would be the cheapest pigment in this period. Leading on from these observations, various attempts were made to develop a quantitative model of the relationship between market share and pigment price. The form of the relationship between pigment consumption and price, and deviations from the expected relationship might demonstrate the influence of 'non-price' factors in the process of pigment diffusion.

A simple approach to determining this relationship which suggests itself would be to seek a simple statistical relationship (e.g. linear regression) between price and market share (or changes therein) in the same or subsequent period. However, this method does not lead to meaningful results when applied wholesale to the data.

Scatter Diagram of Market Share and Pigment Price

A 'scatter diagram' was plotted of 'weighted' price against relative consumption of each of the major white pigments for different years. The distribution of price against consumption does not show a simple relationship, but differs between pigments and in different periods. The results are shown in Figures 3-13 (white lead), 3-14 (zinc oxide) and 3-15 (lithopone and titanium dioxide). To highlight the changing distribution over time the year of each observation is identified (price/consumption), and successive periods have been joined up.

Figure 3-13: Scatter Plot of White Lead Price and Consumption 1924-1974.

Weighted Price of White Lead, plotted against Relative Consumption for various years (year of observation shown, successive observations linked).

Weighted Price = pigment price at 1963 values per 0.01 tons.

Relative Consumption = white lead consumption/combined consumption of major white pigments by all UK industries.

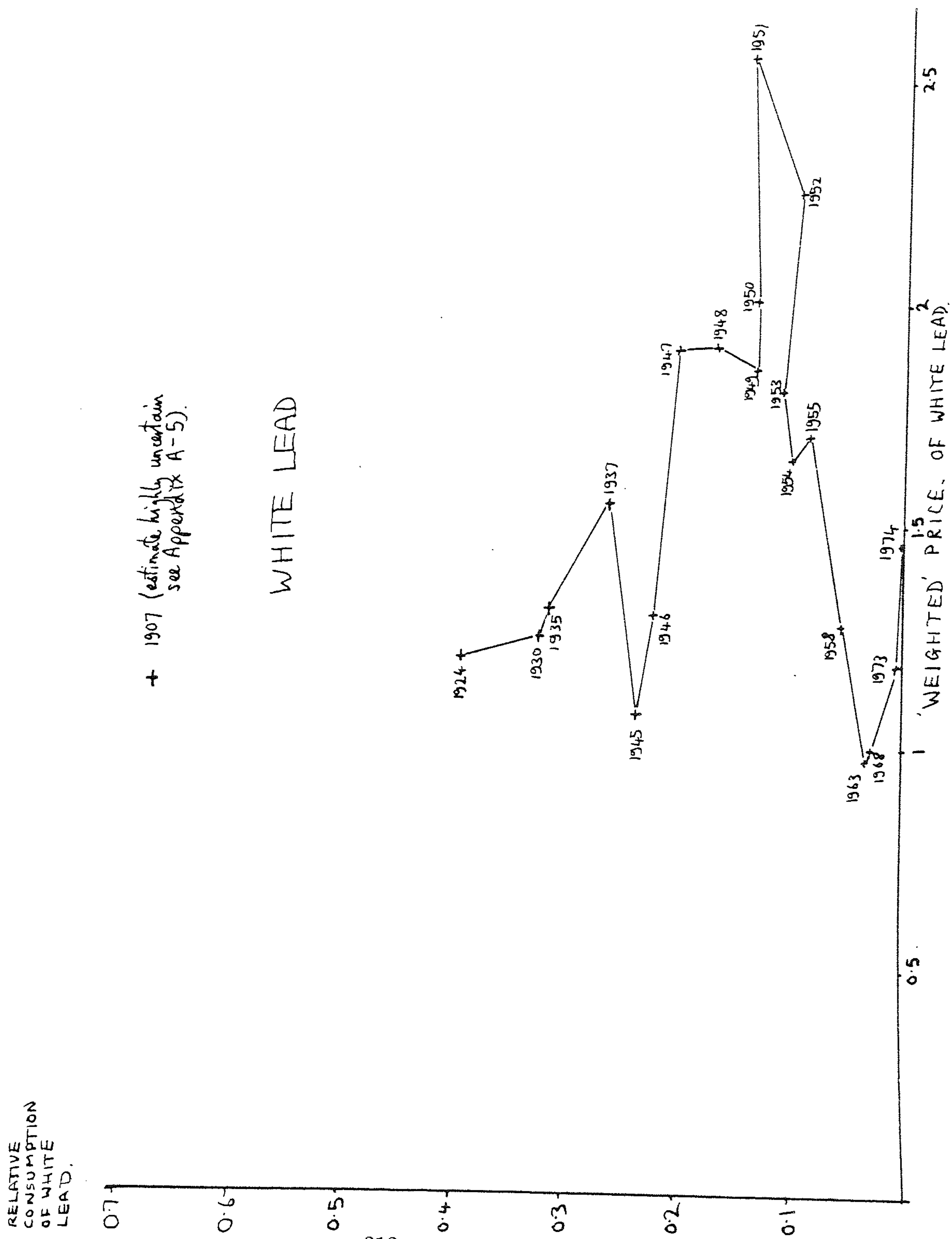


Figure 3-14: Scatter Plot of Zinc Oxide Price and Consumption 1924-1974.

Weighted Price of Zinc Oxide, plotted against Relative Consumption for various years (year of observation shown, successive observations linked).

Weighted Price = pigment price at 1963 values per 0.01 tons.

Relative Consumption = zinc oxide consumption/combined consumption of major white pigments by all UK Industries.

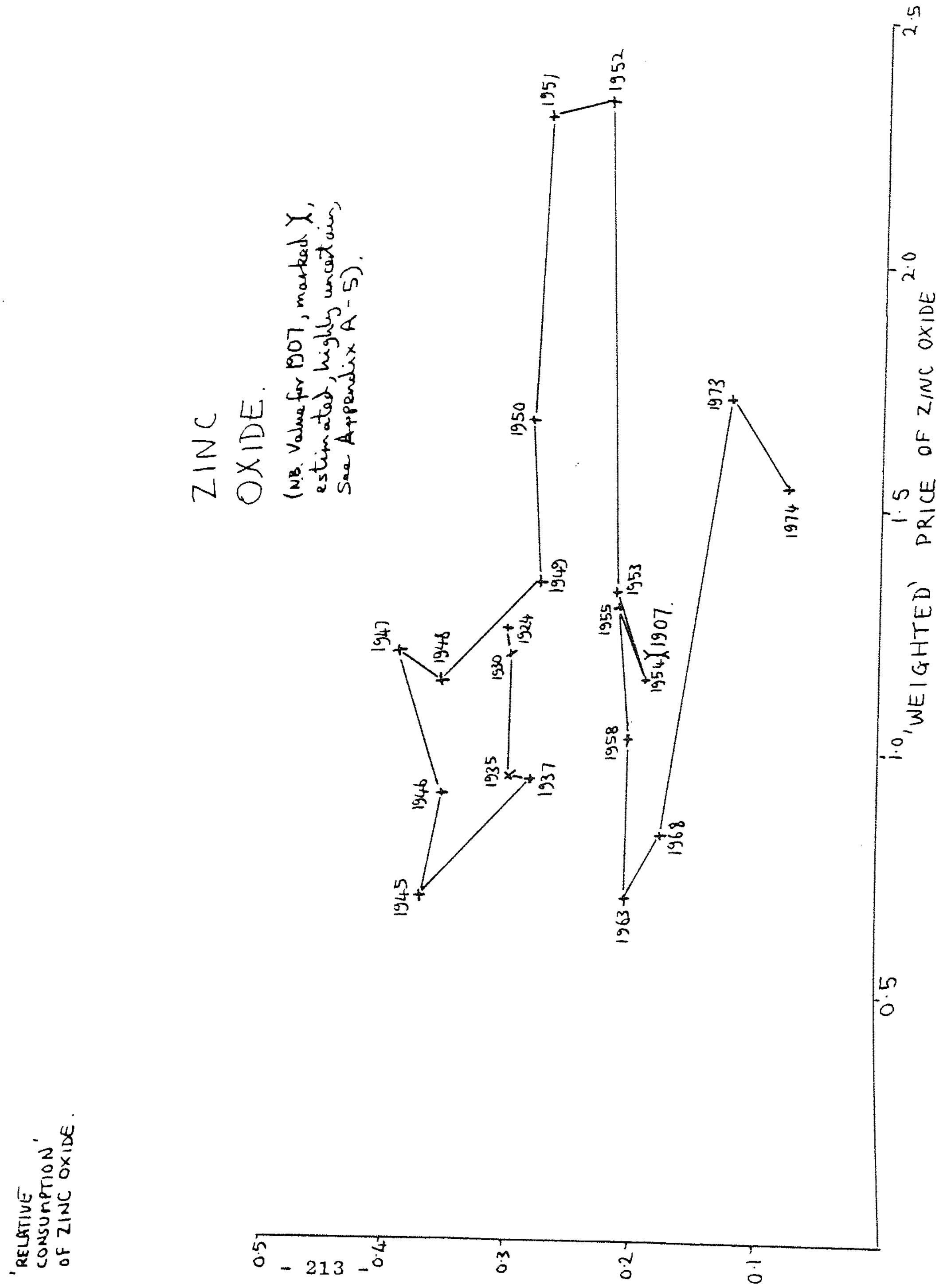


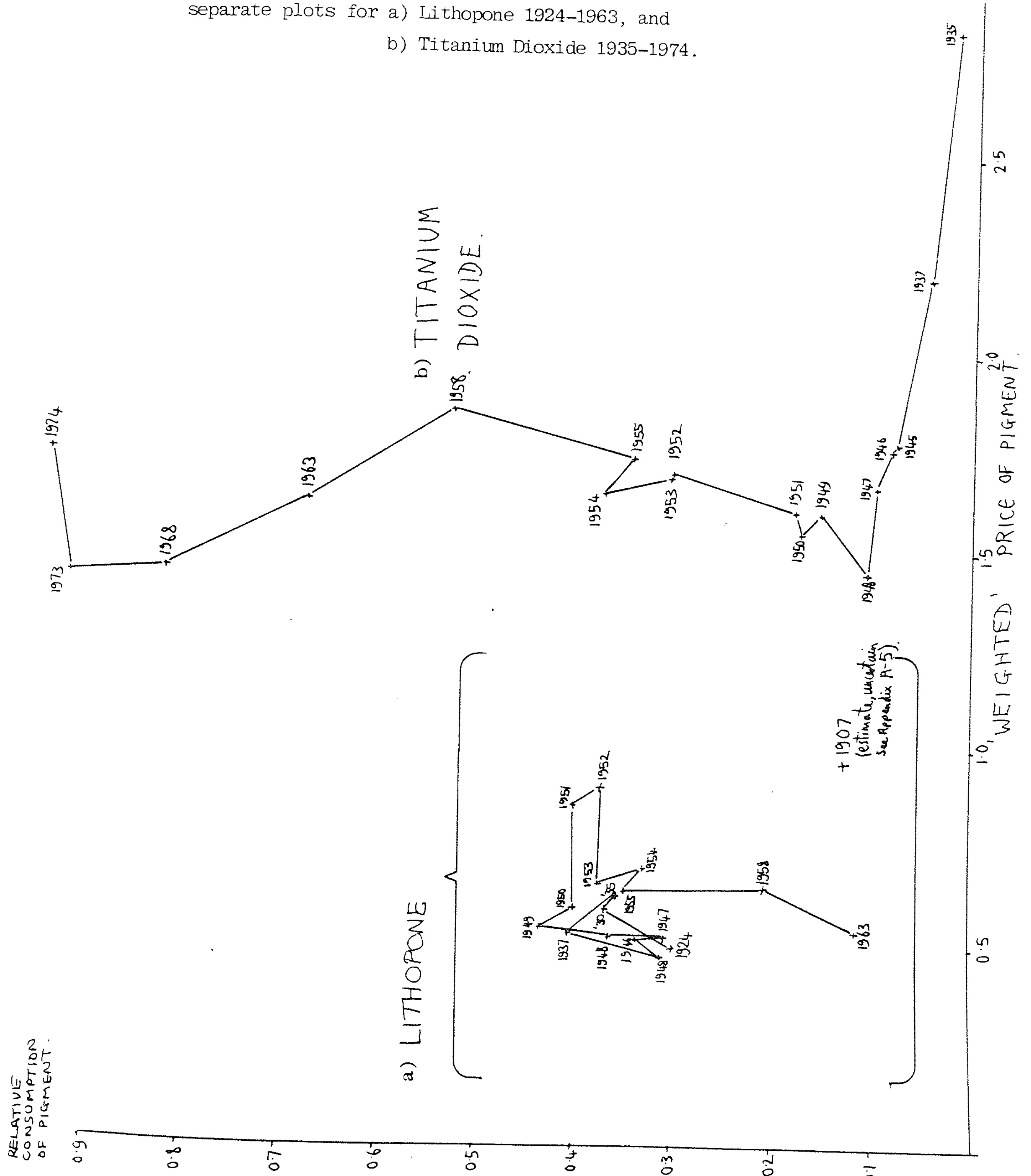
Figure 3-15: Scatter Plot of Price and Consumption of Lithopone 1924-1963 and Titanium Dioxide 1935-1974.

Weighted Price of pigment plotted against Relative Consumption for various years (year of observation shown, successive observations linked).

Weighted Price = pigment price at 1963 values per 0.01 tons.

Relative Consumption = pigment consumption/combined consumption of major white pigments by all UK Industries.

separate plots for a) Lithopone 1924-1963, and
b) Titanium Dioxide 1935-1974.



These scatter diagrams demonstrate a variety of phenomenon which do not conform to any simple model of the relationship between price and market share (for example an assumption that market share or changes therein are a simple function of relative price or changes therein). A number of points stand out in particular:

1. Zinc oxide and white lead show a rather similar pattern. Price increases are associated with a reduction in market share with prices gradually increasing in the period between 1924 and the early 1950s. After this period there is an apparently paradoxical situation of price and market share declining together!
   The latter coincides with a rapid growth in consumption of the new pigment, titanium dioxide. This transformation in pigment price/market share suggests a reversal in market conditions. For example the 1924-50 period could be seen as a process in which gradually increasing prices forced down market share, whereby in the later period, competition from titanium dioxide both forces a reduction in price and erodes the consumption of white lead and zinc oxide.
2. Lithopone presents a rather different picture. Between 1924 and 1955 its market share varies within the range 0.29 and 0.44, while its relative price lies within the range 0.44-0.62 (the range of weighted price, 0.48-0.9 is somewhat greater). After this period lithopone's market share drops dramatically (without any price change) and the product disappears from the market.
   The price and consumption behaviour of lithopone differs markedly from white lead and zinc oxide, suggesting that it may be controlled by different factors. Thus the stability of the relative price of lithopone suggests that its prices may have been set in relation to other white pigments. The minor fluctuations in market share do not seem to have been related to changes in relative price.

3. Titanium dioxide is marked by an exponential decay in price (which temporarily drops below that of lead and zinc) combined with exponential growth in market share. The previous examination of the development of the titanium dioxide industry suggests that production rather than market conditions may have played a significant role in the price/consumption relationship. (For example supply was judged to have initially been constrained by the technical difficulties and massive capital requirements of production. The subsequent fall in price can be related to economics of scale in production).

4. It is apparent that the pigments are not competing in the market solely on the basis of price per ton. Had this been the case, lithopone would have been expected to sweep the market. Titanium dioxide displaced other pigments that were cheaper in terms of price per ton. As noted earlier, on a price per unit hiding power basis titanium dioxide became cheaper than other pigments during the 1950s. However the hiding power of lithopone was greater than white lead and zinc oxide (which were more expensive). Other factors as well as hiding power must also have been in operation.

Although price appears to have been an important factor behind changes in market share of pigments, the relationship between these two factors is complex. In theory it should be possible to analyse this relationship in terms of classical economic theory. (e.g. by assuming a competitive market, calculating the supply and demand curves etc. etc.). In practice the information needed for such an exercise is not available (e.g. on investment, profitability, stocks of materials), nor would it be justifiable to assume that market conditions were constant during this whole period. In particular, following the Second World War, titanium dioxide establishes a foothold in the market, its market share escalates rapidly and the pigment market is in a state of continuous transition until the process of pigment displacement has neared completion.

It might be possible to identify periods of approximate equilibrium between market share and price in which incremental changes in these variables could be plotted against each other. Such a period of market equilibrium might be expected in the 1924-1944 period, prior to the influence of titanium dioxide. Unfortunately data are only available for four of the twenty years in this period.

Examination of the statistical relationship between Market Share (Relative Consumption) and Pigment Price (Relative Price and Weighted Price

Extensive attempts were made to determine possible simple statistical relationships between market share and price of the major white pigments. In particular, correlation coefficients and regression equations were calculated for both the whole period under study, and separately for the 1924-1952 and 1952-1974 periods. The main results of these calculations are reproduced in Appendix A-4.[94]

Over the period as a whole, there was little evidence of a statistical relationship between price and market share. While stronger relationships could be detected over shorter time periods (in particular by distinguishing the period before and after the establishment of titanium dioxide on the market) the relationships varied from pigment to pigment. It was possible to relate these variations to other aspects of pigment performance (e.g. hiding power of pigments, performance in paints, customer preference). However this approach to analysing the data became very convoluted.

A more fundamental problem arose from the fact that the strongest associations were noted between market share and time (and to a lesser extent, price and time) than market share and price.

The shifts in market share of the major white pigments were substantial, whereas with the exception of titanium dioxide, changes in the price differential between pigments were relatively minor during the period under examination. Despite inter-year fluctuations the differentials between the average prices of white lead, zinc oxide and lithopone are remarkably constant (for example they are almost identical for an average of the years between 1924-37 and 1946-63). The only permanent changes in rank order of pigment price took place before or at the beginning of the period for which comprehensive data are available, (white lead became more expensive than lithopone between 1907 and 1910 and became more expensive than zinc oxide between 1924 and 1930). The only other changes in rank order of prices took place in the 1947-1954 and 1973-1974 period. They were transitory and, were associated respectively with the arrival of titanium dioxide in large volumes on the pigment market, and the 'oil-crisis'.

Thus, in addition to the market changes following the advent of titanium dioxide, there are empirical reasons for the failure of this attempt to relate pigment price to market share, arising from the limited period for which data are available on price and consumption and the form of the changes in price that have taken place in this period.

Alternative approaches were therefore examined that revolved around modelling the changes that have taken place in market share of the different pigments over time and relating these to pigment price and non-price factors. An examination was therefore made of studies of technological substitution, which revolved around modelling (and forecasting), and the role of price and other factors in this process

Studies of Technological Diffusion/Substitution

There is a well established literature on the diffusion of innovations, which would appear to offer fruitful opportunities for our study of the changes in pigment consumption. Analysis of technological diffusion has been pioneered by two groups:

- economists, primarily interested in the contribution of technology to economic growth, investigating barriers to technological diffusion.[95]
- (technological) forecasters, whose prime concern was the prediction of the rate and extent of uptake of innovations from historical data on their adoption.[96]

The concerns of these two groups have influenced the issues addressed and types of case study selected; in particular, cases for study are changes (typically in production technology/processes) which offer clear improvements in productivity/profitability.[97] The new innovation is frequently treated as an external influence on the 'user industry', and factors affecting rate of uptake are modelled. The concerns of this study are slightly different, focusing as it does on the substitution of one raw material (pigment) by another in paint formulation. This involves qualitative changes in products as well as changes in costs. The study is concerned with the interaction between price and non-price factors in substitution in a situation in which the advantages of new innovations may be less clear cut. The conceptualisation of the innovation as an 'external influence' may be less appropriate since in this study the technological problems of adoption and the supplier/consumer relationship assume a greater role.

Though a variety of models of technological diffusion/substitution exist, they generally agree that the market share of a new and competitive innovation will increase over time with a sigmoid distribution (i.e. will follow a logistic or S-shaped curve).

This model was derived by analogy with biological population growth. (Pearl's Law)[98] and is justified by a variety of practical arguments about the behaviour of firms (and other groups) and has been found to give a close fit to empirical observation in a large number of cases.[99]

One of the simplest models for such substitution was developed by J.C. Fisher and R.H.Pry.[100] The Fisher-Pry model for competitive substitution is based on the assumption that

i) if substitution has progressed as far as a few percent, it will proceed to completion (since the product's competitive advantage, demonstrated by the initial substitution will increase as its adoption becomes widespread)

ii) the new products market share will increase at a rate proportional to the remaining market share held by the old product.

This can be expressed arithmetically by the equation:

$$\log \frac{f}{1-f} = \phi (t-t_o)$$

Where f is the market share of the new product at time t, and t_o is the time at which the substitution is halfway to completion (f = 0.5), ϕ is the substitution rate and is constant.

$\log f/_{1-f}$, which is described hereafter as the Fisher-Pry co-efficient thus shows a linear relationship with time.

Variants of this model have been generated for non-competitive substitution[101] and cases where substitution reaches a ceiling below 100%[102] (i.e. where the substitution curve is not symetrical round 50% substitution).

Mansfield has concluded, from a comparative study of the rate of adoption of new capital processes by firms, that the rate of adoption of a given innovation is proportional to the number of firms already using the innovation (a finding in conformity with the Fisher-Pry model). Rate of adoption is correlated with the profitability of the innovation and negatively correlated with the capital investment needed for the change.[103] In Mansfield's empirical determinations the substitution rate ϕ was represented by the formula :

$$\phi = Z + 0.530\Pi - 0.027\,S$$

where Z is a constant for a given industry/country

Π is a profitability index (profitability of investment divided by cost of borrowing), and S is an index of the capital needed for the innovation (relative to existing capital employed).

Swan has conducted a subsequent study of international variation in the rate of substitution of synthetic rubber for natural rubber.[104] In this case the costs of displacement are minimal as no addition to the users capital is required. He found that the industry decision to innovate (determining the substitution rate) reflects the expected profitability of the innovation which varied between nations according to demand or acceptance of the change. Other factors affecting the pattern of displacement include the development and availability of the substitute, communication networks in the user industry, the technical capabilities of the user industry. These were expressed primarily in innovation lags (delays in adopting innovation) which were affected also by the sensitivity of the industry to imports containing the innovation, the concentration of the industry and the learning period needed to discover appropriate applications.

It would thus appear that models of this type can be applied to materials changes of the sort currently under investigation. Indeed one of the examples used to corroborate the Fisher-Pry model was the substitution of lead and zinc pigments by titanium dioxide in paint making in the U.S.A.[105]

The data on U.K. consumption of major white pigments has been analysed using the Fisher-Pry model. The 'Fisher-Pry coefficient' (log f/1-f) has been calculated for each pigment and has been plotted against time. The substitution rate (slope of log f/1-f against time) has been estimated graphically or calculated (regression line of log f/1-f on year) where appropriate.

The Fisher-Pry coefficients for pigment substitution in the consumption of major white pigments in all U.K. industry are shown in Table 3.6 a) Table 3.7 shows the relationship between these Fisher-Pry coefficients and time (calculated regression line for the period 1924-1972).

Table 3.6 b) shows the Fisher-Pry coefficients for pigment substitution in the U.K. paint industry and in other U.K. industries.

The Fisher-Pry coefficient has been plotted against time for total U.K. consumption of white lead (Figure 3-16), zinc oxide (Figure 3-17), lithopone (Figure 3-18) and titanium dioxide (Figure 3-19). In addition these figures show the Fisher-Pry coefficients for pigment consumption by the U.K. paint industry.

Where a linear relationship can be determined between the 'Fisher-Pry' coefficient and time (whether by calculation or graphically) this has been shown.

The results are discussed below for each of the pigment in turn for the distribution of the Fisher-Pry coefficient plotted against time (years, 1900=0) in the case of consumption of major white pigments.

i) by all U.K. industries

ii) by the U.K. paint industry and other U.K. industries

TABLE 3.6.a) 'Fisher-Pry Coefficients' for Substitution and Pigment by Other Major White Pigments - total U.K. pigment consumption

'Fisher-Pry Coefficients' calculated by equation log f/1-f where f = market share (relative consumption of pigment by all U.K. industries).

Year	White Lead	Zinc Oxide	Lithopone	Titanium Dioxide
1924	-0.18	-0.36	-0.37	-
1930	-0.32	-0.36	-0.23	-
1935	-0.39	-0.37	-0.26	-1.69
1937	-0.44	-0.40	-0.16	-1.33
1945	-0.51	-0.22	-0.35	-1.07
1946	-0.54	-0.26	-0.29	-1.05
1947	-0.60	-0.19	-0.35	-0.96
1948	-0.69	-0.25	-0.24	-0.92
1949	-0.81	-0.41	-0.11	-0.74
1950	-0.80	-0.39	-0.17	-0.67
1951	-0.79	-0.42	-0.17	-0.65
1952	-0.99	-0.54	-0.22	-0.32
1953	-0.92	-0.57	-0.24	-0.32
1954	-0.95	-0.61	-0.31	-0.21
1955	-1.02	-0.57	-0.26	-0.27
1958	-1.23	-0.61	-0.58	0.05
1963	-1.50	-0.57	-0.89	0.32
1968	-1.53	-0.59	-	0.65
1973	-2.46	-0.67	-	1.06
1974	-2.31	-0.74	-	1.16

TABLE 3.6.b) Fisher-Pry Coefficients for Substitution of Pigments by other Major White Pigments calculated for pigment consumption by the U.K. Paint Industry and by other U.K. Industries

Paint Industry Consumption

Year	White Lead	Zinc Oxide	Lithopone	Titanium Dioxide
1924	-0.13	-0.26	-0.56	-
1948	-0.66	-0.38	-0.17	-0.84
1954	-0.83	-1.05	-0.19	-0.19
1963	-1.30	-1.39	-0.65	-0.44
1968	-1.33	-1.69	-	1.14

Consumption by Other Industries

Year	White Lead	Zinc Oxide	Lithopone	Titanium Dioxide
1924	-0.26	-0.59	-0.11	-
1948	-0.61	-0.08	-0.07	-1.06
1954	-1.14	-0.27	-0.56	-0.24
1963	-1.79	-0.42	-1.16	0.26
1968	-1.82	-0.47	-	0.44

Fisher Pry Coefficient = log f/1-f
where f = market share of pigment (relative consumption of pigment by U.K. paint industry or other U.K. industries).

TABLE 3.7. Relationship between Fisher Pry Coefficient and Time Pigment Consumption by all U.K. industries 1924-1974

Fisher Pry Coefficient = log f/1-f   f = market share of pigment

t = time(years) 1900 = 0

$\log f/1-f = \phi t + C$

ϕ = substitution rate   C = constant

Calculated regression line of Fisher-Pry coefficient on year.

Pigment Consumption by all U.K. Industries 1924-1974

Pigment	Substitution Rate ϕ	Constant C	Relationship between Fisher Pry Coefficient Time: Correlation Coefficient (R^2)	Linearity of Relationship
White Lead	-0.044 ±0.004	1.25 ±0.21	0.869	Evidence of Non-linearity
Zinc Oxide	-0.016 ±0.003	0.30 ±0.15	0.626	Evidence of Non-linearity
Lithopone	-0.0069 ±0.0043	0.019 ±0.207	Relationship indeterminate	
Titanium Dioxide	0.073 ±0.002	-4.27 ±0.13	0.982	Highly linear

Figure 3-16: 'Fisher-Pry' Plot for White Lead/White Pigment Consumption by All UK Industries, 1924-1974.

Substitution of White Lead by Other White Pigments.

Plot of Fisher-Pry Coefficient (log f/1-f) against year; f = market share held by White Lead.

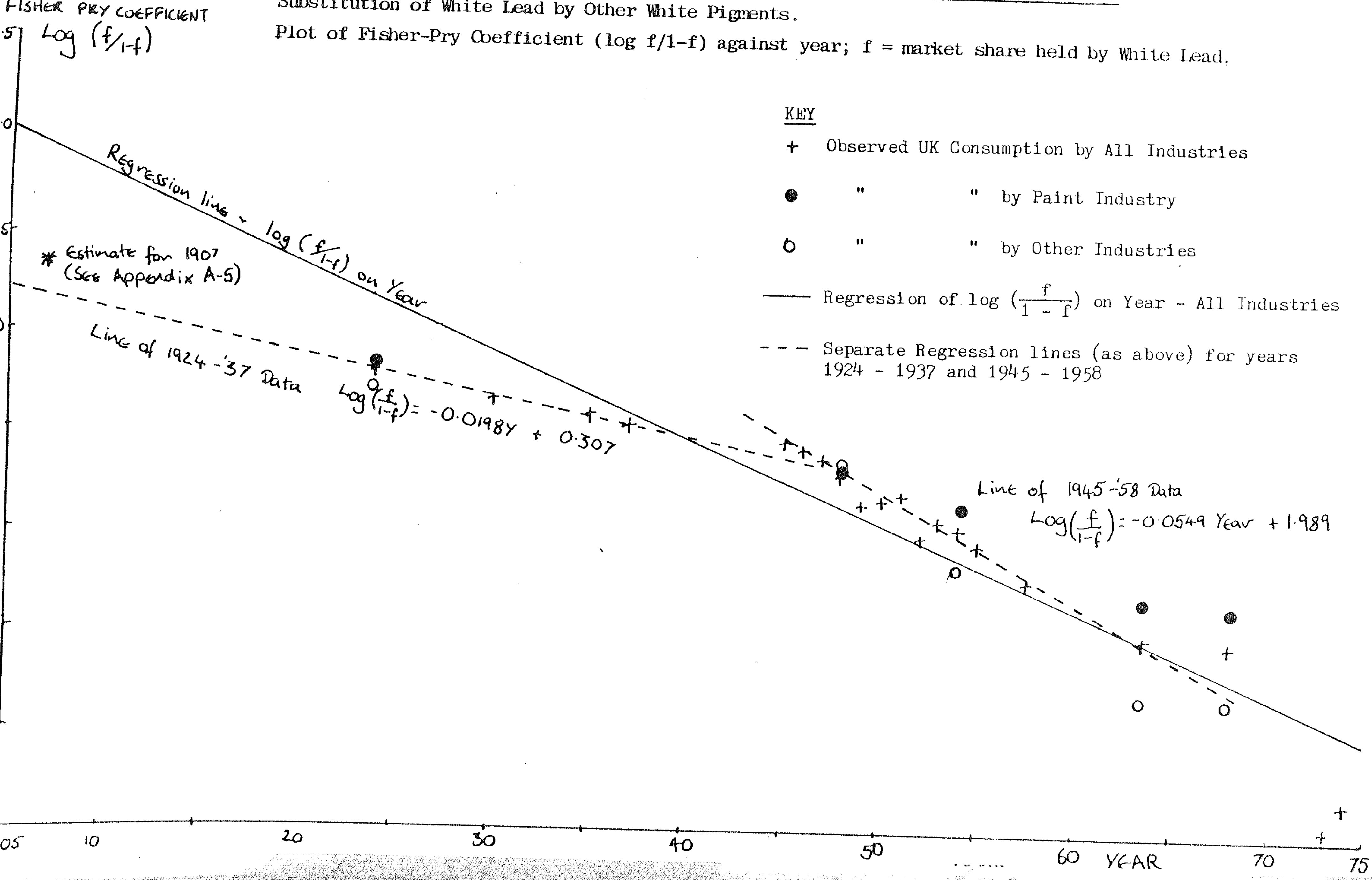


Figure 3-17: 'Fisher-Pry' Plot for Zinc Oxide/White Pigment Consumption by All UK Industries, 1924-1974.

Substitution of Zinc Oxide by/for other white pigments.

Plot of Fisher-Pry Coefficient (log f/1-f) against year, where f= market share held by Zinc Oxide.

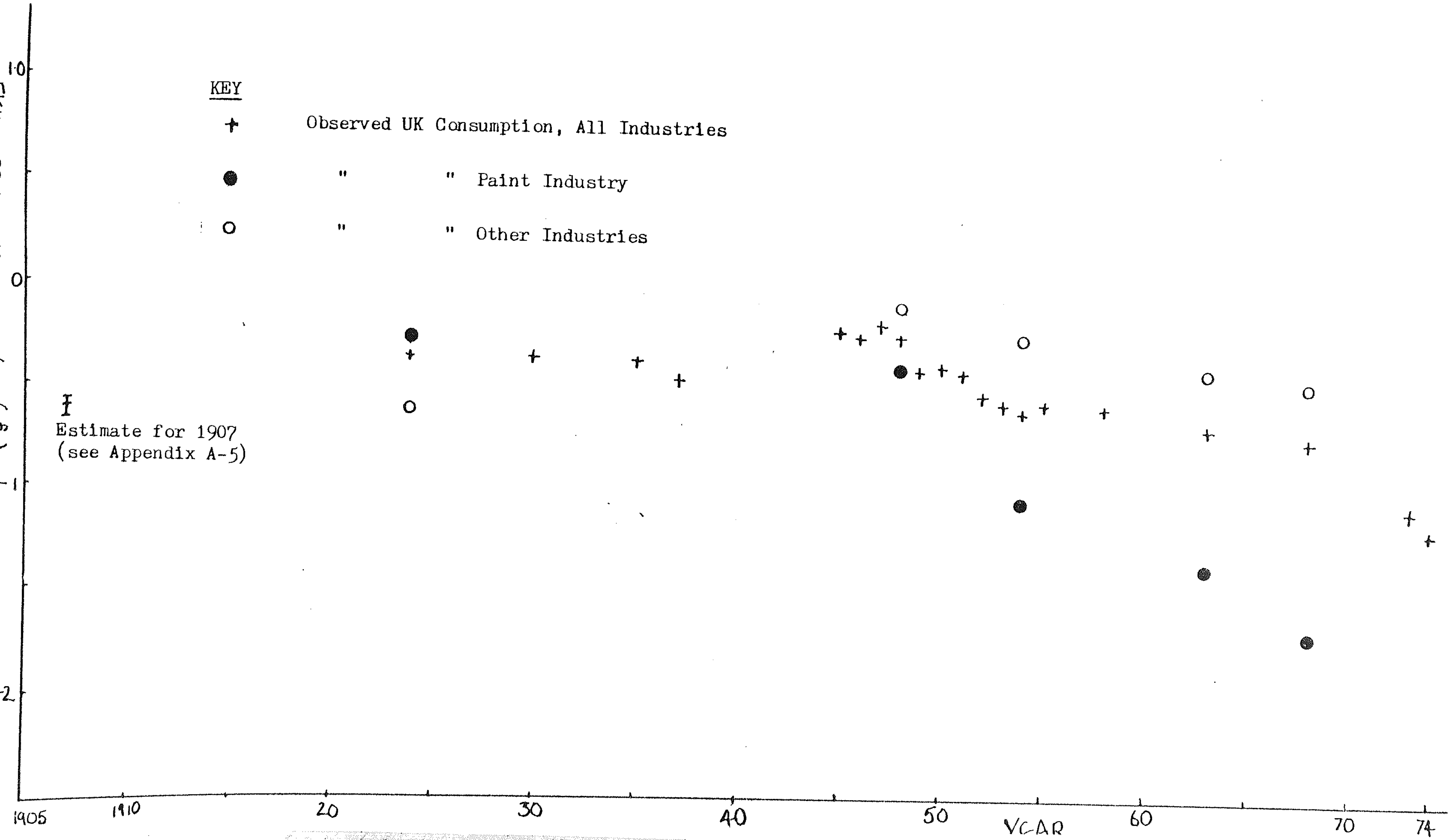


Figure 3-18: 'Fisher-Pry' Plot for Lithopone/White Lead Consumption by All UK Industries 1924-1963.

Substitution of Lithopone by/for other white pigments.

Plot of Fisher Pry Coefficient (log f/1-f) against year.

(f = market share held by lithopone).

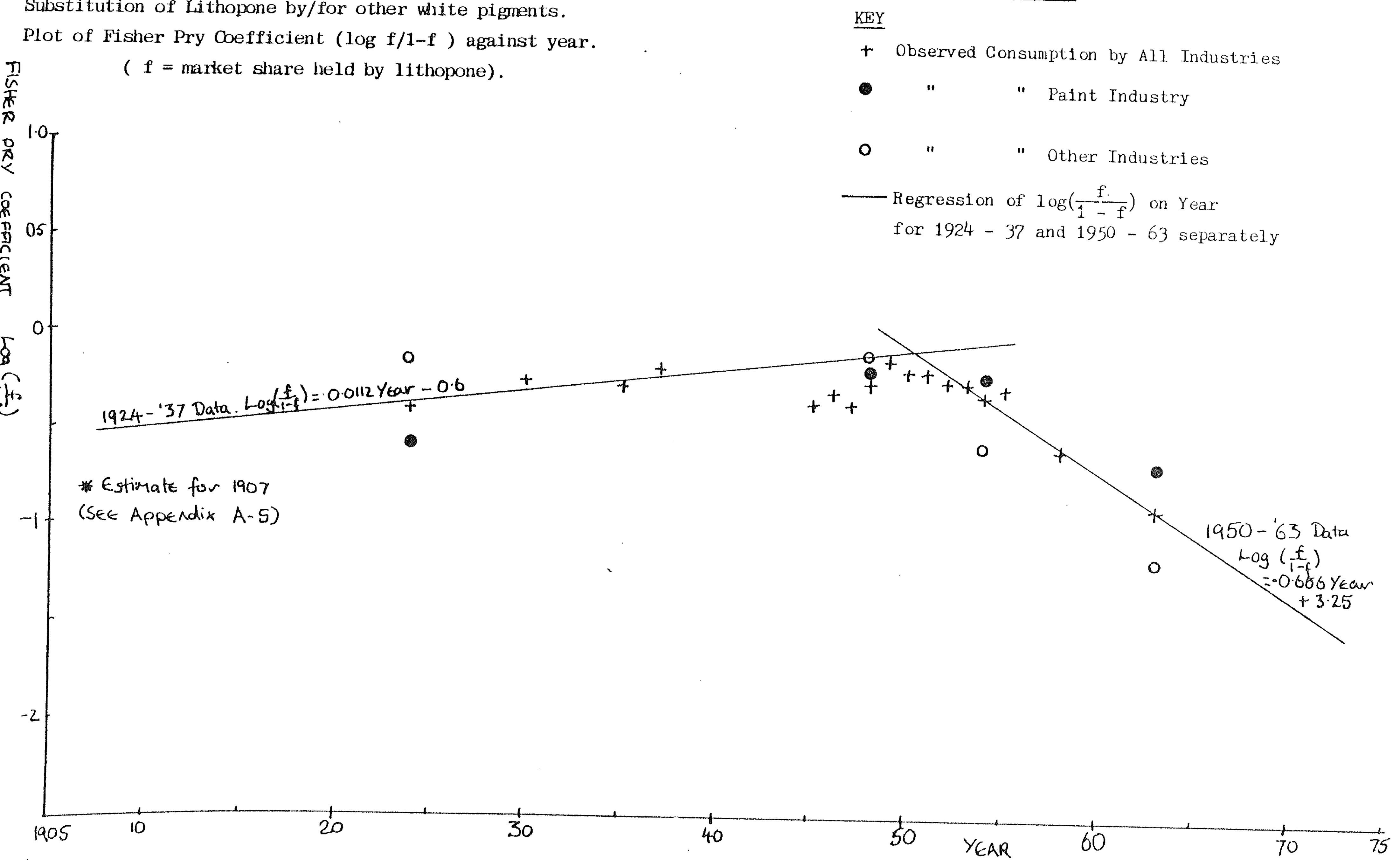
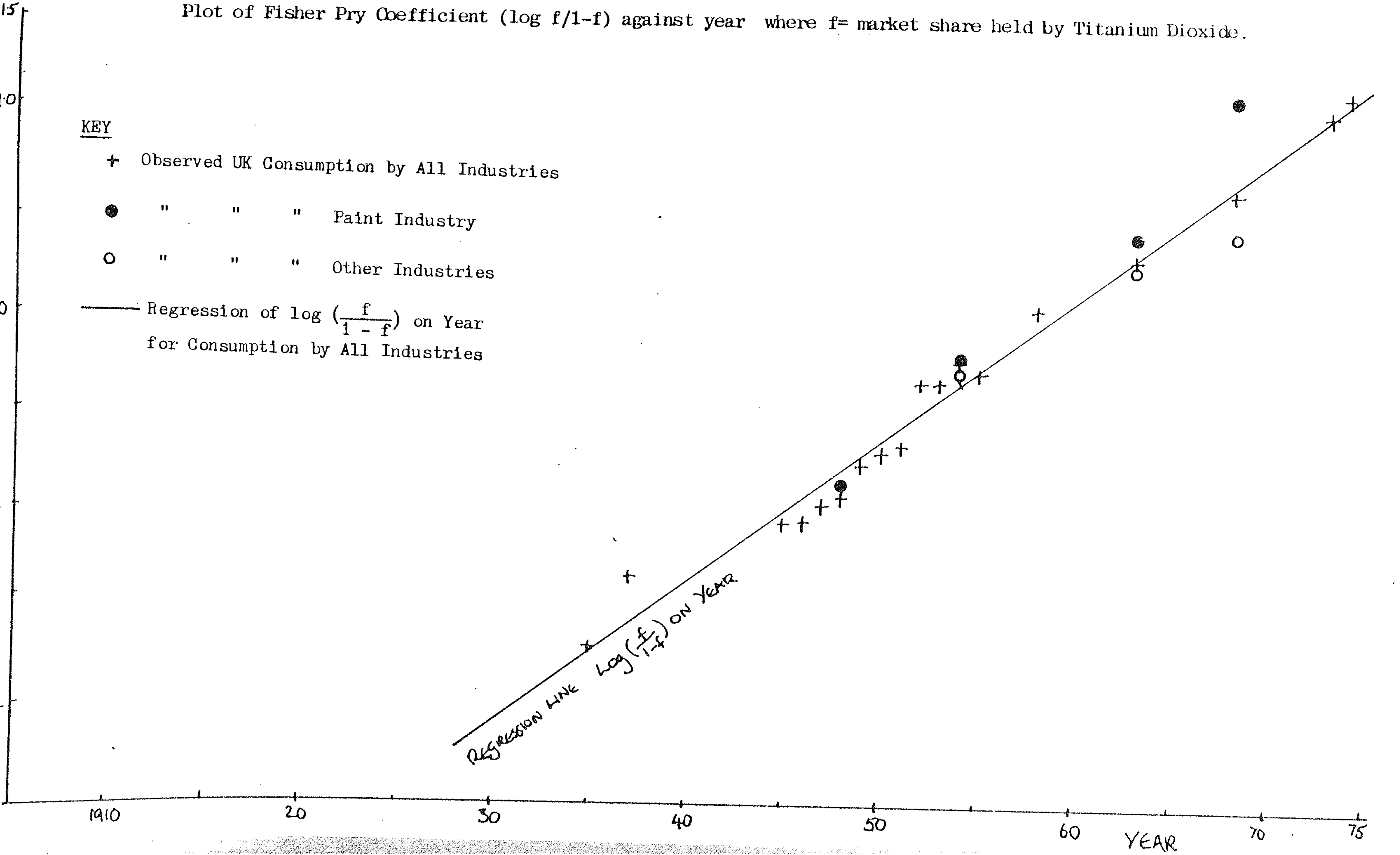


Figure 3-19: 'Fisher-Pry' Plot for Titanium Dioxide/White Pigment Consumption by All UK Industries, 1935-1974.

Substitution of other white pigments by Titanium Dioxide.

Plot of Fisher Pry Coefficient (log f/1-f) against year where f= market share held by Titanium Dioxide.



The Results of the Fisher-Pry Plots of Major White Pigment

Titanium Dioxide

i) The distribution of the 'Fisher-Pry' plot over time is remarkably linear. The correlation coefficient between log f/1-f and year is 0.9817 (R^2). The substitution rate is large and positive (i.e. market share is increasing rapidly): 0.0730 ±0.0002. It would seem that the entry of titanium dioxide on to the U.K. pigment market conforms closely to the Fisher-Pry model of competitive substitution.

ii) Substitution by titanium dioxide of other white pigments consumed in paint making appears to be significantly faster, with a substitution rate estimated graphically at between 0.09 and 0.1. (Conversely titanium dioxide penetrates the non-paint market more slowly).

White Lead

Though there has been a continuous reduction in the market share (f) and consequently the Fisher-Pry coefficient (log f/1-f) for white lead throughout the 1924-1974 period,this has not been at a constant rate.

A regression of log f/1-f on year for the 1924-1974 period has the following form:

$$\log f/1-f = -0.04355 \text{ Year} + 1.2548.$$

However residuals are autocorrelated, not randomly distributed around the regression line. The correlation coefficient (R^2) of log f/1-f and year is 0.869.

Examining the graph of log f/1-f against year, it is clear that there are two distinct periods of substitution.

Between 1924 + 1937/1945, displacement of white lead occurs slowly, with a substitution rate (estimated graphically) of -0.0198.

For the period 1945-1968, displacement takes place more than 2½ times as quickly, with a substitution rate of -0.0549

After 1968, the two available values for log f/1-f for 1973, 1974 are particularly low - which might indicate an even more rapid rate of displacement of white lead in this period. (Possibly linked to external influences, e.g. renewed concern about lead paint hazards, recent regulation of the lead content of paint etc.)

The pattern of consumption of lead in paint making deviates significantly from consumption by other industries, in this later period - displacement occurring more slowly in paint making, with substitution rate (estimated graphically from the 1948-68 period) at -0.039.

Zinc Oxide

i) As with white lead, the substitution rate of zinc oxide appears to change around 1945. In the 1924-1945 period the Fisher-Pry coefficient is more or less static (being slightly depressed in 1937 and slightly elevated in 1945-1947.

   In the 1945-1974 period, the Fisher-Pry coefficient falls from year to year, but does not have a linear distribution over time.

ii) This non-linearity appears to be a consequence of different rates of displacement of zinc oxide from the paint and non-paint market (with the former declining more rapidly than the latter). The rates of substitution of zinc oxide from the paint industry and from the non-paint industries in the 1948-1968 period appear to be constant (i.e. linearly distributed over time), and can therefore be estimated graphically as -0.0635 and -0.0208 respectively.

Lithopone

i) This also exhibits two phases, with slow growth in market share and Fisher-Pry coefficient in 1924-1937 being replaced by a rapid decline from 1949 onwards.

The changeover appears to take place slightly later in the case of lithopone (1948-1952) than for white lead (1945) and zinc oxide (1945-1947).

For the period 1924-1937 the substitution rate is estimated graphically as 0.0112.

For the period 1960-1963 the substitution rate is estimated graphically as -0.0656.

ii) Displacement of lithopone from paint making takes place more slowly than non-paint consumption.

The substitution rate for lithopone consumption by the U.K. paint industry can be estimated (from the figures for 1948-1963) as approximately -0.04 /-0.05.

The Significance of the Fisher-Pry Plots.
(i.e. the relationship between 'Fisher-Pry' coefficient and time)

It has been found that the changes in market share (f) of the major white pigments can be reduced to a set of linear changes over time in the 'Fisher-Pry' coefficient (log f/1-f). This fact does not validate a particular model for technological substitution - a variety of arguments exist to explain the sigmoid substitution pattern (and various sigmoid curves can be fitted adequately to the empirical data).[106] However this relationship provides a method of summarising pigment market behaviour, thereby facilitating a semi-quantitative assessment of the factors underlying that behaviour.

The reason for the change in slope of the Fisher-Pry plots (substitution rates) for lead and zinc pigments is clearly the exponential growth in titanium dioxide consumption, which establishes a market share of 10% after 1946 (and 20% by 1949).

At the same time, the price of titanium dioxide is dropping rapidly relative to other pigments (relative price is 2.2 in 1945, 1.4 in 1947 [below that of white lead] and 1.2 in 1950 [below that of zinc oxide]).

If price per unit of hiding power (rather than price per ton) is compared, titanium dioxide was cheaper from the outset than white lead and zinc oxide and became cheaper than lithopone in 1945 (although the price per unit hiding power for lithopone and titanium dioxide were very close during the 1938-1945 period). In addition, after 1945, titanium dioxide could be manufactured in its rutile form, which had a higher hiding power [approximately ten-fold of white lead as opposed to eight-fold with the earlier anatase form] and which (unlike anatase) was chalk resistant.

The combined effect of reduced price, improved properties and increased supply of titanium dioxide was to transform the competitive environment of the other white pigments, resulting in a change in the substitution rate of these pigments. The timing and extent of these changes allow an insight into the factors determining the market behaviour of the major white pigments - and in particular, pigment price, hiding power and other pigment properties.

Price, Hiding Power and other Pigment Properties as Factors Determining the Rate of Substitution (the slope of the Fisher-Pry plot) of the Major White Pigments

It has been concluded that the slope of the Fisher-Pry plot (log f/1-f against Year) provides a convenient method of summarising the rate of substitution of the major white pigments.

Differences in the substitution rate between pigments, before and after the advent of titanium dioxide and for consumption by the paint industry and other industries provide an opportunity to explore the role of the various factors determining the rate of substitution.[107] The first factors that will be examined are those of price and hiding power which together determined the pigment cost of producing a paint of given opacity. The role of other aspects of pigment performance and other factors will then be examined. The substitution rates are presented in Table 3.8 along with measures of price and hiding power. The rank order of each factor for the four pigments is recorded.

Following Mansfield and Swan[108] the substitution rate would be expected to be proportional to the competitiveness/expected profitability of the innovation relative to its predecessor - in this case a function of pigment price and performance in the paint industry and other industries. Hiding power and other aspects of pigment performance will be discussed later in this chapter.

Price and Hiding Power as Explanations of Changes in Substitution Rates

Price and hiding power would appear to provide a good overall explanation for the substitution rates of the major white pigments. However, these are notable exceptions, which would appear to indicate that other pigment properties may have been influential.

i) 1924-1945

The rank order of magnitude of substitution rates conforms to the inverse rank order of magnitude of price and price per unit hiding power, as would be expected.

TABLE 3.8. Summary Data on Pigment Properties and Substitution Rate

SUBSTITUTION RATE		White Lead	Zinc Oxide	Lithopone	Titanium Dioxide
Substitution Rate +	Pigment Consumption by all U.K. Industries 1924-1937 (+ 45). (Rank Order)	-0.020 (3)	~ 0 (2)	+0.011 (1)	-
	Pigment Consumption by all U.K. Industries 1945-1974 (Rank Order)	-0.055 (3)	-0.042 (2)	-0.066 (4)	+0.073 (1)
	Pigment Consumption by U.K.Paint Industries 1945-1974 (Rank Order)	-0.039 (2)	-0.064 (4)	-0.047 (3)	+0.095 (1)
Approximate Mid-point of Transition Period *		1945	1946	1950	-
Difference between Substitution Rates +	Pre-War All Industries - Post War All Industries	-0.035	-0.042	-0.077	-
	Pre-War Paint Industry - Post War All Industries	-0.019	-0.064	-0.058	-
	Post War All Industries - Post War Paint Industry	+0.016	-0.018	+0.019	+0.022
PIGMENT PROPERTIES					
	Hiding Power (Rank Order)	1 (4)	1.4 (3)	2 (2)	8 [10 rutile]
	Average Weighted Price 1924-1937 (Inverse Rank Order).	1.33 (3)	1.08 (2)	0.56 (1)	[2.5] 1935-7
	Average Weighted Price 1946-1963 (alternate years only) (Inverse Rank Order)	1.61 (3)	1.27 (2)	0.63 (1)	1.65 (4)
	Price per unit Hiding Power Average 1924-1937 (Inverse Rank Order)	1.33 (3)	0.77 (2)	0.28 (1)	[0.31] 1935-7
	Price per unit Hiding Power Average 1946-1963 (Inverse Rank Order)	1.61 (4)	0.91 (3)	0.32 (2)	0.21 [0.16 rutile] (1)

\+ The 'Substitution Rate' (ϕ) is the rate of change per year of the 'Fisher-Pry' Coefficient - Log (f/1-f) - where f is the share held by a pigment of the total white pigment market.

* The 'Transition Period' is the period in which the pigment substitution rate changed following the advent of Titanium Dioxide onto the market in significant volumes.

ii) <u>Timing of Changes in Substitution Rate</u>

The timing of the change in substitution rate (white lead before zinc oxide before lithopone) parallels rank order of price per unit hiding power of these pigments. (See Figure A-4) The price of titanium dioxide per unit of hiding power under-cut that of white lead and zinc oxide from its initial manufacture in the U.K. Lithopone was initially slightly cheaper, and the cross-over point takes place between 1937 and 1945. Lithopone experiences a later change in substitution rate than white lead and zinc oxide, which becomes apparent in the period 1948-1952.

iii) <u>1945/50-1974</u>

The substitution rate of titanium dioxide can best be explained by its very competitive cost per unit of hiding power.

However in this period, it might be expected that the increase in price/hiding power competition provoked by the arrival on the market of titanium dioxide would reinforce the differentials between the substitution rates of the other pigments observed in the 1924-1945 period (i.e. with white lead consumption falling most rapidly, and lithopone consumption falling least rapidly). Instead, the reverse is observed, with the biggest fall in substitution rate taking place for lithopone and the smallest in the case of white lead.

iv) <u>Differences between Pigment Consumption in the Paint and Non-Paint Industries</u> (1948-1968).

The differences between the substitution rate for pigment consumption in the U.K. paint industry and the non-paint industries can partly be explained by pigment hiding power. Lithopone and titanium dioxide have the highest hiding powers, and their substitution rates were more positive in the paint industry than non-paint industries. Zinc oxide had a more positive substitution rate for its consumption outside the paint industry (which can be related to its substantial use as a filler in rubber). Thus hiding power seems to have been a more important factor behind competitiveness in the paint industry than the non-paint industries.

The exception here is white lead, which had the lowest hiding power, but had a more positive rate of substitution (in this case a slower rate of displacement) in paint industry consumption than in consumption by other industries. There must be other properties of white lead making it more desirable in paint making. This will be discussed later.

Rate of Substitution for Pigments in Paint Making

The significant differences noted between pigment substitution rates in the paint industry and in all other industries are an important reminder that the Fisher-Pry model for technological substitution is dependent on the existence of a single market. The subsequent analysis therefore concentrates on the rate of substitution of pigments in paint making, for which information is available for the 1948-1968 period. (The substitution rate for pigment consumption in the U.K. paint industry is assumed to be the same as that for pigment consumption in all U.K. industries in the 1924-1937 period).

Figure 3-20 plots the rate of substitution of pigments in paint making for the two periods: (1, 1924-1945 and 2, 1948-1974) against pigment price per unit hiding power (relative to the most competitive pigment). This indicates two sorts of discrepancies from the pattern that would have been expected had price/hiding power been the only determinant of substitution rate.

i) <u>White Lead</u>. The impact of increased price/hiding power competition from titanium dioxide on the rate of substitution of white lead is significantly less than its impact on lithopone and zinc oxide (even though it was the least competitive in price/hiding power terms). This indicates that some other aspect of pigment performance was operating to protect white lead from the full force of price/hiding power competition. As noted above, this factor seems to have been operating only in the case of paint industry consumption of white lead.

ii) <u>Differences between the two periods</u>. There appears to have been a change in the relationship between substitution rate and price/hiding power competitiveness between the two periods (1924-1945, 1948-1974). In the 1948-1974 period, lack of price/hiding power competitiveness is associated with very rapid displacement from the market (very negative substitution rates), even in the case of lithopone (the cost per unit hiding power of which was 50-67% that of titanium dioxide).

In the 1924-1937 period, lack of price/hiding power competitiveness of zinc oxide and white lead relative to lithopone (36% and 21% that of lithopone) was associated with an approximately static consumption level and a moderate displacement rate respectively. In the 1924-1945 period, price/hiding power appears to be constrained relative to the 1948-1963 period.

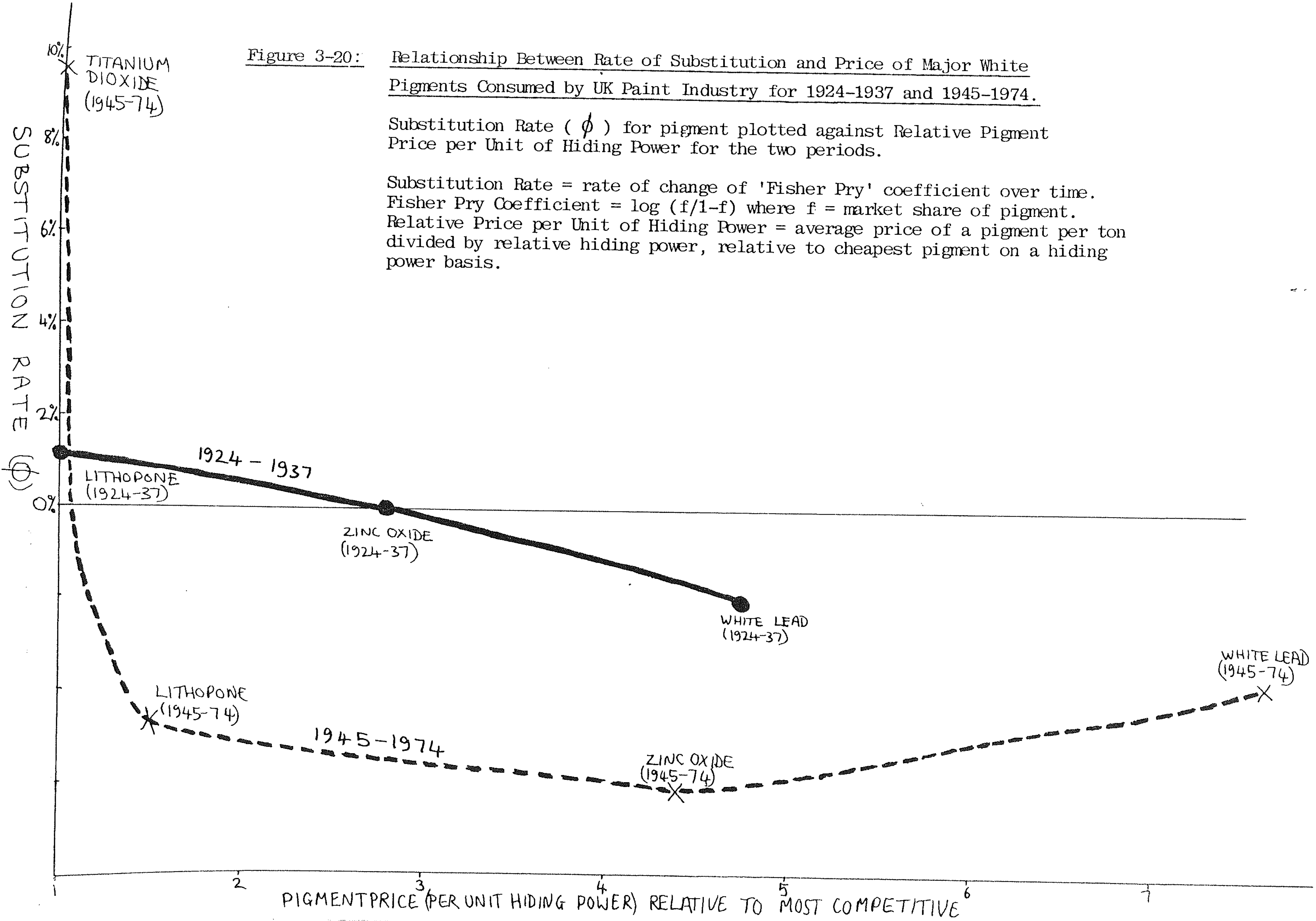


Figure 3-20: Relationship Between Rate of Substitution and Price of Major White Pigments Consumed by UK Paint Industry for 1924-1937 and 1945-1974.

Substitution Rate (ϕ) for pigment plotted against Relative Pigment Price per Unit of Hiding Power for the two periods.

Substitution Rate = rate of change of 'Fisher Pry' coefficient over time.
Fisher Pry Coefficient = log (f/1-f) where f = market share of pigment.
Relative Price per Unit of Hiding Power = average price of a pigment per ton divided by relative hiding power, relative to cheapest pigment on a hiding power basis.

Three types of explanation can be advanced for this discrepancy:

i) Price/hiding power competition is operating in this period but is offset by other aspects of pigment performance. It would appear that such a factor is protecting white lead consumption in paints in the 1948-1963 period, and this is likely also to have been in operation in the 1924-1945 period. To explain the behaviour of zinc oxide it is necessary to postulate that some other factor was serving to protect zinc oxide consumption from its lack of price/hiding power competitiveness in the 1924-1945 period, that became inoperative in the 1948-1963 period.

ii) The paint market is internally differentiated; and that lithopone, zinc oxide and white lead were not competing for the entire pigment market, but for specific sectors of it. For example it could be suggested that lithopone successfully dominated one particular segment of the paint market in 1924-1945 but was unable to compete (due to lack of other necessary pigment properties) in other sectors. The rapid displacement of other pigments by titanium dioxide could be explained in terms of its ability to compete in all sectors of the paint market, or changes in the internal structure of the paint market making it more homogenous, and giving greater weight to price/hiding power as the basis of paint competition.

iii) That pigment/hiding power competition is operating in both periods, but that there are strong constraints on the rate of diffusion/substitution in the 1924-1945 period, which disappear in 1948-1974. Such constraints could be related to user/customer acceptance, lack of knowledge/experience in formulating paints etc. from newer pigments, constraints on the supply of materials etc.

In practice these three types of explanation are inter-related, and elements of all three factors may be in operation.

Although an examination of pigment substitution and its relationship with pigment price (per unit hiding power) has pinpointed areas in which non-price factors appear to be operating, it does not indicate what these factors are. The nature of the non-price factors will become clearer in the light of an assessment of pigment properties, their role in paint performance and the pattern of pigment consumption in paint. This will be examined in the next section. The nature of non-price factors in the pattern of pigment substitution will then be reviewed.

First it is necessary to consider the validity of the methodology adopted and other methods that are available. Appendix A-5 discusses weaknesses of the method used in terms of the premises of the Fisher-Pry model (and variants of this).[109, 110, 111, 112, 113, 114, 115, 116, 117, 118]

An alternative method is presented of calculating the substitution process in terms of pigment consumption on a hiding power rather than a weight basis. A possible extension of this model for an international comparison of pigment consumption to determine the effects of regulation of white lead paint adopted in different countries. However the necessary data have only been obtained in the case of the U.S.A (which is discussed in Appendix A-6).[119, 120, 121, 122, 123]

The limitations of the Fisher-Pry methodology are discussed. In particular, it models technological substitution (i.e. pigment consumption) trends over time, which can then be related to other factors (in this case pigment price, hiding power and other aspects of pigment performance/ pigment utility). The method is relatively insensitive to minor discrepancies and short-term trends. Unfortunately, in the period in which such discrepancies might be expected to be observable in substitution rates (e.g. prior to 1930 due to changes in price relativities and concern about health hazards) data are sporadic. However estimates presented for 1924 indicate that the rate of pigment substitution probably altered in a manner consistent with the above findings. However it was not possible to chart these changes with sufficient accuracy to determine the precise timing, extent and causes of the changes (See Appendix A-5 in particular the footnote and Appendix A-7).

The Fisher-Pry method does not incorporate changes in product price and utility in its modelling of consumption. Other models of technological substitution were reviewed which incorporate into the modelling process changes in the price and utility of an innovation. It was found that their assumptions about the relationship between price and market share of a product did not conform with that observed for pigments. Drawing on these models, an alternative method of modelling market performance was outlined which incorporated the price, utility and acceptability of an innovation. However this model could not be applied to the present study because of data limitations and problems in identifying an expected or empirical relationship between price and market share of a pigment (discussed earlier). It was therefore concluded that the Fisher-Pry model was the most effective method available for analysing the changing pattern of pigment consumption in this study. However it was noted in the case of consumption of white lead for the years 1907 and 1924, the market share of white lead was significantly higher, given its price, than would be expected on the basis of the relationship between these two variables in the 1930-1948 period (which showed an approximately linear relationship). The form of the discrepancy could be seen as a reduction in the 'perceived utility' of white lead (due possibly to concern about, and regulation of, lead hazards, loss of preference for white lead and increased perceived utility of non-lead pigments due for example to improved knowledge about their incorporation into paints) as outlined in the alternative model. However this discrepancy might be greatly reduced or disappear if a non-linear or delayed relationship between market share and pigment price were assumed. It was not therefore possible to establish the validity of the model nor, with any certainty, the extent and timing of changes in the relationship between pigment price and market share or the reasons behind those changes. (See Appendix A-7).

It was notable that both methods of modelling pigment consumption had indicated a change in the pattern of pigment substitution, leading to a reduced propensity to consume white lead over time, in which both price and non-price factors were apparently implicated.

Pigment Properties and Paint Performance

The function of a pigment in paint is to obscure and decorate the underlying surface. In addition, the properties of the pigment in combination with the vehicle used may play an important role in determining the performance of the paint - both its ease of application and the durability of the cost of paint when it is applied.[125]

Pigment performance in particular its hiding power, and the ease with which it could be formulated into a durable paint, played a major role in the debate about the prohibition of white lead paint. In addition, these properties are of importance in the analysis of the relationship between price and market share of the major white pigments.

The performance of the major white pigments will be examined, dealing separately with the hiding power (which principally determines the quantity of a pigment required to make an opaque paint and the other pigment properties determining the quality of the paint and its suitability for different applications.

Because of the interaction between pigment properties and paint formulation in determining paint performance, changes in pigment properties and composition must also be considered in the context of change in paint vehicle and application technology.

Hiding Power

The American Society for Testing Materials has defined Hiding Power as "the power of a paint or pigment as used to obscure a surface painted with it".[126] As such, hiding power is a function of the colour and brightness of a pigment, particle size and refractive index.[127] Hiding power is a constant property of a pigment of given chemical and physical (crystalline state and particle size) composition.

However, as noted in Chapter 4, the hiding power of white pigments was a major source of dispute in the debate about prohibition of white lead. In particular during the 1911 Departmental Committee, witnesses presented contradictory opinions about the relative 'covering power' of white lead and 'lead free' pigments, which in turn affected the amount and therefore cost of pigment needed to paint a surface. The assessments made of hiding power of different white pigments at different times will therefore be examined.

Systematic Determinations of Hiding Power, 1922 to date.

Systematic attempts to determine the hiding power of the different white pigments became available in the early 1920s. This scientific/technical endeavour is specially relevant in the light of the growing use of a variety of white pigments, and to the increasing application of technology to paint formulation by paint making companies.

Table 3.9 lists a variety of determinations of the relative hiding power of white pigments (relative to white lead = 100) in the period 1909 to the present day.[128] The 1909 and 1914 figures are based on the practical experience of painting, whilst the later figures are based on systematic tests of paint/pigment samples.

The absolute values of relative hiding power of white pigments have varied considerably over this period. The rank order of the different pigments in hiding power terms remains largely constant.[129] The differences are thus of scale rather than relative performance. These differences it would seem derive mainly from different methods of measuring hiding power.[130]

The differences in method of assessment that can affect observed hiding power include the vehicle, and concentration of pigments used in the test,

TABLE 3.9. Estimates of Hiding Power of Major White Pigments 1909-1975 Relative to White Lead (= 100)

Year	Lead Sulphate	Zinc Oxide	Lithopone	Antimony Oxide	Titanium Dioxide	Source
1909		109-145[a]				J.C.Smith 1909, in T.Oliver, 1911 op.cit.[136]
1911		125[a]				P.Hasluck, cited in G.B.Home Department, [Cd.7882] 1915 op. cit. p.23.[135]
1922	75	115	125		500	R.L.Hallett, 1922, op.cit.[128]
1930	85	132	260		760	R.L.Hallett, 1930, op.cit.[131]
1931		176	233		956	G.S.Haslam, D.Gamble 1931, op.cit.[131]
1935a		180[c]	171	158	366	Electromechanical test, H.A.Gardner, op.cit.[129]
1935a		132[c]	131	134	256	Visual test, H.A. Gardner, op.cit.[129]
1949		177	228	194	960,[b] 1110	W.H.Madson, 1954, op.cit.[130] The source of these figures is not given, but may be G.S.Haslam, 1931.
1975		140	180		780,[b] 1000	Myers and Young, 1975, op.cit.[132]

NOTES

a. Figures refer to spreading capacity/power rather than hiding power. This appears to be a craft term, not in current use and not precisely defined. It may incorporate considerations of bulk as well as hiding power.

b. Figure relates to rutile form of titanium dioxide. Other figures for anatase form.

c. Figures specify American zinc oxide, made by the direct process and therefore containing up to 5% lead. 'Direct' zinc oxide has a higher hiding power than 'pure' zinc oxide made in the indirect process.

the surface being obliterated, the test of 'obliteration' (e.g. whether total or partial obliteration was examined) and the method of assessment of obliteration (whether measured by eye or by electro-mechanical devices). The role of these factors became understood around 1930.[131]

The assessments of the hiding power advantage of zinc oxide and lithopone over white lead have generally increased since the 1920s. The possible role of changes in the physical and chemical properties of pigments in this process will be examined.

The major improvements in pigment performance affecting hiding power, noted in the literature, are:

1) development of titanium dioxide in forms with higher hiding power - the original anatase form being replaced by rutile in 1941 and then by rutile made by the chloride process - increasing hiding power relative to white lead from 780 to 1000 to 1200[132] respectively.

2) improvements in the light fastness and 'brightness' of lithopone in the early 1920s (since early lithopone pigment would darken on exposure to light), and the production of grades of lithopone with greater proportion of zinc sulphide and consequently greater hiding power (about 15%).[133]

In addition, incremental changes were made in white pigment manufacture that could affect hiding power - primarily due to increased control over composition and particle size.[134] However there is little reason to believe that these changes differed between the different pigments, in a sufficiently marked and systematic manner to account for the scale differences noted earlier.

It can be concluded that, although it is not possible to fully distinguish the effects of changes in methods of assessment, the major changes in hiding power assessments in the 1930-1975 period are probably mainly a result of the former.

Though the improvement in the assessment of the hiding power of lithopone and titanium dioxide after 1922 may be partly attributable to changes in pigment formulation, it is less easy to explain the equivalent improvement in zinc oxide (and for that matter, lead sulphate) in this way. Both methods of assessment and pigment composition may be in operation here.

Determination of Hiding Power prior to 1922

Systematic assessment of hiding power from 1922 onwards all agree that zinc oxide and lithopone have a significantly higher hiding power than white lead. Prior to this period systematic definitions and determination of hiding power are little developed. It is useful to review the views of paint 'experts' of the time.

Hasluck (1911) stated that, to give coats of paint of equal opacity, zinc white has 25% more 'spreading power' than white lead. (i.e. by implication, hiding power is 25% greater).[135]

Cruikshank Smith (1909) produced figures showing that the 'spreading capacity' of a hundredweight of white lead is 600 to 800 square yards, as opposed to 870 for zinc white (i.e. zinc oxide).[136] Though it is not specifically stated that these applications are equally opaque, this appears to imply that zinc oxide has a hiding power of 1.09 to 1.45 times that of white lead. (N.B. the concept of spreading power may involve questions of bulk/density as well as opacity of pigments).

Petit (1907) states that the covering power of zinc white is "at least as good" as white lead, though he held lithopone to have much less covering power than white lead due to the high proportion of Barium Sulphate [it contains].[137]

Expert knowledge and assessment in this period were more ambiguous and contradictory than later systematic determinations. However, as will be seen in Chapter 4, a significant section of the 'paint trade' (including users, paint makers and material suppliers) giving evidence at Home Office Departmental Committees into the hazards of lead pigments claimed that white lead paint had a greater covering/hiding power than zinc oxide paints. This included a significant minority of witnesses at the 1911 Departmental Committee on the use of lead paint (Table 4.10) and the overwhelming majority of opinion at the 1893/4 Departmental Committee into the various lead industries (Table 4.6). At the 1921 Departmental Committee, hiding power was no longer a matter of dispute.

It has not been possible to find documentary evidence for changes over time or variability in the composition of pigments of sufficient magnitude to explain the view that zinc pigments had inferior hiding power to lead pigments in the period prior to 1921.

It would seem that these contradictory assessments of hiding power are a consequence of the predominance of craft knowledge and opinion, in the context of the limited development of systematic, scientific assessment of hiding power.

Scientific assessments of hiding power involved controlled tests of a defined property - the ability of a given weight of pigment (mixed into paint) to obscure the surface being painted. The craft knowledge of hiding power (or covering power, as it was then described) seems to have been based on the practical experience of using paints "on site", there was no standardised definition of the property being assessed. For example, in the evidence before the 1911 Departmental Committee covering power appears to relate to the opacity of a coat of paint 'as applied', without controlling the concentration of pigment applied to the surface (i.e. the thickness of the paint and the pigment concentration in the paint were not controlled). Thus Mumby, representing the Royal Institute of British Architects, stated that "the covering power of zinc (oxide-based paints) is worse, but its spreading power is better"(than paints based on white lead).[138] The specific gravities of white lead and zinc oxide are 6.7-6.9 and 5-6.1 respectively.[139] For the same weight, zinc oxide has a substantially greater volume than white lead, and requires a larger volume of linseed oil to produce a paint of the same consistency, (thereby producing a significantly greater volume of paint, which would cover a larger surface area but with a lower concentration of zinc pigment on the surface in terms of weight per area than white lead).

Mumby's statement would be compatible with current assessments of hiding power if he was referring to the covering power of a given volume of paint (rather than a given mass of pigment). - i.e. if zinc oxide's superior hiding power was offset by a reduced application density compared to the white lead used.

The hypothesis is examined in Chapter 4 that the disagreements between witnesses to the 1911 Departmental Committee regarding covering power arose because one group were defining this property on the basis of a given volume of paint, while the other were referring to a given weight of paint. For this to be an adequate explanation, there should be a comparable difference in evidence on other matters (e.g. regarding cost of paint or painting jobs) due to the use of assessments on a weight and a hiding power basis. Such a difference could not be detected and the hypothesis was rejected. It would appear that in the context of the lack of systematic assessment of hiding power, traditional preferences and self-interest played a significant role in the assessments of zinc oxide hiding power relative to white lead.

Changes in Paint Formulation and The Development of High Hiding Power Pigments

One of the major trends in paint/pigment technology was the development of high hiding power pigments.

As well as the economic benefits, there was a major technological pull from the industrial paint market (in particular vehicle painting). In the early 1920s, mass production had been associated with the adoption of spray painting using nitro-cellulose lacquers. High hiding power pigments were needed to give effective covering from the much thinner paint coats than were applied by hand painting/linseed oil based vehicles.

This led to initial demand for lithopone, and the marketing of high strength grades of lithopone (with a greater content of zinc sulphide), as well as acting as a stimulus to the development of antimony and titanium dioxide pigments. The existence of high hiding power pigments led to changes in the principles of formulating conventional paints - in particular regarding the use of extenders (low hiding power pigments). These were viewed as adulterants up to the 1920s-1930s. However to realise the economic benefits of the high hiding power pigments it was necessary to gain acceptance of the use of extenders. Composite pigments (blends or co-precipitates of extenders and high hiding power pigments) have a higher hiding and tinting power etc. than the high hiding power pigment on its own due to the "dilution effects". Thus 30% rutile titanium dioxide/calcium sulphate composite has a hiding power of 39% that of 100% rutile titanium dioxide although calcium sulphate on its own has little hiding power.

The economical, widespread use of titanium dioxide required a process of education of paint mixers about the role of hiding power and its control. The titanium dioxide manufacturers played a leading role in this process.[140]

Pigment Properties affecting Paint Performance and Quality

Hiding power determined the quantity of pigment used in paint. It is now necessary to consider those pigment properties which affected paint performance - the quality of the painted surface and in particular the durability of the coating. This was the major focus of the 'prohibition debate'. Since the (labour) cost of applying paint was twice that of the materials used,[141] anything that impaired the durability of the paint surface, and thereby necessitated earlier repainting, would have a disproportionately large effect on the total cost of painting.[142]

Different physical and chemical properties of pigments make them suitable for use in specific applications or with certain media. The various properties and uses in paints of the major white pigments are therefore reviewed, with particular attention to changes in opinion and practice in paint formulation in the Twentieth Century. Unless otherwise referenced, the source of this information is :

J.J.Mattiello (ed), Protective and Decorative Coatings, Vol.2 Raw Materials, Wiley, N.Y., 1942.

J.S.Remington and W.Francis, Pigments, their Manufacture, properties and use, Leonard Hill, London, 1954.

W.von Fischer (ed), Paint and Varnish Technology, Reinhold, N.Y., 1948.

White Lead

White lead is a basic pigment. It is sometimes described as an active pigment, in that it reacts with organic acid decomposition products in the vehicle and thereby toughening the coating and stoving vehicle degradation. In addition it was held to form soaps with fatty acids in the vehicle that imparted flexibility to the coat of paint. Its alkalinity conferred anti-corrosive properties when used on metal surfaces. White lead is a drier (it catalyses the oxidation/polymerisation of unsaturated fatty acids in 'drying oils'). In addition it promotes chalking (decomposition of the polymerised resin, at the painted surface provided in particular by ultra-violet radiation, leaving a 'chalky' layer of free pigment on the surface). This was held to be beneficial in some circumstances - for example American wooden houses painted with white lead were washed to remove the chalk and attached dirt, revealing a clean white surface - but could also be a detrimental (e.g. through accelerating decomposition of the film). Lead paints tended to yellow with age, due to continued polymerisation of the vehicle. This discolouration prevented its use in industrial baked finishes (stoving enamels), and, combined with the chalking property of white lead, prevented its use in gloss paints or enamels. At best, a semi-gloss finish was possible.[143] In addition, white lead was converted to (black) lead sulphide in the presence of hydrogen sulphide, leading to blackening of the painted surface, making it unsuitable for use in 'industrial' atmospheres.

The toughness and elasticity of paints made from white lead made it particularly suitable for protective paints (e.g. painting the exterior of buildings). It was held to be the only pigment that could be used successfully on its own for exterior painting (in a simple paint comprising white lead, linseed oil, thinners with the possible addition of drying agents).

The precise nature of the reaction between white lead and the vehicle (typically linseed oil) was the subject of considerable speculation. The proponents of white lead held that there was a particular affinity between the two materials. These arguments appear to date back to statements by the Belgian chemist Stas in the late Nineteenth Century. Stas held that "it is wrongly imagined that white lead is a mixture of paint powder with oil, and that consequently it is not possible to replace white lead by any other powder mixed with oil .... A portion of the lead hydrate and acetate in the dry white lead dissolve in the linseed oil". Lead paint consists of "particles of lead carbonate enveloped, even soldered together .... by the margarate of lead which imparts elasticity and opacity and the linoleate, especially, much impermeability to the coat".[144]

Although several aspects of this reaction have since been disproved,[145] the idea has continued as part of the basic principles of paint formulation.[146]

Zinc Oxide

Zinc oxide is a slightly alkaline, amphoteric pigment. In contrast to white lead it was originally held not to react with the paint vehicle, although such a reaction was held to be achievable by modifying the vehicle (by partial oxidation of the linseed oil).[147] However zinc oxide is currently described as an active pigment by virtue of its ability to react with the vehicle - indeed it was found unsuitable for use with the early synthetic resins because of their high acidity and consequent reactions with the pigment. The reaction of zinc oxide with the vehicle, and acid decomposition products from the vehicle is held to prevent yellowing of the paint film, and to yield a smooth, hard paint surface.[148]

Zinc Oxide has a stable colour and is not blackened by hydrogen sulphide. Its ability to absorb ultra-violet light at wavelengths destructive of organic resins reduced photodecomposition of the paint layer (i.e. chalking). This chalk-resistant property made it the preferred pigment for gloss paints and enamels (N.B. Prior to the Second World War the term enamel was used to describe a paint based on linseed oil supplemented with pine or other resin to improve film strength and water resistance. Enamels were used for marine paints and external painting, and were more expensive to produce and apply than conventional paints).

Critics of zinc oxide at the 1911 Departmental Committees on the use of lead paints alleged that zinc oxide had poor resistance to damp and industrial atmospheres, claiming that in the presence of sulphurous gases, the oxide would be converted to (water soluble) zinc sulphate, leading to dissolution of the pigment and breakdown of the paint film in moist environments (hence restricting the use of zinc oxide to the more expensive enamels).[149] Subsequently, opinion shifted full circle, and zinc oxide was held to be an essential component of paint for damp environments.[150]

Because of its ability to react with the vehicle, zinc oxide was subsequently used in varying proportions in paint to confer the following properties:

to aid mixing and grinding, consistency control, penetration control and sealing (i.e. primers and undercoats), to promote even drying and hardening the painted surface,

to improve moisture resistance, to minimise discolouration and improve tint retention,

to aid gloss and gloss retention and reduce chalking, though the precise chemistry of these effects was not completely understood. Zinc oxide also conferred mild fungicidal and rust protective properties to paint.

The production in the 1940s of zinc oxide in a partially crystalline ('acicular'), as opposed to amorphous form was held to improve the weathering resistance of a paint.

Until it was progressively displaced by titanium dioxide from the late 1950s onwards, zinc oxide was one of the chief pigments used in gloss paints and enamels, and as a component in industrial paints. Leaded zinc oxide was increasingly used for external and industrial paints.

Lithopone

Lithopone (and other pigments based on zinc sulphide) is neutral and does not react with industrial atmospheres (i.e. sulphur dioxide or hydrogen sulphide) or with the paint vehicle. The presence of traces of salts in early grades of lithopone could lead to reactions with the vehicle, creating a colloidal structure in the liquid paint known as bodying. This could result in deterioration of the paint. However, in the 1920s, improved control and analysis of lithopone consumption allowed the virtual elimination of these salts, or their restriction to a degree that was held to be desirable by producing a paint of thicker consistency.

The first successful application of lithopone was in water dispersed paints with albumin or glue 'vehicles' known as distempers (which accounted for 50% of U.K. lithopone consumption in 1921). The major outlet for this pigment continued to be for interior paints.[151] Early grades of commercial lithopone tended to darken in exposure to light - although this problem was overcome around 1920. Initially problems were experienced in formulating paints for external application from lithopone, but it was increasingly used (in combination with zinc oxide) in such paints during the early 1920s in the U.S.A.[152] It was subsequently judged that lithopone could be used successfully in exterior paints if, "as with all paint products, careful attention [is given] to the other ingredients."[153] The relative inertness and non-absorptive surface of lithopone allowed the preparation of stable ready mixed paints.

The high opacity of lithopone made it suitable for use in nitrocellulose lacquers for industrial spray painting - which was rapidly increasing in the 1920s and 1930s and created a market for high opacity grades of lithopone (with a higher zinc sulphide content).

Subsequently lithopone was increasingly used in the manufacture of enamels because of its "technical suitability" (fine particle size promoting gloss, stability), "economy in use" (its high hiding power allowed its use in combination with cheap extenders) and its "cheapness".[154] It was particularly used with synthetic resins (because of its inertness compared to e.g. zinc oxide).

Though the bulk of lithopone consumption continued to be used in interior and industrial paints, exterior uses in house paints and traffic paints are noted.

Antimony Oxide

Because of its high cost (exceeding that of lead and zinc pigments on a weight basis and that of titanium dioxide on a hiding power basis) paints based solely on antimony oxide did not achieve significant use.

Antimony oxide was instead used in combination with other pigments (at about 10-15% of total pigments) in many paints and enamels, to which it was held to impart durability, opacity, gloss, flow and to reduce flooding.

To overcome its tendency to attack by hydrogen sulphide yielding yellow antimony sulphide, antimony oxide was used in conjunction with (5%) zinc oxide.

Antimony oxide was also used (because of its slow rate of chalking, its good colour retention and it ability to reduce cracking of the film) in combination (15-60% of total pigment) with anatase titanium dioxide in spray paints and synthetic enamels for high quality car and industrial coatings. The introduction of rutile titanium dioxide, which overcame the problems of chalking and fading of the anatose form, largely eliminated this application. Latterly, attention has been focused on the use of antimony oxide to impart fire-resistant properties to paint.

Titanium Dioxide

As already noted the most notable property of titanium dioxide as a pigment was its exceptional hiding power. This was sufficiently great for the pigment to be used as a minority constitutent, in combination (by blending or co-precipitation) with lower hiding power pigments (barium and calcium sulphate, magnesium silicate, lithopone) and still retain a substantial hiding power advantage over other white pigments.

In addition, the chemical inertness of titanium dioxide made it suitable for use with a range of media and in chemically resistant paints.

The first titanium dioxide marketed was in the 'anatase' crystalline form. This was a photocatalyst and led to excessive chalking. Anatase titanium dioxide could not be used on its own with linseed oil, which slowed the adoption of this pigment. The chalking problem could be controlled by the addition of barium carbonate extenders, antimony oxide pigments, or by careful choice of resin.

After 1941 it became possible to produce titanium dioxide in its rutile form, which was chalk resistant.[155] Subsequently there were further developments in titanium dioxide to make it less surface active (e.g. coating the pigment surface with silica, alumina or titania since the 1950s). The bulk of titanium dioxide currently produced is surface coated. In this form titanium dioxide is held to confer durability to paints by its ability to absorb ultra-violet light.[156]

Thus titanium dioxide properties were extensively developed throughout its existence on the market. This stands in contrast to lead and zinc pigments which, after initial product improvements, became largely standardised (with no significant changes after the 1930s), and development being largely confined to process innovations.

The first successful applications of titanium dioxide were in paints where a minimum concentration of pigments was needed - NC lacquers, and high gloss enamels.

Its chemical and light stability facilitated its use in stoving enamels (industrial paints that were cured by baking)[157] both these based on vegetable oil, and the later synthetic resins.

Finally it began to be used in increasing quantities for ready mixed house paint, in conjunction with lead or zinc pigments. The post-war introduction of alkyd resins for housepainting in Britain paved the way for the more rapid introduction of titanium dioxide pigments in house paints.

Pigment Properties or Paint Formulation as the key to Paint Performance

The traditional view of paint performance and in particular durability saw this as very largely a function of pigment properties. Thus Stas in 1885 held that 'zinc white could not replace white lead for all purposes because of the nature of zinc white itself which is not in the power of man to change'.[158] The case for white lead rested on a 'particular affinity' between the pigment and the linseed oil vehicle which other pigments did not possess at all or to the same degree.[159]

Not surprisingly, in the debate about the possible prohibition of white lead paints, the 'white lead lobby' stressed the technical difficulties of eliminating white lead from paint. Though this appeal to the 'natural barriers' to prohibition had a strong tactical element, it also had a basis in the state of development of paint technology at the time.

The subsequent development of 'lead free' paints for various applications, and the eventual displacement of white lead pigment requires a re-evaluation of the role of pigments in paint performance. It is therefore necessary to examine the changing technology and principles of paint formulation during the Twentieth Century.

Currently, pigments are not seen as the determinant of paint performance/durability. The exception to this is the protective paints designed to inhibit corrosion of metal surfaces. Special chemically active pigments are used (including lead or zinc chromate and phosphate and traditional red and white lead pigments) for this purpose, and it is now thought that their protective function is due to increasing the pH at the painted surface.

From the point of view of paint performance/durability, the major developments in paint performance have been in the area of (resin) vehicle systems. (compare for example, Table 2.5 : innovations in vehicle systems and paint application technologies and 2.11 : innovations in pigments).

The developments in paint vehicle technology during the Twentieth Century described in Chapter 2, have included the development of more resilient resins (e.g. alkyds) based on traditional 'drying' systems and the development of new drying mechanisms (e.g. 2 pack polyurethane paints). The change from linseed oil to 'synthetic' resins has allowed more precise control of resin properties and the production of a range of resins geared for specific applications. In addition a range of additives have become available to impart particular properties to the paint/vehicle system.

The current situation can be compared to the state of paint vehicle technology at the turn of the century when the main vehicles available were linseed and other drying oils, possibly enhanced by addition of natural resins or partly polymerised/oxidised. There has clearly been a dramatic increase in the range and the control of vehicle properties.

The contribution of pigment properties to paint performance depends largely on the vehicle system used. The wide variety and tight control over vehicle properties allows them to be matched with the intended application of the paint and the properties of the pigment used.

For example, as noted above, zinc oxide and white lead pigments are active or basic pigments that can react with acid groups in the vehicle. There were problems in utilising basic pigments with the early 'synthetic resins' which had high acidity. Current resin systems are available with a range of 'acid values' that can be matched to the pigment properties. Indeed in the case of many of the newer resins (e.g. water-dispersed resins, thermoplastics) the acid value is not significant and they can be used freely with different pigments.[161]

The changed attitude to the contribution of pigments properties to paint performance clearly reflects the substantial development in paint technology involving a number of linked factors including :

- the availability of a range of pigments and vehicle systems with more precisely controlled properties
- better understanding of the principles of paint formulation linked to the development of systematic testing of paints and analysis of the chemical and physical processes involved in paint formulation and use
- particularly important in the latter was the emergence of specialised paint manufacturing firms, and the increasing use of 'ready made' proprietary paints.

Thus the change in thinking and increased understanding of the role of pigments in paint formulation was a product of the increasing development of paint technology which in turn was a consequence of developments amongst, and the interaction between, raw material suppliers and paint makers and users.[162] Many of these changes were beginning to appear in the first quarter of the Twentieth Century and coincided with the regulatory debate about lead paint.

With the benefit of hindsight a number of observations can be made about the basis of the traditional view of the contribution of pigment properties for paint performance, the belief in the superior performance of white lead paint compared to zinc paints, and changes in these views over the years.

At the time of the 1911 Departmental Enquiry there was considerable experience in formulating paints based on white lead (with linseed oils) and much less experience in the use of zinc pigments. Paints were predominantly mixed on site from raw materials by craftsmen. Due to the variability of raw materials it was not possible give "strictly definite proportions for producing perfectly good .... paint"; much depended on the skill of the practitioner.[163]

Many of the problems in performance of zinc pigments appear to have stemmed from the expectation that they could be used in the same way as white lead, without altering the formulation of the paint. For example Petit, describing the requirements of a paint, includes the property that it "ought to dry very rapidly without the use of driers" - a condition which white lead "fulfilled to a nicety".[164] This was not possible in the case of zinc pigments, which were not driers (unlike white lead), and more and different driers had to be used to make them into paints with linseed oil.[165]

Oliver (1911) noted that zinc oxide's lack of drying power could explain why "a painter accustomed only to white lead may fail with zinc oxide".[166]

It is interesting in this context to note that the crux of the minority report by Sutherland, dissenting with the recommendation of the 1911

Departmental Committee (which recommended the prohibition of white lead paint in painting buildings) and in particular his attack on the chief evidence of the feasibility of adopting lead free paints (the testimony of Patterson from the Office of Works), rested on this traditional conception of a paint as a "substance mixed from ordinary pigments to which are added oil and turpentine and dryers". 'Lead free', proprietary paints based on secret formulae and enamels and varnish paints (in which the drying oil was supplemented by addition of varnish or other resins) were not felt to be an adequate alternative to lead paints, even though their durability was not disputed.[167] The regulatory debate, and this particular episode are discussed further in Chapter 4.

Lack of drying power was not the only difference between zinc pigments and white lead. The lower density of zinc pigments meant that they required more oil on a weight basis than white lead to produce a paint of the same consistency - changes in the consistency of the vehicle would be needed to give a workable liquid paint with the same pigment concentration.

Failure to appreciate the changes required in paint formulation would appear to underly many of the problems in performance of early lead-free paints,[168] as well as the belief that zinc oxide did not react with the linseed oil. Thus Petit found that linseed oil and zinc oxide did not react, and just formed a simple mixture. However by special treatment of linseed oil (exposing to air or warming - which would lead to partial polymerisation of the oil) "it is possible to make .... a body with quite a peculiar affinity for zinc oxide".[169]

At the 1911 Departmental Committee, many of the proponents of zinc oxide drew attention to the need for changes in vehicle formulation to make durable paints.[170] This was associated with a growing appreciation of the importance of vehicles in paint performance. M. Toch in 1915 pointed to the lack of systematic research into the relative value of different vehicles compared to the frequent study and comment on the protective quality of the pigments.[171]

In the face of increasing experience of formulating paints around zinc pigments and their successful use in a range of applications (notably industrial paints and interior house paints), as well as the emergence of new white pigments, titanium and antimony oxide, there was a discernible shifting of ground in the arguments put forward by the white lead lobby. Thus Klein (chemist to the Brimsdown Lead Company) stated in 1922 that "all pigments have their definite limitations and are suitable for specific purposes". Elsewhere he states that "the idea today is not that any one paint is the most suitable for all purposes .... it would be sheer madness to use white lead in all circumstances".[172]

The white lead lobby conceded that zinc based paints might be adequate for indoor use, without exposure to excessive moisture or temperature but held that white lead was still needed for exterior paints, and in damp environments. The newer pigments (antimony oxide and titanium oxide) were seen for the same reason as posing a threat mainly to zinc pigment markets rather than white lead.

The belief that substitutes for white lead would not make durable paints, particularly for external application, was gradually eroded in practice over the next 20-30 years as paints based on zinc oxide lithopone and titanium dioxide were successfully used. The association between white lead and high quality paint was longer lived. Whilst some commentators, particularly those connected with the lead industry, continued to insist that the reduced use of white lead was at the expense of performance,[173] others have explained the continued attribution of quality and durability to the lead paints used in the 1920s and 1930s to the higher standard of craftsmanship of painters and better preparation of the surfaces to be painted at that time.[174]

The Pattern of Consumption of White Pigments Within the Painting Industry

Though quantitative data are not available on the pattern of consumption of the major white pigments in the different sectors of the painting industry, it is possible to outline the changes that took place on the basis of the overall pigment consumption data, information on pigment performance and paint applications, and general comments on this question.

A broad distinction can be made between three major types of paint application.

Industrial Paint for painting manufactured goods; within this, vehicle painting was a leading sector, both in terms of volume of paint used and technological development. Industrial paints comprised a small proportion of total paint consumption, (say 20-30%) at the turn of the century, but currently accounts for about half the paint used.

Paints for Buildings These are divided approximately equally between paints for exterior (and other environmentally hostile) applications, which are described as Protective Housepaints, and those for interior application, described as Decorative Housepaints.

Obviously there will be overlap between these applications e.g. similar enamel paints might be used in ship painting and the exterior and interior of buildings.

Estimate of Size of Sectors of Painting Industry

Currently, industrial paints account for about 50% of total paint sales, with the remainder divided approximately equally between decorative and protective paints.[175] The volume of paint consumed in these sectors of the painting industry can be estimated for earlier years on the basis of figures for numbers of painters employed (presented in Appendix B-6).

Prior to the widespread introduction of spray painting in industrial painting (which employed 8% of industrial painters in 1931 and 45% in 1951) the technology of paint application was substantially similar between industrial and housepainting - viz the application of liquid paint by brushing. It has been assumed that the volume of paint applied by a manual painter in housepainting and industrial painters was the same.

In 1921 there were 124,000 housepainters as opposed to 60,000 industrial painters. The latter include an estimated 8,000 decorators employed in industry to paint buildings. Transferring these to housepainters yields an estimate of around 28% of total paint consumption for industrial painting (i.e. industrial painters account for about 28% of all painters). The number of spray painters at this time was insignificant. (this estimate is applied to paint consumption in 1924)

In 1911 the number of housepainters was greater (160,000). Though the total number of industrial painters is not known, the number of ship and vehicle painters is marginally greater in 1911 than 1921. Assuming the number of other industrial painters changed to the same extent yields an estimate of total industrial painters of 52,800. This in turn yields an estimate of the portion of paint consumed in industrial painting of 25%. (In the same way, the industrial paint sector is estimated as accounting for 23½% of paint consumption in 1901).

For 1931, an estimate of low certainty can be produced using this method, of 31½% of paints for industrial use. This is based on an estimate of a 3.2 fold increase in productivity for spray painters over brush painters, derived from the reduction in painting workers as a proportion of all workers in shipbuilding and vehicle making between 1921 and 1931 associated with the introduction of spray paints. This method of estimation cannot be used for later years because of the large numbers of spray painters in industrial painting and the increasing volumes of paint purchased and applied by home occupiers after the Second World War.

For 1963 an estimate can be obtained from the Input/Output tables drawn up from the Census of Production.[176] These show that, of the output of the paint, varnish and printing ink industries, £48million was purchased by the construction industry, £26million by domestic consumers and £1million by public authorities. Consumption by other industries (excluding consumption in the metal can, board, paper products and printing industries which were presumably mainly printing ink) amounted to about £52million. This yields an estimate of 41% of the paint market being for industrial paints.[177]

The proportion of paints for industrial use has been estimated graphically, assuming additionally that most of the increase in paint consumption has been due to the growth in the industrial paint sector. This yields approximate estimates of the proportion of paints for industrial use of 24½% in 1907, 28½% in 1924, 36% in 1948 and 38% in 1954. The remainder has been assumed to be divided equally between decorative and protective paints.

Trends in pigment consumption in the different sectors of painting (industrial, decorative and protective) are estimated, from qualitative statements available and on the basis of technical considerations.

Industrial Paints

This sector was most advanced in terms of technological development of both materials and methods of paint application - particularly in the use of 'synthetic resins', stoving paints and spray painting from the early 1920s. Major developments in this sector were stimulated by the growth of mass production primarily in the vehicle industry.[178]

As noted above, white lead was not suitable for stoving paints. Nitro-cellulose etc. spray paints required high opacity pigments (initially lithopone/zinc sulphide and subsequently titanium dioxide and antimony oxide). The introduction of 'synthetic resins' in place of linseed oil eliminated the perceived advantages of using white lead. The desire for high gloss finishes, (other than by varnishing matt paints) for industrial products worked against white lead and in favour of zinc pigments. Thus all the developments in paint application and vehicle technology served to encourage the displacement of white lead pigments. In addition it was noted that concern about the hazards of applying lead paint by spray had discouraged vehicle manufacturers from using white lead.[179]

Though the bulk of industrial paints were based on white lead at the turn of the century (the major exception being enamel paints, particularly for marine applications), it would appear that the use of white lead pigment was largely discontinued between the 1920s and the Second World War, replaced by non-lead pigments.

The chief exception to this was in priming and anti-corrosive paints for which lead pigments continued to be used after 1945.[180] These were chiefly white lead, red lead and latterly, lead chromate, calcium plumbate. White lead primer was preferred for wooden surfaces - and its use in industrial painting would have been substantially curtailed by the transfer from wooden to metal products (e.g. car bodies). Red lead (and in the 1950s calcium plumbate) was the preferred primer for metal surfaces. The current consumption of lead pigment in paint (1500 tons) is believed to be consumed primarily in the shipbuilding and construction industries.[181] Less than half of this will be white lead,[182] which will mainly be used for wood priming (i.e. in the construction industry), although there is continued consumption of white lead (flake white) in artists' colours.

Decorative Housepaints

At the turn of the century these would primarily have been based on white lead. The exception was water-based paints. Low performance whitewashes based on lime and other extenders had traditionally been used. The introduction of lithopone led to glue and water-based paints with better performance, known as distempers; at least 6,000 tons of lithopone were being used in this way in 1921 for painting interior plasterwork.[183]

In the interwar years zinc oxide paints would have been used for gloss finishes on woodwork. Though the exact pattern of change is not known, there was an increasing use of lead-free pigments in interior painting such that, by 1930 paint films were less likely to contain substantial quantities of lead.[184]

By the time of the Second World War, lithopone was held to be widely used in other decorative housepaints (indeed its predominant use was in interior paints), both in undercoats and top coats.[185] In the following 20 years, titanium dioxide became the dominant pigment for both oil paints and the increasingly used emulsion paints.

Though a Departmental Health and Social Security investigation in 1980 was unable to determine how much leaded paint was currently used in domestic premises, it concluded that white lead was more likely to be used for exterior surfaces.[185]

Protective Housepaints

This was considered the most demanding application for paints, and one for which the use of lead pigments was held to be most necessary. At the turn of the century such paints would have been based on white lead alone. The interwar years saw the increasing use of zinc oxide and lithopone and latterly titanium dioxide in the formulation of protective housepaints. Such paints typically contained a mixture of pigments, often including white lead or leaded zinc oxide.

Whilst gloss and enamel paints were traditionally based on zinc oxide, the use of lithopone and titanium/extender combinations increased, particularly with the early synthetic resins.

The displacement of white lead from protective housepaints seems however to have been limited in Britain until after the Second World War, when anatase titanium dioxide began to dominate the pigment market, and when the rapidly increasing use of alkyd resins eliminated the basis of white lead's claim to confer durability to (linseed oil based) paints. The use of white lead paints became restricted mainly to primers for wood.[187] In 1968 the Paint Makers Association of Great Britain recommended its members to phase out the use of lead primers and reduce the lead content of protective and decorative paint (as a result of concern about the hazards to children). Faced with continuing public concern, and moves taken in the U.S.A. to ban lead based paints from the interior of dwellings, the Association recommended that the sale of proprietary lead based paints be discontinued by 1973 (Although members were permitted to make such paints for sale to the trade).[188]

An attempt will be made to reconcile the quantitative data on pigment consumption in paints with these general, qualitative observations about the pattern of pigment use in different types of paint and paint applications.

To illustrate the implications of the latter for the former, a set of estimates have been drawn up, showing how the consumption of major white pigments might be distributed across different sectors of painting.

Illustrative Estimate of how Pigment Consumption in Paints might have been allocated between different sectors of Painting

By making a set of 'realistic' assumptions about the structure of the paint market it is possible to map out the possible distribution of the major white pigments into the different sectors of painting (industrial, decorative and protective paints). This has been carried out for the years 1907, 1924, 1948. The assumptions are as follows:

1) there is no set of figures for paint industry consumption of major white pigments in paints in Britain prior to 1924. However for 1907 consumption of white lead, zinc oxide and lithopone (estimated) in all U.K. industries was 34, 10 and 6½ thousand tons respectively. 95% of white lead was consumed in paint making in 1910. (See Appendix A-1 and A-5, footnote) and this proportion has been assumed to be applicable for 1907 (i.e. approximately 32,000 tons). A similar proportion of zinc oxide has been assumed to be consumed in paint, since by this stage the main alternative use of zinc oxide in rubber had not been significantly developed (i.e. 9,500 tons). Lithopone consumption in paint has been assumed to be 5,000 tons since there was a significant alternative outlet (linoleum) at this time. For subsequent years the figures for pigment consumption by the U.K. paint industry from Appendix A-2 (Table A.10) have been used.

2) In line with the statements made above, it is assumed that the substitution of pigments has had the following pattern of changes between successive periods:

1907 - Lithopone is assumed to be used solely for interior decorative paints - primarily distemper.

- Zinc oxide, as the basis of enamels, is allocated across all sectors.

1924 - the increase in lithopone consumption is allocated to decorative and industrial paints. The increase in zinc oxide consumption is allocated mainly to industrial paints followed by protective. Lead is displaced least from protective paints.

1948 - Lithopone and titanium dioxide are assumed to have made their greatest penetration of the industrial market, while zinc oxide achieved significant use in protective paints.

1954 - Titanium dioxide has expanded at the expense of zinc oxide and white lead. The position of lithopone is broadly static.

1963 - The above process has continued, and lithopone has also been displaced by titanium dioxide.

Once a pigment has been substituted by a newer pigment it is assumed that the process is not reversed. It is assumed that trends established in earlier periods continue in later periods.

An estimate of the consumption of the major white pigments was obtained in the following manner:
Changes in the consumption of each pigment were distributed to the different classes of paint in accordance with the above set of statements. To gain some corroboration of these estimates, the total pigment consumption in each sector of painting was then calculated. The original allocation was then adjusted to bring these two sets of figures in conformity with each other.

Two sets of estimates were produced. The first assumes that the tonnage of white pigments consumed by each sector of the paint market is proportional to that sector's share of the paint market. The results are given in Table 3.10.

TABLE 3.10. Estimated Consumption of Major White Pigments in Different Classes of Paint (thousand tons) 1907-1963

Adjusted so that combined weight of pigment consumed in each sector of painting is proportional to the size of that sector.

Year	Class of Paint	Total White Pigments	White Lead	Zinc Oxide	Lithopone	Titanium Dioxide
1907	ALL	46½	32	9½	5	-
	Industrial (24½%)	11½	8	3½	0	-
	Decorative	17½	9½	3	5	-
	Protective	17½	14½	3	0	-
1924	ALL	53½	23	19	11½	-
	Industrial (28½%)	15½	5	7½	3	-
	Decorative	19	5½	5½	8	-
	Protective	19	13½	6	½	-
1948	ALL	83	15	24½	33½	10
	Industrial (36%)	30	1½	9½	13	6
	Decorative	26½	1½	7	16	2
	Protective	26½	12	8	4½	2
1954	ALL	77½	10	7	30½	30
	Industrial (38%)	29½	1	3	12	13½
	Decorative	24	1	2	15	6
	Protective	24	8	2	3½	10½
1963	ALL	79½	4	3	14½	58
	Industrial (41%)	32½	½	1	3½	27½
	Decorative	23½	½	1	9	13
	Protective	23½	3	1	2	17½

It is notable that the weight of pigments consumed in all sectors of the paint market falls between 1948 and 1954. In fact the volume of paint probably increased because of the much greater hiding power of titanium dioxide. Since the estimate of the size of the sectors of the paint market primarily reflects volume of paint consumed a more realistic estimate of pigment consumption can be obtained if the above exercise is carried out using the number of hiding power units of pigment consumed in paint (rather than the weight) of pigment. The consumption of pigment was therefore converted to the equivalent hiding power that would be obtained from one thousand tons of white lead. The same method of estimating was applied, and the results are shown in Table 3.11. This gives slightly different results to Table 3.10. In particular, the 'hiding power' based estimates necessitate the conclusion that consumption of the higher hiding power pigments is more evenly distributed across the different sectors of the paint market. This is particularly significant in the case of titanium dioxide after 1948 because of its much greater hiding power .

The best estimate probably lies somewhere between the two sets of figures. The estimates presented are admittedly speculative. The method of corroborating/adjusting these estimates does however enhance the confidence of the results.

The main concern here is the distribution of white lead into the different sectors of the paint market. The method of corroboration is not very effective in confirming the estimate of allocation of white lead in later years (i.e. after 1948). However for the changes that take place between 1907 and 1948 this method gives some assurance of the validity of the estimate.

TABLE 3.11. Estimated Consumption of Major White Pigments in Different Classes of Paint (thousand tons) 1907-1963

Adjusted so that combined consumption of pigments in hiding power units (pigment weight x relative hiding power) in each sector of painting is proportional to the size of that sector.

Year	Class of Paint	Total White Pigments	White Lead	Zinc Oxide	Lithopone	Titanium
1907	ALL	46½	32	9½	5	
	Industrial		9½	3½	0	
	Decorative		6½	3	5	
	Protective		16½	3	0	
1924	ALL	53½	23	19	11½	
	Industrial		3½	8½	2½	
	Decorative		3½	4 1/4	8	
	Protective		15	6 1/4	1	
1948	ALL	83	15	24½	33½	10
	Industrial		2	9	8½	5
	Decorative		2	5	18½	2
	Protective		11	10½	6½	3
1954	ALL	77½	10	7	30½	30
	Industrial		1	2 3/4	8	13½
	Decorative		1	1½	18	6½
	Protective		8	2 3/4	6	10
1963	ALL	79½	4	3	14½	58
	Industrial		½	1	4	24½
	Decorative		½	1	7½	16½
	Protective		3	1	3	17

The pattern of consumption of white lead in different classes of paint

Whilst white lead was the major pigment used in paint at the turn of the century - in all sectors of painting, in the first half of the Twentieth Century it begins to be displaced from industrial and decorative paints by zinc oxide, lithopone and latterly titanium dioxide. This process is detectable by 1907, is well advanced by 1924, and is virtually complete by 1948. The consumption of white lead in protective paints shows a somewhat different pattern, retaining a substantial share of this sector prior to the Second World War. It is only displaced to a minor degree by zinc oxide and lithopone. The substitution of white lead from protective paints takes place to a significant degree in the post-war period in the face of competition from titanium dioxide. The inescapable conclusion from this review of the literature on paint consumption, and illustrated by the set of estimates above is that by the time of the 1921 International Labour Convention, the use of white lead paint for interior decoration must already have been substantially discontinued.

Assessment of Non-Price Factors in the Pattern of Pigment Consumption in the Paint Industry

The role of hiding power in the pattern of pigment substitution has already been examined. It was possible to account for the rate of pigment substitution (in the Fisher-Pry plot) in terms of the price of pigments per unit of hiding power (as opposed to price per ton). Four major anomalies were found to the expectation that lack of price/hiding power competitiveness would be associated with a large, negative substitution rate, namely that :

1) in the 1924-27 period the rate of displacement of white lead was slow despite its lack of competitiveness relative to zinc oxide and lithopone.

2) in the 1924-37 period, zinc oxide consumption did not fall rapidly despite its lack of price/hiding competitiveness relative to lithopone.

3) by the same token, in the 1924-27 period the rate of adoption of lithopone was slow despite its price/hiding power advantage (in comparison to titanium dioxide in the 1945-74 period, which had a similar price/hiding power advantage, but had a more rapid rate of adoption).

4) the rate of displacement of white lead in the 1945-74 period was slower than that of zinc oxide, and lithopone in particular, although it was the lest competitive in cost/hiding power.

Three possible explanations were suggested for these anomalies - the influence of other aspects of pigment performance, internal differentiation in the paint market, and structural constraints on technological change in the 1924-37 period which largely disappear in 1954.

Consideration of pigment properties and applications throws light on each of these anomalies, which will be discussed in turn.

1),4) <u>White Lead 1924-37, 1945-74</u>

White lead was widely perceived as having properties that discouraged its displacement in particular for protective paints by non-lead pigments. White lead did yield durable paints with linseed oil - partly because of the properties of this pigment and partly because there was greater experience of formulating effective paints from these materials. Knowledge of vehicle properties and paint formulation was more developed for white lead than 'lead free' pigments, and non-lead paints required more complex formulation (e.g. mixtures of pigments, modified resins and driers from the traditional system).

In decorative paints, where durability was a less significant factor, and in industrial paints, where changes in vehicle composition and application technologies made white lead unsuitable, white lead was rapidly displaced prior to the Second World War - in conformity with its higher price per unit of hiding power.

The retention of white lead in protective paints in the 1924-37 period can be attributed to its advantageous properties, in the context of knowledge about paint formulation. This advantage was largely eliminated by changes in the resins used in protective paints in post-war Britain (the post-war introduction of alkyd, gloss paints). The continued preference for white lead in this period can partly be attributed to the residual use of linseed oil resins, but must also be a result of a traditional preference for white lead (i.e. not underpinned by 'real' technical considerations). This is confirmed by the frequent references to 'prejudice' in favour of white lead throughout this period, amongst both painters and consumers. White lead paint was associated with quality and its use was institutionalised (e.g. leases often stipulated the use of white lead protective paints as did local authority contracts).[189]

2) Zinc Oxide, 1924-48

The largely static market share of zinc oxide between 1924 and 1948 would appear to be a result of its displacement of white lead, which can be traced back to the turn of the century for applications which lithopone was not competing (i.e. industrial enamels, and protective paints based on leaded and 'acicular' zinc oxide). Zinc oxide was displaced by lithopone where it could be successfully applied (e.g. interior paints and latterly some industrial paints - e.g. spray paints).

3) Lithopone 1924-37

(In comparison to titanium dioxide 1945-74) - the growth of lithopone during this period appears to have been largely limited to decorative and some industrial paint applications - i.e. it was not competing across all sectors of the paint market. However, market differentiation alone cannot fully account for all the difference between substitution rates. If the estimates for behaviour of different sectors of the paint market are correct, the rate of substitution of lithopone for other pigments in industrial and decorative paints (ϕ in the Fisher-Pry plot) between 1907 and 1948 is almost twice the rate of substitution by lithopone in the pigment market as a whole (0.018 cf 0.011) in the pre-war period. However this is still less than a quarter of the substitution rate for titanium dioxide in paint in the post-war period.

This would appear to indicate that there was indeed an increase in the sensitivity of the paint market to competitive (in terms of price/per hiding power) substitutes between 1924-37 and 1945-74. This increase could be attributed to a range of linked factors:

- in the 1924-35 period 'conservatism' towards new pigments deriving from : limited knowledge about formulating paint, in turn a product of the dominance of craft ideas /practice and the limited scientific development of the paint industry; association of traditional methods with high quality/performance.
- in the 1945-74 period there were widespread changes in vehicle composition, and increased development of the technology of paint formulation, which reduced the barriers to utilising new materials. Moreover, titanium dioxide was largely displacing non-traditional pigments - in particular lithopone and zinc white - for which traditional preference had not been established.

It can be concluded that the substitution rate for the different pigments can be explained primarily by the price of the pigment per unit hiding power. The variations in substitution rate (between pigments and at different periods) from this model can be accounted for in terms of pigment properties and application in paint, knowledge about formulating paint, introduction of new resin systems, and attitudes by painters and paint consumers to the different pigments.

CHAPTER FOUR

THE HISTORY OF REGULATION OF WHITE LEAD PAINT I

POLICY FORMATION

Introduction and Brief Overview

The next two chapters document and analyse in detail the history of regulation of white lead paint. Chapter 4 examines the period up to 1921 which was primarily concerned with regulatory policy formation. This account focuses on the role of medical-scientific, economic, technical and administrative factors, and the positions of the different parties in this highly polarised regulatory debate. This debate progressed through two government enquiries and an international convention as well as public fora. Chapter 5 examines the subsequent deliberations leading to the implementation of a particular regulatory strategy. The main arena of action is the state political and administrative apparatus with divisions within the state, of policy, function and relationship with the various affected parties playing a major role in developments.

The separation between these two phases is made on the basis of chronology and the arena of discussion. Notwithstanding this separation, the processes of policy formation and implementation are in reality interpenetrating. The analysis will be conducted in extreme detail. To assist the reader in following this discussion, an overview of the different phases in the development of regulation of lead paint hazards is presented in Table 4.1.

Though the major concern of this account is the promulgation and subsequent rejection of proposals to prohibit the use of white lead in paints, the development was based on previous experience of regulating lead processes. It is useful therefore to start with a brief examination of the pattern and form of regulation of occupational lead (and particularly pigment) hazards in Britain.

TABLE 4.1. Main Phases in the Development of Regulation of Lead Paint Hazards

1. The Nineteenth Century

A government Departmental Committee on lead industries, which touched briefly on hazards to painters from white lead (but rejected prohibition of white lead because of the lack of efficaceous substitutes), concentrated mainly on controlling hazards of white lead production. A control strategy, developed through regulation of the white lead and pottery industries, was extended to other factory based lead processes.

2. 1900-1914

International concern about lead poisoning amongst painters led to the appointment of twin Departmental Committees in 1911 to investigate the danger to painters from painting buildings and vehicles (and other industrial products) with lead paints. These eventually recommended the prohibition of white lead paint. The First World War interrupted this movement for prohibition.

3. 1921- the post-war situation

Wartime shortages had led to use of lead substitute paints, with mixed results. In response to a movement, lead by the White Lead Corroders (manufacturers), against prohibition, a further government committee of enquiry was appointed in 1921. In the meantime, the government had been party to the International Labour Convention in 1921 which recommended a compromise solution of prohibiting interior use of lead paints, but allowing their use for exterior painting (subject to hygiene precautions). This compromise was accepted by the government enquiry.

4. 1923-1926

Vigorous representation between different affected parties and the Home Office (and other government bodies) took place over a number of years. Draft legislation to enact the International Labour Convention was introduced but not completed. As the deadline for ratifying the Convention approached, the Lead Paint Act and Regulations were introduced that did not prohibit the use of white lead, but merely laid down hygiene precautions to be adopted. Similar Regulations were introduced in vehicle painting etc.

5. 1927 onwards

Though the Lead Paint Act was seen as an experimental measure, its introduction preceded a fall in the incidence of lead poisoning amongst painters, and the movement for prohibition died down.

The Pattern of Regulation of Lead Hazards

Lead processes were one of the first areas of occupational health hazard to be regulated, with initial controls established before general legislation on occupational hazard existed.

Whilst the first general legal provision for occupational health (ventilation where dust was generated to an injurious extent) for all factories was established by the 1879 Factories Act, specific precautions had already been required for white lead manufacture (the employment of women forbidden by the 1878 Factory Act) and in potteries where lead glaze was used (taking of meals in drying shops prohibited under the 1864 Factory Act).[1]

Further requirements were introduced for white lead plants, paint and colour works and potteries in the Factories Acts of 1879, 1882 and 1883 (mainly regarding meal and washing facilities). The 1883 Act required occupiers of white lead factories to draw up Special Rules for the conduct of their business for approval by the Home Office.[2] In 1891 these were replaced by Special Rules drawn up by the Home Office under powers in the 1891 Factories Act to regulate dangerous trades. Further Special Rules, passed during the 1890s, covered most lead processing operations in factories - including the manufacture of lead paints and colours. Paint-using industries were not covered by these Rules.

Between 1903 and 1913 these Special Rules were updated and replaced by Regulations[3] (except in the case of white lead which was not amended until the 1921 Lead Compounds Manufacturing Order).

Paint use did not come under specific Regulations until the 1926 Vehicle Painting Regulations and the 1931 Shipbuilding Regulations. House painting could only be covered by Regulations in 1927 after the 1926

Lead Paint Act extended the coverage of the Factory Acts to include the painting of domestic premises.

The pattern of Regulation of the various lead using industries and processes is shown in Table 4.2. [4, 5]

This pattern of introduction of Regulations for both paint and non-paint lead processes can be related to administrative considerations and the extent and nature of the hazard involved.

1. <u>Administrative Factors</u>

The industries covered by Regulations under the 1901 Factories Act, between 1900 and 1921 had (with the sole exception of filecutting) been previously subject to the Special Rules passed between 1891 and 1899 under the 1891 Factories Act. The various lead industries that were not covered by Special Rules either did not become subject to Regulations or were covered substantially later than those which had been subject to Special Rules. It thus seems that the existence of previous statutory control facilitated the introduction of Regulations (compared to regulating 'from scratch'). The other major administrative factor was the exclusion of house painting from the coverage of the Factories Act (and consequently from inspection by the Factories Act as well as the compulsory notification of cases of lead poisoning required under the Factories Act of 1895).

2. <u>The Extent of the Hazard</u>

There is a relationship between the industries which were subject to Special Rules and Regulations and the number of deaths from lead poisoning (available only since 1900; shown in Table 4.2. for the 1900-1913) period).

Thus in the period 1900-1913, in 5 industries not subject to Special

NOTES TO TABLE 4.2.

1. Inspectors have had power since 1879 to require fans where dust is generated to an injurious extent, and since 1895 similar power regarding fumes. Washing conveniences have been required since 1896 where lead is used. Messrooms and exclusion from workrooms during mealtimes have been required since 1901 where lead is so used as to give rise to dust or fume. The Women and Young Persons Order 1921 prohibited the employment of such workers for certain lead industries and certain processes (unless prescribed controls were enforced) using lead compounds (even those not in factory premises). Section 58, 59.
The Lead Processes (Medical Examinations) Regulations 1964 stipulated the use of Haemoglobin estimation in medical examinations of lead workers under existing Regulations.

2. Employment of workers under 18 prohibited from 1879, taking of meals in workrooms prohibited from 1882.

3. Taking of meals prohibited in dipping department (1879) and majolica painting (1882)

3a. (1864) Factories Act forbad meals in lead glaze drying shop.

4. (1864) Factories Act forbad meals in places where dry powder or dust is used from 1882.

5. The 1904 Electric Accumulator Regulations were updated in 1925 and the 1922 Indiarubber Regulations were updated in 1955.

6. Interior spraying of lead paint prohibited by Shipbuilding Regulations 1931.

7. The Lead Compounds Manufacturing Order 1821 required control of the manufacture and handling of lead compounds, and in particular white lead. Control included damping dust or ventilation as well as washing and meal facilities and medical examinations.

Sources:

G.B.Home Department [Cd. 7882] 1915, op.cit. p.76 [4]

Fife and Machin, 1966, op.cit.[5]

A.Redgrave [C. 4362] 1882, op.cit.[1]

Rules and Regulations, 59 deaths occurred (11.8 per industry). In the same period, in industries subject to Special Rules and Regulations, 7 non-paint industries had 154 deaths (22 per industry) and the 3 paint/pigment making industries had 46 deaths. (15 per industry). The reduction in lead poisoning that can be observed following the regulation of these industries, compared to the relatively static poisoning levels in non-regulated industries, indicates that this relationship must have been much stronger during the 1890s.

The major exception here is the paint using industries, which were not regulated under Special Rules, and only subject to Regulation after 1926, which had 134 deaths per industry group. (37 excluding house painting).

Reasons for the exceptional treatment of Paint Using Industries

This exceptional (non) treatment is unsurprising in the case of house painters (who were outside the scope of the Factory Acts).

The exceptional treatment of industrial users of paint would appear to derive from the fact that they were not scheduled as dangerous trades (and therefore open to regulation by Special Rules) by the Home Secretary in 1891 (in contrast to white lead, paint and colour manufacture). Nor did the subsequent Departmental Committee on the Various Lead Industries 1893/4 recommend their inclusion.[6]

The omission of industrial painting can be attributed to the dispersed nature of the activity (the above enquiry focused in contrast on specific lead using industries) and to the lack of systematic information about poisoning. Though Departmental Committees were established to enquire into industries 'known or surmised' to be unhealthy,[7] systematic information on the incidence of lead poisoning was not, at that time, available.

Systematic notification of the numbers of cases and deaths from lead poisoning in various industries became available on a systematic basis from 1900 (see Chapter 6 for a discussion of their validity). These are shown in Figures 4-1 and 4-2, distinguishing poisoning amongst paint users, paint and pigment makers and other lead industries. They reveal that paint use was the major single cause of paint poisoning and fatalities.

An examination of figures for lead poisoning from 1898 to 1902 reveal that prior to 1900, the major sources of poisoning were potteries and white lead manufacture.[8] (See Table 4.3)

The number of cases of lead poisoning fell very sharply between 1898 and 1902 in these industries. Since no comparable fall could be noted amongst paint users, these moved from being a relatively minor to a major contributor to total lead poisoning.

Thus it could be argued that the need to regulate the hazards of paint use was only apparent after the successful control of the hazards of pigment and paint manufacture (and other non-paint uses of lead), which left paint use as a major cause of lead poisoning.

However it is suggested that another factor may have been operating. In the absence of national notification of poisoning cases (prior to 1906), relative risk, and the medical career of individual workers would adopt a greater significance in the assessment of harm, and thus the political process of regulation of hazard.

Table 4.4 shows the incidence (per thousand workers per year) of fatalities and cases of lead poisoning for the 1900-1913 period in various industries.[9] This indicates that the incidence of lead poisoning tends to

Figure 4-1: CASES OF LEAD POISONING NOTIFIED TO H.M.F.I. 1900 - 1965. Distinguishing poisoning from:

a) Use of Lead Paints

b) Paint and Pigment Manufacture

c) Other Industries

Source: Annual Reports of the Chief Inspectors of Factories

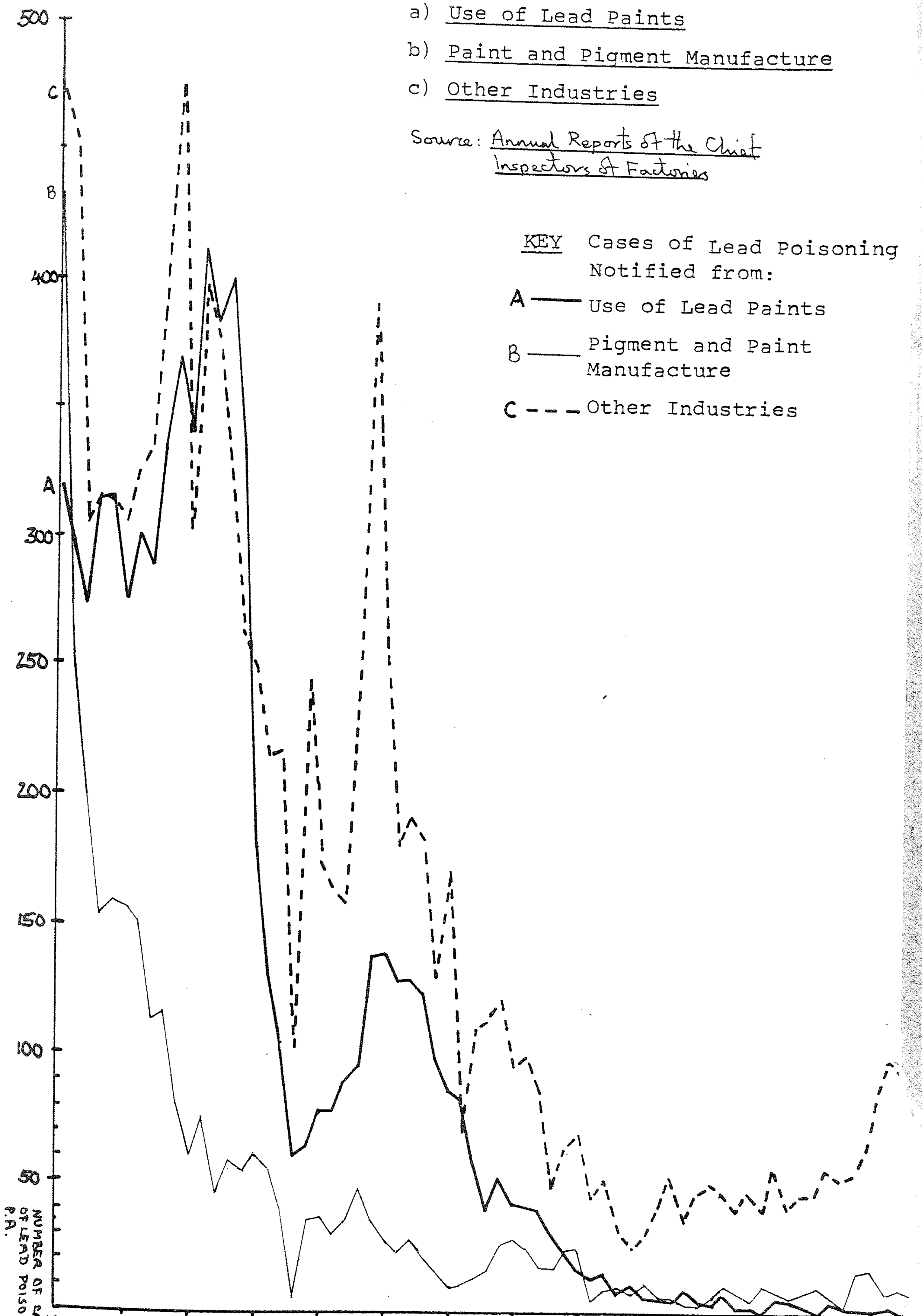


Figure 4-2: DEATHS CERTIFIED AS DUE TO LEAD POISONING 1900 - 1960. attributed to employment in:

a) Use of Lead Paints

b) Paint and Pigment Manufacture

c) Other Industries.

Source: Annual Reports of the Chief Inspector of Factories.

KEY

Fatal Lead Poisoning attributed to

A ——— Use of Lead Paints

B ——— Pigment & Paint Manufacture

C - - - - Other Industries

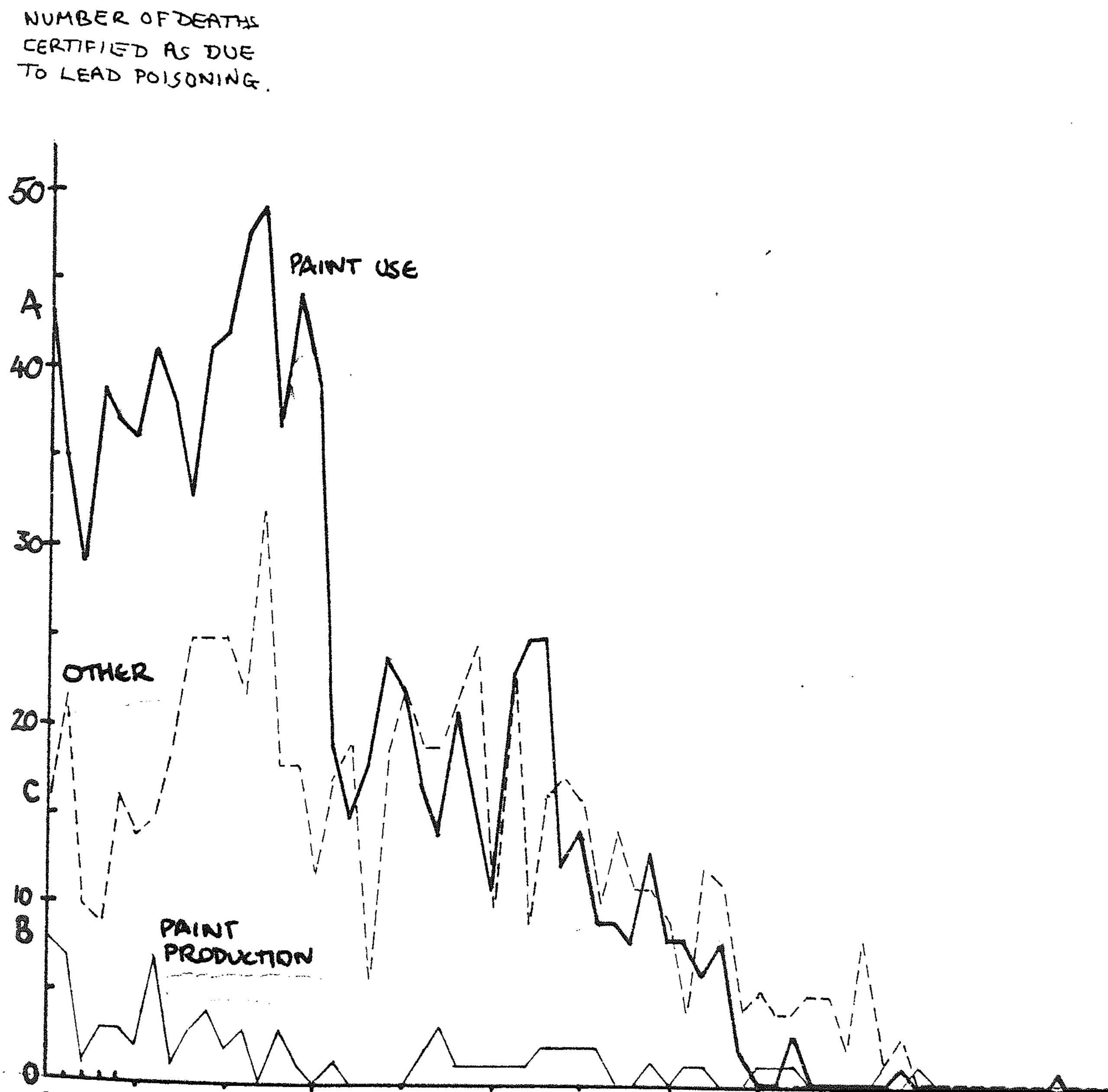


TABLE 4.3. Notified Cases of Lead Poisoning in Various Industries 1898-1902.

2. Figures prior to 1900 may be incomplete.

Source: Annual Report of the Chief Inspector of Factories for 1902, [Cd. 1112], HMSO, London 1902, p.207.
G.B.Home Department [Cd. 7882], loc.cit. 1915.

TABLE 4.4. Incidence of Lead Poisoning in Various Industries in the Period 1900-1913.

Incidence of Lead Poisoning 1900-1913

Source: G.B. Home Department [Cd. 7882], 1915, op.cit. p.77-8[9] be greater in those industries mainly concerned with the processing of lead than those in which products containing lead were consumed or were ancillary to the manufacturing process. Incidence of lead poisoning amongst paint users was low. Given this situation and the dispersed nature of painting activities, the number of cases of poisoning in any painting establishment would be minute. Even a large painting establishment with 100 workers would average one case in two years [house painting] or five years [coach painting]. There would be little opportunity for the scientific and, more significantly, political 'recognition' of the extent and severity of the hazard. In this way a major contributor to total lead poisoning was overlooked.

In contrast, the white lead industry was highly concentrated, had a high incidence of poisoning, cases of which received considerable attention in the press, and had been subject to increasing regulation from the early days of Factory Legislation.

The Methods of Regulation of Paint Manufacture and Paint Use.

Significant differences can be noted not only between the pattern of development of regulation, but also in the content of regulation adopted between pigment paint manufacturing and paint using industries.

The provisions of these Regulations are analysed in Table 4.5, according to the control measures involved. The most significant difference between paint production and paint use concerns the dust control measures : measures to prevent the escape of the toxic material which form the core of any control strategy.

Dust Controls

Regulation of paint production has revolved around engineering controls

TABLE 4.5 Analysis of Regulations covering Manufacture and Use of Lead Paint

TITLE	Paint & Colour Manufacture Regulations 1907	Lead Smelting etc. Manufacture 1911	Lead Components Manufacturing Order 1921	Vehicle Painting Regulations 1926	Lead Paint Regulations 1927	Shipbuilding Regulations 1931
S.R. & O.	No.7, 1907	No.752, 1911	No.1443, 1921	No.299, 1926	No.847, 1927	
PIGMENT/PAINT USE COVERED	Making paint from Red or White lead. Making lead chromate by boiling.	Red lead oxide manufacture	White lead manufacture	Vehicle Painting	Painting of Buildings.	Shipbuilding including Ship painting.
CONTROL MEASURES						
DUST CONTROL						
1. Extract Ventilation, Materials Handling.	✓	✓	✓	✓ Mixing dry pigment.	-	-
2. Extract Ventilation for process.	✓	✓		✓ Spray Painting.		
3. Enclose Hazardous Process	✓	✓	✓			
4. Damping Dusty Process		✓	✓	✓ (a)	✓ (a)	
5. Change Hazardous Process			(✓) (d)	✓ (a)	✓ (a)	
6. Prohibit Certain Process				(✓) (b)	✓ Interior spray painting	✓ Interior spray painting
'HYGIENE' FACILITIES						
7. Washroom	✓	✓ Bath or douche	✓ Bath or douche(e)	✓	✓ Wash bucket	
8. Mess Room	✓(f)	✓ (f)	✓	✓		
9. Cloakroom	✓	✓	✓	✓	✓	
10. 'Housekeeping'		✓	✓ Floors to be smooth			
PROTECTIVE EQUIPMENT						
11. Respirators		✓ (h)	✓			
12. Overalls	✓	✓	✓	✓ (c)	✓ (c)	
ORGANISATIONAL CHANGES						
13. Methods of Handling			✓ (g)	✓		
14. Periodic Medical Examination/ Suspension	✓ Monthly	✓ Monthly	✓ Weekly	✓ Where required	✓ Where required	
15. Prohibition of Women and Young People	✓	✓			✓	
16. Information for Workers				✓ (i)	✓ Warning leaflet to workers(i)	
17. Duties for Workers to cooperate with above measures.	✓ 7, 8, 12, 14.	✓ 7,8,9, 11, 12, 14.	✓ 1,3,4,7, 11, 12, 14.	✓ 7,8, 12,14.	✓ 4,7,9, 12.	

NOTES TO TABLE 4.5

a) Painted surfaces to be kept damp during 'rubbing down'. Lead pigment for mixing into paint to be as a paste in oil (not dry powder).

b) Spraying with lead paint only permissable if local extract ventilation is applied.

c) Not employers duty to provide overalls.

d) Drying stores to be ventilated prior to worker entering. However, other methods may be approved.

e) Washing time to be allowed.

f) Messroom required unless workers leave premises for meals.

g) Trays for carrying newly 'corroded' pigment to be impervious.
Trays not to be carried on head.

h) If dust control measures (1) to (5) not practicable, respirators to be provided.

i) Warning labels on lead paint containers.

[items 1-3] of ventilation and enclosure for dusty processes. The sole paint user industry in which such controls were required, vehicle painting, is itself a factory based operation. Such controls were not required for non-factory based operations.

Regulation of paint use has involved controlling dusty processes by changing the method of use of materials [items 4-5] (e.g. damping dusty processes, use of pigment in paste form rather than dry powder) and the prohibition of certain highly hazardous processes [item 5] (e.g. interior spray painting). As such, the control strategy for paint use revolves around changes in working practices. The importance of workers behaviour to such a strategy, is emphasised by the inclusion of measures such as warning leaflets to workers and hazard labels for lead paint. Measures of this sort were less central to, or absent from, Regulations in pigment/paint manufacture.

The regulatory strategy of engineering and other controls that were 'independent of the workman' was one that had been applied to most factory based lead processes between 1890 and 1915, with great success. In contrast, the Factory Inspectorate at that time were sceptical about the utility of a regulatory strategy that was based on worker behaviour.[10, 11.]

The next two Chapters will examine the factors which led to this pattern of paint manufacture and use. This Chapter focuses on the generation and application of a successful regulatory strategy of engineering controls for factory based lead processes and the controversy that arose regarding the strategy to be adopted for regulating the hazards of paint use.

The Nineteenth Century: Regulating White Lead Manufacture

Although attempts had been made to develop substitutes for white lead as a pigment in the Eighteenth Century, efforts to introduce state control over lead hazards did not develop until the end of the Nineteenth Century, with the development of a regulatory framework under the Factories Acts.

Early Attempts at Regulation

The first specific controls on lead pigment/paint was under the 1878 Factories Act, which forbad the employment of young children and women from some processes in white lead manufacture. Taking meals in white lead workrooms was prohibited in 1882.

In 1882 Alexander Redgrave, the Chief Inspector of Factories, submitted a report to the Home Secretary on "the need of further powers" to protect white lead workers.[12] Though it was the most systematic enquiry into pigment hazards up to that time, the report was notable for its brevity and lack of in-depth technical examination of the hazard or its control. Of particular interest was the radically different assessment of the causes of lead poisoning, and the control strategy it embodied. The hazards to white lead users (and the possibility of white lead substitutes) were not considered. The report concluded that lead poisoning could occur through not only inhalation and ingestion of white lead, but also by absorption through the skin from contact with white lead in wet or dry form. (SIC) Dilute sulphuric acid drinks were recommended as a prophylactic! The report characterised the problem of controlling the hazard (in white lead factories) as a problem of disciplining workers to use protective clothing and follow safety measures. (Redgrave urged dismissal of those workers not carrying out these requirements.)

Following Redgrave's Report, a short Act of Parliament was introduced which required occupiers of white lead factories (i.e. employers) to draw up 'Special Rules' for their activities which were to be submitted for approval to the Home Secretary (and possible amendment). A schedule to the Act laid down the types of hazard control to which the special rules should conform. This involved general workplace ventilation (as opposed to extract ventilation of processes), lavatory accommodation, baths for women, rooms for meals, provision of overalls and respirators and 'acidulated drinks'.[13] Thus the control strategy concentrated on <u>personal hygiene</u> and gave little attention to the use of extract ventilation and other engineering controls over the escape of white lead dust.

The Departmental Committee on the Various Lead Industries 1893-4

Despite these special rules, lead poisoning continued to be prevalent in white lead manufacture. In 1890 this hazard again came to the fore. Thomas Oliver gave an address to a British Association for the Advancement of Science meeting in Newcastle, on the hazards to workers in white lead factories, especially young women. Publicity and public concern had been attached to young women, previously healthy, who had fallen ill and died of lead poisoning after working in a white lead factory for as little as 3 months.[14]

A new set of Special Rules for white lead manufacture was issued in 1892 by the Home Secretary, under powers embodied in the 1891 Factories Act. These replaced the previous employers' special rules. Whilst they retained some of the personal hygiene requirements of the earlier rules (washing accommodation, overalls, respirators) they contained important new provisions, reflecting a new control strategy :

i) provision of special (i.e. extract) ventilation of certain dusty processes - namely the washing and crushing of 'corrosions' (i.e. to separate the lead metal from the newly formed white lead), grinding white lead (in water or in oil - to make paint), and the emptying of stoves used to dry the pigment.

ii) weekly medical examination of workers was to be instituted.[15]

In 1893, a Home Office Departmental Committee was appointed to investigate 'the various lead industries' in accordance with powers under the 1891 Factories Act to investigate dangerous trades (frequently known as the Henderson Committee after its chairman). The report of this Committee led to widespread introduction of Special Rules for lead industries and processes. A major section of the investigation focused on the manufacture of white lead.[16] Only minor changes were made in the existing Special Rules for white lead as a result of the committee's report. The revised Rules in 1894 included 'greater detail' as to the enforcement of cleanliness, and, more significantly required the compulsory notification of every case of lead poisoning (a duty that was extended to all factories under the 1895 Factories Act).[17]

However the committee's deliberations are of great interest because it was the first systematic government enquiry, and contributions were invited from scientific and medical specialists and interested parties (published in minutes as an appendix). The report allows assessment of the thinking underlying the 1892 Special Rules and moreover considered the question of lead substitutes. The report's deliberations are summarised below regarding the model of lead poisoning, the control strategy for white lead, and the question of substituting white lead.

The Medical Model of Lead Poisoning

i) Route of Entry of Lead into the Body. Though the report, like its predecessor, concluded that white lead could be absorbed through the pores of the skin (especially in the presence of perspiration and friction) as well as by inhalation and ingestion of dust, inhalation was identified as the most usual manner by which lead poisoning was contracted.[18]

ii) Susceptibility. Eight out of thirteen doctors expressing an opinion on the matter held that women were more susceptible than men to the effects of lead exposure. (14 out of 17 doctors held that young women were especially susceptible.). The report therefore recommended banning women from dusty trades in white lead manufacture from 1896, and the introduction of age certification for women to ensure that young women were not employed illegally.

Control Strategy for White Lead

The report shows a significant shift in emphasis, from that by Redgrave, in stressing the importance of applying engineering controls to dust generating processes in white lead manufacture. A major factor behind this change was the identification of inhalation as the most significant route of entry of lead causing poisoning. The demonstration by A.P.Laurie (a chemist from Cambridge University, on the committee) that lead dust could penetrate the respirators currently available (viz 'a cambric bag'!) led the committee to express caution in their recommendation of the use of respirators. Thus personal protective equipment was given equal weight in the report to the adoption of changes in the manufacturing process to control the escape of lead dust. These recommendations were :

i) The specific requirement for local exhaust ventilation in packing the finished product (since the clause requiring 'ventilators' in the 1892 Special Rules had been ignored).

ii) Damping certain dusty processes (e.g. stripping the stacks of corroded lead, covered in white lead).

iii) Mechanisation, to eliminate human contact with dusty processes - in particular of the stoves used to dry the finished pigment. On this point the committee felt unable to recommend legislation, but merely 'urged' adoption of this change because of complaints about the high price and unsatisfactory performance of mechanical drying stoves available.[19]

The recommendations were based on a detailed examination of the technology and industrial practice of white lead manufacture. The committee concluded that the manufacture of white lead could be 'rendered sufficiently free from danger' by appropriate precautions and recommended that the existing Special Rules be continued, with extensions in the ways outlined above. In reaching this conclusion, they rejected proposals to substitute white lead by less dangerous pigments.

Substitute Processes

The committee had been directed to enquire "whether the alleged injury to health caused by existing processes can be diminished by the adoption of any new processes in substitution to those already in use".[20] Within this remit, they considered the possibility of producing less toxic substitutes for white lead; in particular Zinc White (Oxide) and Lead Sulphate (Lithopone was not mentioned) apparently at the behest of A.P.Laurie, who had conducted research into the materials used by (mainly artistic) painters in history.[21]

The opinions of witnesses (mainly from the paint and pigment trade) were sought. Their views on the relative durability, covering power and price of white lead and zinc white are summarised on Table 4.6.[22] There were notable discrepancies between different witnesses, not only regarding matters such as durability of paints made from zinc and lead, which could only be determined by experiment, but also on more directly ascertainable questions such as price. The paint trade were predominantly sceptical about the suitability of zinc white as a substitute for white lead.

Laurie argued that, though lead substitutes were "fair", it could not be said that there was "any substitute on the market ... which the ordinary trade would take and use as readily as white lead." He therefore suggested that the committee should recommend :

> "a thorough experimental trial ... [of the lead substitutes] to encourage manufacturers to do their best to produce a substitute, [since current substitutes] are near being sufficiently good that perhaps a little more invention might really produce a satisfactory substitute."[23]

However, Laurie resigned from the committee in its first month (after another chemist had been coopted onto the committee), and the committee's report specifically opposed this recommendation, considering that the question of white lead substitutes "is much better left to be settled by competition in the open market" than by an experimental trial.[24]

Despite Laurie's intervention, and the inconsistency between other witnesses, the conclusion of the committee regarding the possibility of substituting white lead was unequivocal; and phrased in a way that devalues the opinions of the critics of white lead as incompetent or prejudiced (the proponents of white lead by implication being free from such partisanship, although an examination of the witnesses showed that many had vested interests).

> "With regard to all these so-called substitutes (for white lead), the committee have invariably found that on close enquiry of persons competent to judge and unprejudiced on either side, the substance in question was in some way inferior, and they have come to the conclusion that there is at present no substitute that can take the place of Carbonate of Lead made by the Old Dutch Process."

The only concession the committee made in this direction was to argue that there was less danger from the manufacture and handling of lead sulphate pigment. Though it was £3-4 per ton cheaper they felt that it was inferior in colour and covering power to White Lead.[25]

Reasons for the rejection of substituting White Lead

There are indications of a wide variety of factors underlying the committee's rejection of the substitution of white lead. The alleged inferiority of white lead substitutes is only a partial explanation (and one can only speculate about the role of 'interests' in this finding).

i) The committee's remit was to control hazards to those engaged in making white lead. The hazards to users were not considered. In this context the committee had a viable control strategy for regulating white lead hazards (of lead manufacture by Special Rules), even though this did not alleviate hazards to users.

ii) The committee were concerned about foreign competition. They noted that zinc oxide manufacture was not a home industry, and that substitution would therefore involve importing pigments. Moreover they argued that banning the manufacture of white lead in Britain would merely result in import of foreign made white lead.

TABLE 4.6. Assessment of Relative Performance of Zinc White and White Lead by Witnesses at the 1893 Departmental Committee on the White Lead Industry

Declared Interests	Named Witness	Performance of Zinc White relative to White Lead		
		Durability	Covering Power	Price
Paint Wholesaler	Merels	-	60%	240%
	Aldridge		'Covers less well'	
	Dixon	Less effective in damp	15/19	19/15
Paint Grinder	Thorp	Less durable : Resists sulphurous fumes better		
Paint Grinder	McArthur			
White Lead Mfrs.	Jefferson		Inferior	
	Bainbridge	Only sufficient for interior use		
Academic	Laurie	Resists sulphurous fumes	Same Keeps colour better	

Source: G.B. Home Department [C7239], 1894, *op.cit.*[22]

iii) Underlying this concern were particular assumptions about the effectiveness and propriety of state intervention in the face of market forces. Viz their rejection of Laurie's suggestion of a trial for substitutes (which implied that innovation was a responsibility of industry not the state and that diffusion could only be left to market forces rather than being directed on the basis of technical experiment and presumably enforced by future legislation). In this respect they may have been influenced by the powers available under Special Rules, since they only considered banning white lead manufacture, and not its sale or use.

Many of the issues raised surrounding the substitution of white lead were central to later debates, which will be discussed below.

The Success of the Regulatory Strategy for White Lead Manufacture

The Special Rules (as amended following the Departmental Committee in 1894) only remained in force until 1899. Then, in the light of figures, available for the first time for cases of notified lead poisoning (which showed an increase in poisoning in white lead manufacture, as opposed to a decrease in potteries) a new set of Rules were introduced and accepted (without recourse to arbitration) by the manufacturers. The major changes involved the exclusion of women from the most dangerous processes, and the requirement for further engineering controls (particularly regarding the ventilation of stoves). These Special Rules remained in force until 1921, when they were converted into Regulations, with no great change in provisions.[26]

The evidence from lead poisoning statistics, available on a consistent basis since 1900, is that the new control strategy was very successful at reducing the epidemic levels of lead poisoning, prevalent at the end of the Nineteenth Century, by an order of magnitude prior to the First World War.[27]

However, this reduction must not be seen as a simple effect of regulation, since it coincides with important changes taking place in the economic and technological development of the white lead industry.

Changes between 1904 and 1963 in numbers of establishments and employment in white lead manufacturing are documented in Table 4.7.[28] Although figures do not exist on a comparable base for these years, there are strong indications of a process of industrial concentration and labour shedding (primarily as a result of economic and technological development up to 1920, though the subsequent fall in U.K. production must have influenced this process).

Even at the turn of the century, the 'old Dutch' process for preparation of lead was being replaced by the 'Chamber' process (see Chapter 3 for description of these processes) which required 5 operatives in place of 13.[29] This alone would have had a substantial impact on the numbers exposed to white lead. Thus the process of regulation and the processes of modernisation and mechanisation of the white lead industry in the early Twentieth Century were complementing each other in reducing the numbers of cases of poisoning. However these two processes are themselves strongly related. It must be remembered that the thrust of the regulation was towards modernisation of production equipment (and presumably also favoured industrial concentration). However, legislation stopped short of mandating wholesale changes in the production process itself, particularly in the face of economic and technological obstacles (as illustrated by the 1893 Departmental Committee's unwillingness to go further than 'urge' mechanisation of drying stoves in this case). Legislation must be seen as an indirect and constrained pressure for technological change. However, as the case study of pulping of pigments (below) illustrates, informal regulatory pressures by the enforcement agency may also be significant.

TABLE 4.7. Number of Establishments and Employment in White Lead Manufacture

YEAR	Number of Establishments Manufacturing Dry White Lead	Number of Establishments Manufacturing White lead, Dry and in Oils	Numbers Employed in White Lead Manufacture	Numbers Employed on Lead Processes in White Lead Manufacture	SOURCE [28]
1901	18 } *				1901 Annual Report of the Chief Inspector of Factories
1904	27 }		1824 *		1904 Annual Report of the Chief Inspector of Factories (returns may not be complete)
1911				1405	Annual Reports } 191
1912				1382	of the Chief } 191
1913				1201	Inspector of } 191
1914				1119	Factories for } 191
1921			2489		1921 Census of Occupations
1948	16				1948 Census of Production
1951	9				1951 Census of Production
1963		22			1963 Census of Production

* Factory Inspectorate returns may not be complete, or on a comparable basis to Census data.

The sources of data and estimates of employment in white lead manufacture are discussed in Appendix B-6.

The Extension of this Regulatory Strategy to other Industries

As reliable statistics for Industrial Diseases (including lead poisoning) became available, around the turn of the century, it became clear that the number of cases of poisoning amongst white lead workers and in the potteries were falling rapidly. Between 1900 and 1901 the number of cases was nearly halved in these two industries.[30] This marked improvement took place in the two lead industries which had caused the greatest public concern, and which had been subject to legislation earliest. The Factory Inspectorate attributed this to the introduction of engineering controls in those industries, backed up with more stringent medical examination. Dr. Thomas Legge, Medical Inspector of Factories, was a strong proponent of this view. In the 1905 Factory Inspectors Report,[31] he stated that "the reduction in cases of poisoning [in white lead works] from 399 in 1899 to 90 in 1905 is due no doubt largely to structural alterations and dust extracting systems." This emphasised the "effects of dust (in contradistinction to cleanliness of hands) as a cause of poisoning" although "the effect of periodic medical examination by the appointed surgeon (week by week with treatment for some) must count for much".[32]

In contrast to the rapid reduction in lead poisoning in white lead manufacture and potteries, poisoning levels in other lead industries were static. As a result the latter's relative contribution to total lead poisoning increased. The success of the regulatory strategy adopted in the white lead and pottery industries encouraged its extension to other lead industries (both by making available a viable control strategy, and by revealing these industries as relatively more hazardous).

Paint and Colour Works

One of the first industries to which this strategy was extended was

'Paint and Colour Works'. In 1900 these had only amounted to a sixth of the number of cases of lead poisoning in white lead works (56:358). By 1905 it amounted to about half (57:90). (See Chapter 6 for full details). In 1905 Dr. Legge produced a report identifying hazardous processes in the manufacture of paints from lead pigments and the preparation of coloured lead pigments (chromates), and suggesting changes in the existing Special Rules which had been in force in the industry since 1894. This report was circulated to factory occupiers and other 'interested parties'.[33]

Progress was rapid, and within 18 months a set of Regulations had been enacted. Because of its relevance to the paint using industry (and in order to make comparisons with the process of development of Regulations for use of lead paint) the negotiation and implementation of these Regulations will be charted in detail.

The principal requirement of Legge's proposed Regulations was for enclosure or local exhaust ventilation (to remove dust 'at its point of origin') to be applied to any 'lead process' giving rise to dust. The draft Regulations defined a lead process as the 'manipulation of materials containing lead'.

Replies to the Factory Inspectorate's circular were available by November 1905, and it was decided to hold a conference with employers in January 1906. Workers' representatives were not invited at this stage although it was recognised that "any Regulations might affect them seriously and their views will have to be taken into account".[34] Revised draft regulations were sent to the employers. Arising from this conference, three amendments to the draft Regulations were made:

i) The most significant change was to the definition of lead processes (requiring enclosure or ventilation). Instead of applying to all lead compounds, this was restricted to the manipulation of <u>any</u> red and white lead and lead chromate, and the manufacture of lead chromate by 'a boiling process'. The requirement for ventilation etc. thus did not apply to the manipulation of lead paste in oil or as a slurry in water.

ii) Artist Colour makers were exempted.

iii) Manufacturers of Varnish Paint (often based on 'lead free pigments', and incorporating a high proportion of resin to pigment by addition of varnish to linseed oil) were exempted.[35]

The Paint and Colour Manufacture Regulations were introduced on 21 January 1907, and came into force on 2nd February.[36] These certified the manufacture of paints and colours as dangerous processes under the 1901 Factory and Workshop Act, and applied to the use of dry White lead or Red lead in the manufacture of paints and colours, and the production of lead chromate by a boiling process. They covered 268 firms in 1907,[37] (in contrast, the white lead industry, was considerably more concentrated, with approximately 27 plants). (See Table 4.7.)

As with the White lead Special Rules, the emphasis of these Regulations was on engineering controls (local exhaust ventilation and enclosure of dusting processes), backed up by medical examinations.

A similar approach was embodied in the 1911 Lead Smelting Regulation which encompassed the manufacture of red and orange lead oxides (including red lead oxide pigment), which also included the requirement of damping materials and workrooms to inhibit the dispersal of dust into the air.[38]

The provisions of these Regulations have been summarised in Table 4.5.

The Production of Pigments in Pulp Form, an example of the interaction between technical change and regulatory pressures.

The trend towards the production of lead pigments as a paste in oil affords a useful illustration of the complementary effects of technical change and regulation (and within this, of the potential significance of informal regulatory pressures as opposed to legislation).

The traditional method of extracting newly formed white lead from the water that was used to separate the white lead from the native metal was by allowing the pigment to settle, then pressing and drying the pigment in ovens. Emptying the latter and packing dry pigment were the dirtiest and most hazardous processes in white lead manufacture. A method of converting this slurry directly into a paste of white lead and oil was developed in France at the turn of the century, apparently for commercial rather than health reasons (the slurry was mixed with linseed oil and the water was extracted by pressing). This process, known as pulping, was observed by Sir Thomas Oliver, who brought it to the attention of the Home Secretary. A Home Office circular was issued in 1902 to the pigment and paint making companies.[39]

The adoption of this technique could be encouraged by the White Lead Special Rules (which required the adoption of ventilation for stoves and handling dry lead pigments) and the 1907 Paint and Colour Regulations (which required ventilation/enclosure for handling dry pigment, but exempted pigment pastes).

Though no figures exist for the rate of uptake of pulping, the production of white lead as a paste or as liquid paint was believed to be increasing during the 1900-1910 period.[40] Certainly, by 1930, 44.2% of white lead was sold by manufacturers as a paste in oil. The proportion of white lead sales in paste form is not shown earlier but was probably very low.[41]

The dramatic fall in the incidence of poisoning in white lead works between 1900 and 1910 was attributed by the Medical Inspector of Factories to 'the adoption of automatic methods and the conversion of the dry white lead into oil paint'.[42]

Finally, it must be noted that this shift away from production of dry lead pigments both promoted and was encouraged by changes in the nature of the painting trade. Thus the use of ready mixed paints doubled between 1909 and 1911 for one paint grinder.[43] The shift from using dry pigments to paste and readymade paints was welcomed by painting employers by bringing a claimed 40% saving in labour costs (by reducing the requirements for labour and particularly skilled labour) in 1921.[44]

Between 1904 and 1913 the Factory Inspectorate's regulatory strategy was applied to all the lead industries which had been subject to Special Rules. These were factory-based processes, either mechanised, or conducted at fixed plant, and the requirements for engineering controls (ventilation and enclosure) were easy to put into practice.

This updating of regulation was initiated primarily within the Factory Inspectorate and Home Office. The availability of a (technically / economically) feasible control strategy simplified the process of regulatory policy formation to simply applying the strategy to the specific circumstances of the industry to be regulated. There was little controversy about the implementation of these Regulations, which mainly revolved around relatively minor modifications and exemptions.

The lack of downward trend in lead poisoning from processes not subject to Regulations attracted increasing attention from the Factory Inspectorate. The problems of regulatory development here were more complex, partly because of the lack of regulatory experience, but more significantly because the processes involved were not tied to plant or machinery, and the application of engineering controls were less feasible. Following the successful regulation of pigment and paint production, paint use became a particular focus of concern.[45]

The Regulation of Paint Use

In 1905, the Factory Inspectorate undertook an enquiry into the coach painting industry "because of the fact that no corresponding reduction in the number of cases of lead poisoning can be observed from year to year in this industry or in the many industries grouped under the head of paints used in other industries such as has been noted in china and earthenware and white lead".[46] This enquiry concentrated on changes in dusty processes (particularly smoothing dry lead paint between coats) and substitute materials. The latter was adopted because in this industry the application of local exhaust ventilation was seen as impractical.[47] There is evidence that the Factory Inspectors adopted an informal policy of encouraging substitution of white lead paints at least for interior use, which seems to have led to results.[48] However, direct approaches by the Factory Inspectorate could only have limited effect on the road and rail vehicle making industry which employed 175000 people in 2900 establishments in 1901. The 'most important coach factories' alone numbered 603, employing 9600 in painting and other operations involving lead pigments in 1903.[49]

The 1905 investigation was primarily concerned with technical matters, and did not lead to the introduction of Regulations, nor to a reduction in lead poisoning in coach or other industrial painting. Indeed the number of cases and fatalities from lead poisoning amongst industrial painters rose between 1905 and 1912. (See Figures 4-3 and 4-4) For discussion of source and significance of these poisoning statistics see Chapter 6 .

Though concern about lead poisoning amongst coach and industrial painters

Figure 4-3: CASES OF LEAD POISONING NOTIFIED TO H.M.F.I. AMONGST HOUSEPAINTERS AND INDUSTRIAL PAINTERS 1900 - 1974.

Prior to 1927, lead poisoning amongst house-painters notified to H.M.F.I. on a voluntary basis only.

Source: Annual Reports of the Chief Inspector of Factories.

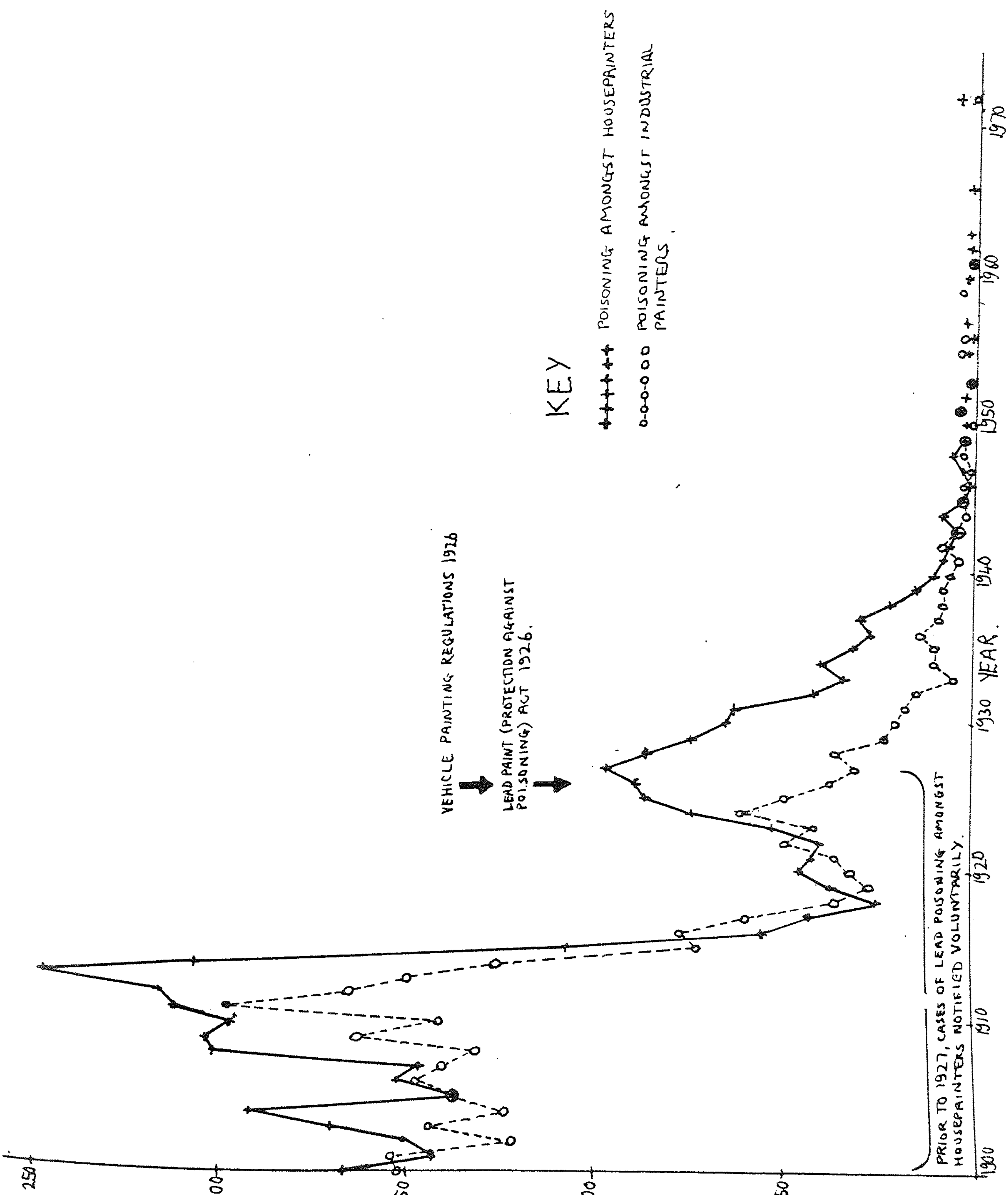
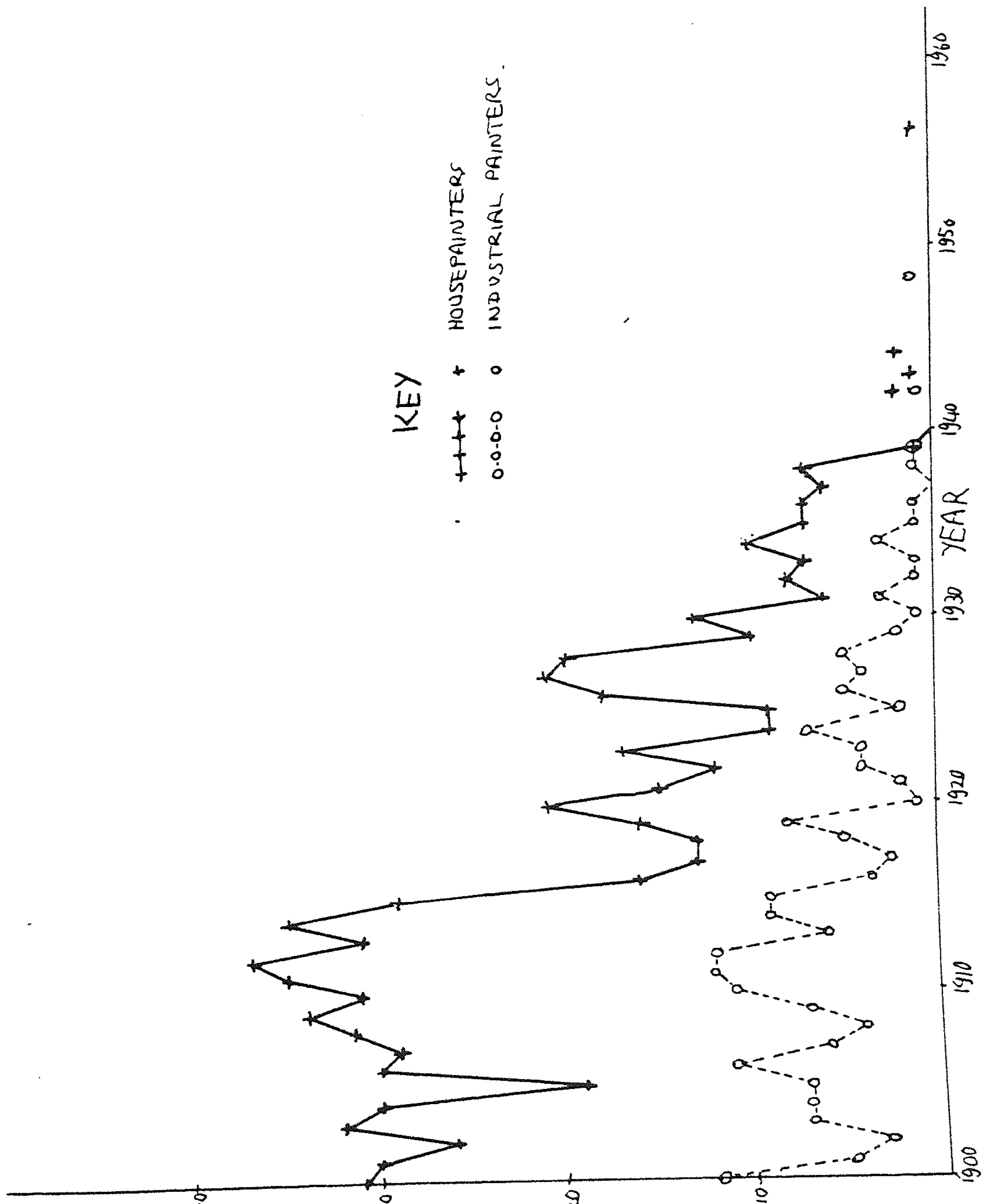


Figure 4-4: DEATHS CERTIFIED AS DUE TO LEAD POISONING AMONGST HOUSEPAINTERS AND INDUSTRIAL PAINTERS 1900 - 1960

Source: Annual Reports of the Chief Inspector of Factories



continued, it was rapidly surpassed by concern about an even larger body of poisoning amongst housepainters. Though these were not covered by the Factories Act requirement for compulsory notification of lead poisoning, they were covered by the Workmans Compensation Act 1906. In particular figures for deaths amongst housepainters certified as due to lead poisoning were published by the Registrar General after 1900. These are plotted in Figure 4-4, which also shows the number of such deaths amongst industrial painters. This showed housepainters to be suffering an average of 30 deaths a year from lead poisoning compared to 7 for industrial painters and 4 in pigment paint manufacture. Indeed fatal lead poisoning in housepainters substantially exceeded the total for all other industries combined between 1900-1910.

In addition, non-fatal cases of poisoning amongst housepainters were being reported to the Factory Inspectorate by medical practitioners in greater numbers than for any other industry. Such notification was made on a voluntary basis (or in the erroneous belief that notification of poisoning was compulsory) and certainly is a much less complete representation of the extent of lead poisoning in housepainters than the compulsory notification that applied to factories. The validity of these poisoning statistics is discussed in Chapter 6.

Attitude of Factory Inspectorate to Housepainters

Partly as a response to the scale of lead poisoning amongst housepainters indicated by these statistics, a dramatic reversal in the policy of the Factory Inspectorate can be noted. From arguing that poisoning in housepainters was not their problem in 1900,[50] the Inspectorate's position was shifted by 1907 to an active espousal of the need to regulate the industry.

In 1900, the Chief Inspector of Factories, Arthur Whitelegge had circulated a memorandum to medical practitioners, requesting them not to notify cases of lead poisoning not contracted through work in factories and workshops covered by the Factories Acts, in particular amongst housepainters and plumbers. The reason was that "reports of the kind being non-statutory would be incomplete, and could have but little statistical value". This was done "in order to avoid unnecessary trouble on the part of all concerned".[51] Despite this, the number of cases of lead poisoning and fatalities notified by medical practitioners increased. (We discuss this in our section on poisoning statistics). The Chief Inspector decided that these cases should not be "followed up by enquiry and report by the certifying surgeons and inspectors, as this had involved much waste of time" (in 1900) " ... as no remedial action can be taken by the (Factory) Department".[52]

In 1905 a similar memorandum was sent to General Practitioners in Glasgow, Liverpool and Birmingham and 10 other towns to again discourage such notification.[53]

Despite this active discouragement, voluntary notification of cases of poisoning amongst housepainters not only persisted but in fact increased. (for discussion of this see Chapter 6). This, combined with the large numbers of fatalities recorded by the Registrar General amongst housepainters and plumbers, appears to have precipitated a change of attitude in the Factory Department. In particular, the Principal Medical Inspector of Factories, Dr. Legge, from 1907 began to draw attention to the extent of the hazard amongst housepainters (and plumbers) and the need for controls. In 1907 he sent a memorandum on lead poisoning to the Building Accidents Committee outlining the probable routes of exposure to lead fumes. He noted the 39 fatal cases of lead poisoning in housepainters and plumbers and pointed out that by extrapolating probable incidence of poisoning from fatalities, an estimated 867 cases of poisoning probably occurred in housepainters in 1907, exceeding all other industries.[54] Legge's annual report for 1907 drew particular attention to the lack of downward trend in lead poisoning amongst industrial paint users (especially coach painters) as well as housepainters and plumbers (though they were "not really covered under Section 73 of the 1901 Factories Act").[55]

This shift of opinion of the Factory Department must also be seen in the light of the growing international campaign to protect the health of paint users by regulation of the use of lead paint and in particular for the prohibition of white lead paint.

The International Campaign for the Regulation and Prohibition of White Lead Paint

The international movement for the prohibition of white lead in paint (in particular used in painting buildings) has been documented in some detail, in particular in 'White Lead' published by the International Labour Office in 1927[56] and elsewhere.[57] Rather than attempting to reiterate this detailed history, the salient points of the international campaign are summarised and discussed below. A brief chronology of developments in various countries, including political campaigns and regulatory actions between 1900 and 1912, is presented in Table 4.8.

There was a protracted and rigorous campaign for prohibition of white lead paints, most notably in Austria, Belgium, France, Germany and Switzerland, prior to the First World War.

The most significant aspects of the history of the campaign for control of lead paint hazards between 1900 and 1914 are summarised below, focusing on the role of the International Association for Labour Legislation, trade

TABLE 4.8. A Brief Chronology of the International Campaign for the Regulation and Prohibition of White Lead Paint 1900-1912

1900

In France - Between 1900 and 1902 a number of ministerial decrees issued forbidding the use of white lead (after a 5 year period) in work executed on their behalf.

1901

Belgium - Brussels Federation of Painters' Union petition for prohibition of white lead in municipal works, was supported by the Brussels Chamber of Commerce who referred it to the government.

1902

Austria - Painters' union petitions government to issue orders to protect painters.

Switzerland - (October), the Central Association of Painters etc. submits a petition for the federal government to prohibit the use of white lead in government tenders.

France - Painters go on strike in support of prohibition of white lead.

Belgium - (November-December) Justice and War Ministries forbid use of lead paint in painting carried out under their instructions.

1903

Germany - (December). German Painters' union call for prohibition of white lead in painting. Resolution submitted to the Imperial Chancellor, and discussed at the Reichstag. (24th February 1904). In face of employers' opposition, prohibition rejected and government eventually introduce an order which laid down conditions under which white lead paint could be used. (27th June 1905).

1904

Switzerland - (January). The Swiss Federal Council decided to prohibit on a temporary basis the interior use of white lead in work tendered by the Confederation. (This was followed by similar orders in the of Basle and Zurich).

1905

Germany - Order regulating the use of white lead paints introduced; and provokes some opposition from employers, and strong criticism by workers' representatives, who called for complete prohibition of white lead.

The Wurttenburg Railway Authorities decide to cease the use of lead colours in their workshops.

Belgium - (13th May) - regulations on use of white lead paints introduced.

Table 4.8 (Continued)

1906

Austria - (1st June) - Vienna Painters' Sick Benefit Society requests the provincial government to prohibit white lead paint in work it tenders. The Provincial government for lower Austria issued such an order on 27.8.1906 and requested Minister of the Interior to consider similar legislation nationally.

1907

Germany - Baden Railway Board prohibits use of lead colours in its workshops. Berlin council prohibits white lead in municipal constructions. Pianters' Guilds in various towns in Silesia decide to discontinue the use of white lead paint.

1908

Austria - (April), law passed prohibiting internal decoration with white lead (except in steamy environments) and requiring identification of the lead content of paint.

Switzerland - (June) Federal Council invites Federal Administrative bodies to prohibit internal decoration by white lead in their works.

1909

France - (April) - declaration of lead content of colours and putties required.
- (July) - use of white lead prescribed - after 5 year preparatory period.

1910

1911

Germany - (May) - Federation of Painters and Decorators reiterated their demand for the prohibition of the use of lead paints.

Great Britain - Government Departmental enquiries into hazards from lead paint in the painting of coaches and buildings appointed.

1912

Germany - (August) - Building workers congress demanded prohibition of white lead in building and decorating work.

Source : International Labour Organisation, 1927, op.cit.[56]
Sir Thomas Oliver, 1911, op.cit.[57]

unions, employers, and wider social institutions.

1. <u>The Role of the International Association for Labour Legislation</u>

Initially, the most significant role in promoting action on white lead appears to have been the International Association for Labour Legislation, (IALL) which discussed the hazards of manufacturing and using lead paints at its constituent assembly on 28th November 1901.[58] Trade union pressure seems to have developed somewhat later, with considerable variation between different countries.

The second meeting of the IALL received reports on the possibility of using white lead substitutes and (in a resolution which also called for the prohibition of white phosphorous) sought abolition as far as possible the use of white lead paints. This resolution was supported by representatives of ten European countries (not including Britain). In the words of the ILO : "from this time forwards, the international movement in favour of substitutes for white lead was merged in the work of the IALL".[59]

The Third General Assembly of the IALL at Basle in 1904[60] confirmed its previous resolution 'advocating prohibition of all work where (white) lead can be replaced by substitutes' and calling for 'strict regulations wherever prohibition has not yet been adopted'. This position was restated at the 1908 Fifth meeting in Lucerne,[61] which called for the labelling of paints and colours containing lead, and at subsequent meetings of the IALL up to World War I.

On 15th December 1909 the IALL produced a petition to promulgate the campaign against lead poisoning in painters.[62] It restated the IALL's policy that white lead should be prohibited especially for interior painting - in line with their general policy of demanding 'only such measures as were urgently necessary for the protection of health and at the same time, technically and economically feasible.

The petition cites attempts to control white lead hazards by requiring safety precautions (rather than prohibition) by the French Ministry of Commerce, 18th July 1902 and 15th July 1904 and the German Federal Council, 27th June 1905. These were held to be impracticable because of the difficulty of enforcing them which "render the application thereof illusory".[63]

2. The Role of Trade Unions

Although an International Congress on the Protection of the Workers, convened by the Swiss Workers Federation in 1897 mentioned the substitution of white lead by zinc white in its discussion of dangerous industries, "the agitation against white lead carried on by the workers' organisations was, to begin with, merely part of the general movement for the protection of workers, which was at first limited to protecting the health of women and children. But once the labour movement was disciplined, and organised into large and powerful trade unions, the campaign against white lead became more definite and widespread".[64] Trade union activity on white lead started in Belgium (1901), Austria, France and Switzerland (1902) and Germany (1903). Public activity by British trade unions seems not to have developed until stimulated by the 1911 Department Committees of Enquiry (See Table 4.8.).

3. The (Divided) Role of Employers

The initial response of employers to proposals for legislation over lead paint hazards appears to have been one of wholehearted opposition, uniting paint/pigment manufacturers and painting employers (Master Painters). As the debate about regulatory strategy developed, some Master Painters' organisations modified their attitudes, which in turn opened up divisions between themselves and the paint manufacturers.[65]

Sections of painting employers supported the use of lead substitutes. (e.g. the Association of Swiss Master Painters who in 1903 did not object to the proposed prohibition of white lead in internal painting in government contracts). Others supported prohibition of white lead in preference to onerous regulations for the use of white lead paints (e.g. the Belgium General Federation of Master Painters in 1905 opposed the regulations that had been introduced for using white lead paints and requested complete prohibition - a reversal of the position of their members 2 years earlier).

Divisions occurred between the painting employees and the white lead manufacturers on the subject of prohibition (In Belgium, the white lead manufacturers submitted an objection to the proposed total prohibition of white lead paints 6th December 1912 and called for the status quo - regulation - to be maintained), with the latter demanding continued use of lead paints with regulations to protect painters' health as a means of maintaining their industry. The extent and significance of these divisions will be discussed in more detail in the British case, where divisions amongst different sections of the employers are crucial in understanding the development of regulation in Great Britain.

4. The Involvement of Wider Social Institutions

The debate went beyond the directly interested parties and engaged wider social institutions. Various professional and public bodies became involved, chiefly in support of legislation over lead paint hazards.[66]

The most striking illustration of this is the demonstrations organised by the League of Red Cross Societies in support of implementing the 1921 International Labour Conference Draft Convention on White Lead Paint. These took place in Brussels (24th April 1923) and Paris (3rd March 1923)

The latter had the additional goal of bringing pressure for strict enforcement of the Act of 1909 prohibiting use of lead paints in interior house painting and its extension to coach painting and red lead paints.[67] Various technical bodies expressing support for prohibition in this period include :

France 1901	-	General Council of Civil Construction Architects Society (Aisne Department)
Belgium 1902	-	Chemists Association
Holland 1907	-	"Democratic Engineers and Architects" Association (Sociaal-Technisek, Vereeniging van demokratische Ingenieus en Architekteh).

The control of the hazards of painting buildings shows specific features because of the existence of lead free substitute materials for white lead. The exposure of painters to lead hazards is thus a consequence, in part, of the decision by the customer to use lead paints.

This opened up the possibility of applying pressure on the consumer to eliminate lead paints. In particular it gave greater purchase to those campaigning against white lead, who were able to push local and national government bodies as well as private employers to adopt leadless substitutes. The campaign has thus more immediate and realisable objectives than simply seeking national legislation over the hazards.

The International Campaign about White Lead Paint Hazards and the Situation in Britain

As is indicated in Table 4.8, the regulatory debate in Britain was more muted, and developed later than in the major European countries. In the latter, notably Austria, Belgium, France, Germany and Switzerland, it had been the trade unions who had initially raised the question of the need to control lead paint hazards (particularly by prohibition). Subsequently other social forces (including sections of painting employers and disinterested parties) had become involved. This had led to attempts to prohibit or restrict the use of white lead paints by both central and local government bodies in several of these countries.

The late development of the prohibition movement in Britain would appear to be related to the limited extent of trade union pressure prior to the 1911 Departmental Committees of Enquiry into the use of lead paints. Moreover, the establishment of these Committees must be seen as a consequence not of union pressure but of :

i) the vigorous international movement for the control of white lead paint hazards,[68] and

ii) the active support for extension of Factory regulation to include these hazards conducted by the British Factory Department during the 1900-1910 period.

The fact that concerted activity around the hazards of lead paint appears to have developed during and after the 1911 Departmental Committees suggests that state regulatory activity must be seen as a potential stimulus to involvement by popular interest groups. Thus the state must be seen as having an active role in the regulation of hazards, rather than simply a reactive role (as might be implied by some models of the state).

The 1911 Departmental Committees of Enquiry

In January 1911, one of the first moves of Asquith's newly elected Liberal Government, was the appointment of two Home Office Departmental Committees, to examine the risks from lead paints. They were the 'Committee on the use of lead in painting of buildings' [The Departmental Committee appointed to investigate the danger attendant on the use of paints containing lead in the painting of buildings] and the 'Committee on the use of lead in painting of coaches etc.' [the Departmental Committee appointed to investigate the danger attendant on the use of lead compounds in the painting, enamelling and varnishing of coaches and carriages]. We shall refer to these as the Painting of Buildings Committee and the Coach painting Committee.

The Chairman, Sir Ernest Hatch, and three other government representatives on the two committees were the same. The employers' and employees' representatives, not surprisingly, differed. The major committee was on painting of buildings, and the two enquiries were carried out together [24 of the 36 days of the 'coach painting committee' were joined with the 'buildings committee'.[69] The technical appendices and minutes of the two committees were published as single volumes.[70]

The 'coach painting committee' did not restrict itself to coach and carriage painting, but also considered the use of lead paint on other vehicles (cars, trams, railways, perambulators) and certain industrial goods (e.g. safemakers).

The 'buildings committee' considered in addition the painting of ships and civil engineering (large steel structures e.g. bridges).

The Painting of Buildings committee submitted its findings in November 1914, which were published the following year. Whilst the Coach painting committee report had been drafted by 1915, its completion and signature were interrupted by the War. It was not therefore submitted until January 1920.

The deliberations of the two committees were published in four volumes which we shall refer to as 1911 Painting of Buildings Report, 1911 Coach painting Report, 1911 Committees - Appendices and 1911 Committees - Minutes.[71]

Brief outline of the progress of the Committees

The 1911 Painting of Buildings committee called 93 witnesses 'adequately covering all aspects of the problem'. In addition 25 witnesses were brought forward by the white lead manufacturers [the White Lead Corroders section of the London Chamber of Commerce], which were accepted by the committee.[72]

The committee recommended that the importation, sale and use of paint materials containing more than 5% soluble lead[73] be prohibited, with certain exceptions (e.g. artists paints), three years from the date of publication of the report. The report was signed by 7 of the 8 man committee, including the representative of the National Federation of Building Trades Employers, as well as the government and trade union representatives. However, Mr. W.G.Sutherland, Secretary of the National Association of Master Builders and Decorators submitted a memorandum dissenting with the majority report, and arguing for the adoption of regulations to enforce strict precautions in the use of lead paints for a trial period, backed up with investigation of the efficacy of lead substitutes.[74]

No action was taken by the government arising from the 1911 Painting of Buildings Report, because of the intervention of the First World War. After the war, the terms of the regulatory debate shifted significantly.

The 1911 Departmental Committees were the most exhaustive government investigation into the regulation of occupational lead paint hazards in Britain. The information it contained was a major source of data for the 1921 International Labour Convention.[75] It would appear that this was one of the first systematic studies of risks and regulatory strategies for an industrial chemical. The investigations of these committees will therefore be analysed in detail.

The role of Medical Considerations and of Economic, Technical and Administrative factors in the assessment of regulatory strategy will be examined separately.

The bulk of the deliberations of the 1911 Coach Painting committee were subsumed under the 1911 Painting of Buildings committee. The latter was published first, and its findings were very influential on the conclusion of the Coach painting committee. This account therefore focuses on the Painting of Buildings committee, indicating where different technical questions were considered and different conclusions reached by the Coach painting committee.

Medical Considerations in the Regulatory Debate

Overview

The primary medical concerns of the 1911 Departmental Committees were with the routes of entry of lead (affecting the assessment of the most hazardous processes, and thus control strategy) and the diagnosis and extent of lead poisoning. The predominant view before the committees conformed substantially to present day models of the nature of the hazard of lead paint (i.e. lead absorption) and in particular of the development of frank lead poisoning from occupational exposure (due primarily to inhalation of lead bearing dust). However the committees had to deal with two theories regarding harm from lead paints that would be seen in the light of current knowledge to be erroneous.

At the enquiry the theory that lead paint released volatile lead compounds (which had been cited by the proponents of abolition of white lead paint especially in France) was decisively refuted. Drawing on the remnants of this theory, a 'counter theory' was presented to the committee, by witnesses produced by the White Lead Corroders, that volatile organic compounds (in particular the turpentine solvent used and aldehyde/ketone are composition products of the 'drying' linseed oil) released by freshly applied lead paint produced symptoms that could be confused with lead poisoning. It was suggested that some of the cases of poisoning (including fatalities) ascribed to lead paint were, in fact, due to 'turpentine poisoning' and that the risk of lead poisoning from lead paint was less than had been suggested on the basis of notifications to the Factory Department. Despite counter-evidence, this theory was taken up by the opponents of prohibition of white lead until it was 'demolished' at a further Departmental Committee of enquiry in 1921.

Routes of Entry/Source of Harm

Inhalation of lead bearing dust was firmly established as the most significant route of entry in industrial lead poisoning by the major scientific witnesses and publications of the period. (The views of the British Factory Inspectorate, particularly the Medical Inspectors, were particularly influential in this assessment).[76] The report concluded that this route of entry was most important for housepainters; that swallowing dust was a relatively small risk, whereas skin absorption and other routes were of negligible importance and of theoretical interest only.[77] However, as the 1907 French Government Enquiry into White Lead, which led to the banning of white lead paints, a theory had been proposed by M.Breton, Dr. Heim, Mr.Herbert and Dr.Marie, that freshly applied lead paint released volatile lead compounds. The existence of such emanations from lead paint would obviously add considerable weight to the case for prohibition of lead paint. Two chemists were brought forward as witnesses by the White Lead Corroders specifically to contradict this theory (Dr.Goadby and Prof.Armstrong).[78] However, the theory was in any way shortlived. Professor Baly who had presented evidence to the British Committees in March 1911, which appeared to confirm the findings of the French researchers, returned to the committees 11 months later to retract his earlier findings. (attributing his error amongst other things to having been poisoned by the paint).[79]

The Principal Chemist of the Government Laboratory, Dr.J.J.Dobbie, was also asked to investigate the matter. The results of his exhaustive analyses were presented to the committee. He found no volatile emanations containing lead from lead paint or paste. The only lead released from lead paint or paste etc. was in solid form. He attributed the findings of the French researchers to:

1) the unreliability of the indicator used to detect the presence of lead (Trillats reagent).
2) penetration of particles of solid lead through cotton wool filters and possibly
3) contamination of reagents with lead.

Dr. Dobbie did detect trace emanations of aldehyde and organic acid vapours (mainly formic and acetic) from linseed oil based paints. Lead pigments (sulphate and carbonate) appeared to accelerate the release of such compounds, though zinc oxide and barium sulphate did not have this effect.[80]

These findings, along with the animal experiments conducted by K.W.Goadby served to inflame another dispute about the validity of diagnoses of lead poisoning.

Goadby's somewhat inelegant experiments on cats to determine the health effects of volatile emanations from freshly painted surfaces, showed lead paints as having the same effects as lithopone and zinc white paints. The ill effects were attributed to inhalation of the turpentine thinners. Post-mortems showed frequent kidney damage which Goadby suggested was of a different type to that caused by lead exposure.[81]

Dr. Goadby argued that turpentine vapours could be the cause of complaints by painters of headache, nausea and 'a certain kind of colic' (pain in digestive tract) from fresh paint. He argued that in the past this might have been diagnosed as lead poisoning. Moreover some of the fatalities certified as due to kidney failure from lead poisoning may have been due to turpentine.[82]

The thesis that some of the cases certified as lead poisoning in painters were due to organic vapours was taken up by another witness presented by the White Lead Corroders, Professor (of Chemistry) H.E.Armstrong. However this theory seems to have had little impact on the findings of the Departmental Committees. (Although Sutherland, in his dissenting Memorandum, used the theory to question the validity of the lead poisoning statistics).[83] The White Lead Corroders continued to espouse this theory until it was demolished at a further Departmental Committee appointed in 1921 (the Committee on Industrial Paints).[84] (Mortality statistics calculated by the Registrar General for workers exposed to turpentine but not lead, e.g. varnish workers, showed that "turpentine as a serious agent in the production of chronic painters illness was not to be compared with white lead".)

In the promulgation of these theories, interests and commitment to a particular regulatory strategy, seem to have played a major role. However, neither theory seems to have significantly affected the deliberations of the Departmental Committees.

The lack of impact of these two 'perturbing hypotheses' must be seen in the light of :

i) The availability within the state of reliable and authoritative information of these matters,

ii) the substantial development of the science and occupational hygiene of lead from the successful control of hazards in other lead industries.

This body of knowledge even allowed a degree of precision in assessing the risks of lead exposure, and indicated 'a priori' that dust evolved in the use of lead paint would involve a significant risk of lead poisoning. The 1911 Painting of Buildings Report cites Legge and Goadby's finding that work in atmospheres containing 0.2 milligrams of lead or more per cubic metre of air could in the long term lead to chronic plumbism.[85] Although no figures were produced for the exposure of house painters to dust (since this trade lay outside the remit of the Factory Inspectorate), the results of measurement of airborne lead levels from comparable processes in Coach painting were presented by the Factory Department (derived from their investigation in 1905). This found that 'sanding down' painted surfaces prior to applying another coat of paint generated 'enormous' amounts of lead in air - between 3-100 milligrams per cubic metre (an order of magnitude higher than exposures in the potteries).[86]

In this way it was possible to identify the most hazardous processes involved in painting with lead paints. These were mixing paint, dust released from paint laden overalls, dust from sandpapering coats of paint, contamination of food with unwashed hands and possibly fumes from burning old paint.[87]

Thus, knowledge about relatively stable and easily monitored factory-based lead processes could be formulated into airborne exposure standards that could be applied to more variable and less well known lead processes where a direct correlation between specific processes and ill health were not available and might not be feasible. This must be the first occupational hygiene standard for exposure to a chronic health hazard. It was a powerful technique which, it could be argued, formed the basis for the development of modern industrial toxicology and hygiene.

The Extent of Harm - the Level of Lead Poisoning

Statistics relating to lead poisoning amongst housepainters were available from three sources :

1) voluntary notification of lead poisoning cases to the Factory Inspectorate by medical practitioners.
2) statutory reporting of deaths certified as due to lead poisoning.
3) records of the painters unions for disability and death amongst their members.

These were used to estimate the total burden of ill health and death from lead poisoning, relative mortality rates, and incidence [relative risk] of poisoning and death, amongst housepainters and other trades.

The Total Burden of Ill-Health

Dr. Legge Medical Inspector of Factories, presented to the committee the statistics relating to deaths certified as due to lead poisoning for housepainters (for England and Wales, referred by the Registrar General's Department) and cases of lead poisoning amongst housepainters and plumbers (together) voluntarily notified to the Factory Department by medical practitioners for the years 1900-1913.[88]

Deaths from lead poisoning amongst housepainters over this period amounted to 427, which exceeded the total number of deaths from lead poisoning in all factory based lead processes together (421).

The number of voluntarily notified cases of lead poisoning was increasing over the period, but was held to be a substantial underestimate. An estimate of the number of cases of poisoning that might be expected if notification were compulsory, based on the ratio of fatalities to poisoning in factory industries, gave an average number of cases of poisoning of 720½ p.a. compared to, for example, 197 cases of lead poisoning in fact voluntarily notified in 1910. The implication being that voluntary notification of poisoning amongst housepainters covered less than one third of the level expected with compulsory notification.[89] It was also noted that poisoning in housepainters was twice as likely to be severe. The significance of these figures and Dr. Legge's estimate is discussed further in Chapter 6.

In addition figures for disability compensation and death were presented from the records of two painters' unions - the National Amalgamated Society of Operative House and Ship Painters and the Scottish Society of House and Ship Painters.[90]

Mortality Ratios

From these union records (and from returns by the Registrar General), the 'excess of deaths due to certain diseases' was calculated. Plumbism was 31 (55) times more frequent as a cause of death amongst 'housepainters' than 'all males' in England and Wales. Bright's disease (kidney failure) 2 (3) times as frequent, Phthisis (fibrosis of the lung) 1.6 (1.4). Of every 100 deaths amongst housepainters, there was an excess of 12 (13) deaths from the above diseases ascribed to lead (Former figures derived from union records, latter from Registrar General).[91] In contrast, J.H.Schooling, a statistician and actuarian giving evidence for the White Lead Corroders, calculated the Standardised Mortality Rate for painters and plumbers in England and Wales (Registrar General's figures for 1900-2) and pointed out that plumbism accounted for only 0.23 deaths p.a. per 1000 workers and constituted 1/54th of total deaths in that occupation which was seen as 'relatively trivial'.[92]

Incidence of Poisoning

The 'attack rate' of lead poisoning amongst housepainters was calculated (from the estimate produced by Dr. Legge). Its incidence was 4.8 per 1000 workers per year, compared to 84.6 for white lead workers and 25.6 for paint and colour workers, and 17.4 for the average of the 9 scheduled lead industries. The mortality rate per 1000 workers per year were, respectively, 0.29, 2.14, 0.46 and 0.76 for these groups for 1900-13. Thus although the total poisoning from housepainting was high, the relative risk to workers in the job was low. This was attributed to the seasonal nature of painting work and the use of lead free paints, both of which reduced the intensity of absorption of lead-paint dust in housepainting, and which Legge held (although the evidence for the statement is not provided) would reduce the incidence by over 75%.

As in the case of routes of entry/source of harm, the various criticisms of the evidence on the extent of harm from lead poisoning amongst housepainting appear to have had little impact on the findings of the committee.

Sunderland's dissenting Memorandum on the report reiterated all the evidence and opinion which suggested that the figures for lead poisoning might be an overestimate, questioning whether the data before the committee were "sufficient to justify .... the crippling of a large industry".[94] - i.e. the emphasis was on the uncertainty of the evidence rather than the lack of harm.

The issue which remained at the centre of the debate was the absolute number of victims of lead poisoning amongst housepainters (in particular the thirty deaths each year over the 1900-1913 period). Those who criticised the validity of these figures were only able to suggest that a proportion of cases might have been misdiagnosed.[95] They were not able to demonstrate that this proportion was substantial.

A major reason for this was the fact that the state (and the painting unions) had an effective monopoly of systematic information about lead poisoning amongst housepainters.

Though individual Master Painters (employers) expressed surprise at the number of cases of lead poisoning in housepainters, and stated that they did not know of cases of poisoning amongst their employees, they were unable to present serious countervailing evidence to weaken the impact of the Factory Inspector's statistics.[96]

The employers had not instituted medical examinations of their workers which might have provided them with counter-information on lead poisoning. The only countervailing evidence, produced by the White Lead Corroders' witnesses was fairly rudimentary, and did not directly refute the poisoning statistics.[97]

In retrospect it is possible to remark that the opponents of prohibition of lead paint made little impact on the subject of <u>relative risk</u> for housepainters compared to other trades. Though it was noted that the incidence (and thus risk to individual workers) of lead poisoning was much lower amongst housepainters than workers in lead processing factories, this was not sustained as an argument for the state not acting to reduce this harm.[98] The situation can be contrasted with current regulatory debates (described in Chapter 1) where the argument has been systematically advanced that certain levels of risk may be acceptable and that regulation should not be adopted for relatively minor sources of risk.

Similarly, although elements of an argument for balancing of risk against cost of control were presented (and in particular the effect of prohibition on capital and jobs in the white lead industry and lead mining and smelting, and on the balance of trade) these were not articulated into a specific cost/benefit argument.[99] The lack of a more general espousal of risk/cost/benefit analysis at that time may have been a significant factor here.

The committee thus established the existence of a massive burden of ill health and fatalities due to the use of lead paints in housepainting. It noted that "practically every witness whose attention was called to the figures, admitted that the extent of illness and death attributed to .... [the] ravages [of plumbism] was very deplorable, and agreed that immediate action should be taken to reduce it to a minimum".[100] This situation stands in contrast with many other regulatory debates in which regulatory action became subject to scrutiny at a time when scientific/medical knowledge about the harm was subject to a high degree of uncertainty, and became a critical aspect of the decision making process. This case study, of the extension of regulation to an unregulated industry, represents to some extent a simplified decision making process. The key issue in this debate thus became the technical and economic consequences of different regulatory strategies. Arguments against regulation at all, and in particular medical arguments were not the most significant aspects of the debate.

<u>The Exclusion of Considerations of Consumer Risk and Consumer Interest.</u>

One element of harm, which is central to present day regulation of lead in paints, is the hazard to the consumer/occupants of houses. At that time, lead poisoning had already been noted in householders whose homes had recently been painted and amongst children whose toys were painted with lead.[101] Indeed, in Queensland, a campaign conducted by two local doctors since 1898, had stimulated the local section of the British Medical Association to request in 1918 the Australian Federal Government to limit the amount of lead in paints to reduce the hazard of lead poisoning amongst children.[102] Despite these embryonic and sporadic references to consumer hazards, this issue was not taken up at the 1911 Departmental Committee, nor in the subsequent regulatory debate that continued until 1927. Consumer interests were not represented at the 1911 Departmental Committee.

This state of affairs can be related to political, administrative and scientific factors:

1) The terms of reference of the 1911 Departmental Committee Enquiry dealt solely with "the dangers to health of persons engaged in the painting of buildings" [and of "coaches, etc."][103] This is not surprising given the political debate leading to the establishment of the committee in which the gross levels of poisoning amongst housepainters figured overwhelmingly. Within the state the agency which played a key role in raising the issue was the Factory Inspectorate. Consumer hazards fell outside their jurisdiction and scope of expertise. This fragmentation of responsibility of the regulatory agencies must be seen in the light of the history of regulatory development.[104]

2) The expert witnesses from the Factory Department and industrial and academic circles derived their knowledge from occupational lead poisoning in other industries, consumer safety was not discussed by these witnesses at the committee. Moreover it must be borne in mind that

the hazards being investigated were of such magnitude that consumer hazards were insignificant in comparison. Consideration of consumer hazards came into the fore as diagnosis became more sensitive and as the threshold at which the effects of lead absorption were classified as poisoning (i.e. unacceptably harmful) fell, much lower levels of lead absorption were involved than in occupational lead poisoning, and attention focused on the hazards to health of specially sensitive groups (particularly children), and 'sub-clinical' effects.

3) The exclusion of consumer harm can also be related to the strategies of the different parties involved in regulatory debates. Thus the White Lead Corroders invoked the cost to the consumer of more expensive and less efficaceous paints. In contrast, the painters' unions and the proponents of prohibition failed to take up the parallel issue of hazards to consumers, or to develop an alliance with consumer interests.

Economic, Technical and Administrative Aspects of the Regulatory Debate

Introduction

The bulk of the enquiry of the 1911 Departmental Committees dealt with the effectiveness and consequences of the two regulatory strategies that were apparent :

Prohibition - of the use of white lead paint or

Regulation - enforcing precautions for the 'safe' use of lead paints (via a set of Regulations).

As noted in Chapter 1, these options represent divergent sites of control.

Prohibition involves changing the product (using safer substitutes for white lead pigment), leaving the process of painting unchanged.

Regulation introduces changes in the methods of use of the hazardous material. In painting processes (especially housepainting) there were inherent technical and economic obstacles to adopting the engineering controls etc. that had been successfully applied under the Factory Acts to control factory based lead processes. In these circumstances, Regulation focused on changing the individual's working methods, which was held by the Factory Inspectorate to be unreliable and impossible to enforce.

The major foci of the debate were :

1) the effectiveness of Regulation - the administrative and technical obstacles to adopting adequate safety precautions for the use of lead paint, and the consequences of this for painters.

2) the efficacy of 'leadless' substitutes for white lead and other lead pigments - the cost of procuring and applying lead substitute paints, and their performance, particularly regarding covering power and durability, relative to lead paint.

3) the macro-economic consequences of prohibition of white lead.

These three aspects are discussed in detail below. Notable features of the debate were as follows:

a) the different regulatory options had a radically different distribution of costs and benefits to the 'interested parties'.

<u>Regulation</u> put the cost and onus of compliance on to the paint users (Master Painters, painting workers), who also suffered the hazards.

<u>Prohibition</u> removed the hazard for paint workers (and pigment makers), and did not have costs for paint users (except insofar as lead free pigments were less durable and harder to apply).

However the white lead makers suffered very severe costs (viz the probable elimination of most of their industry).

(Imputed) Costs to the customer and costs to the state were also significant factors.

b) this uneven distribution of costs to/interests of the different affected parties was reflected in the regulatory strategy preferred by witnesses from different parties.

There were splits in the ranks of employers, most notably between the lead corroders (white lead manufacturers) and the paint makers and in particular the Master Painters - though the latter were less homogeneous and exhibited internal divisions.

c) this polarisation of attitudes to regulatory strategy was associated with a distinct polarisation of witnesses' assessments of technical aspects of regulation (particularly regarding efficacy of lead substitutes).

d) in contrast to the medical aspects of the debate, in which the state was the major and most authoritative source of information, information on the technical and economic aspects of the regulatory strategy was mainly derived from industry witnesses.

e) though there was residual opposition to lead substitutes, the majority of witnesses were in favour of their adoption and the prohibition of white lead paints - there had thus been a dramatic shift of opinion since the 1893 Departmental Committee.

The Effectiveness of Regulation

The committee found two 'self evident' alternative methods to mitigate lead poisoning in the painting trade :

i) controlling the industry by a strict code of regulations OR

ii) prohibiting the use of lead altogether (with narrowly defined exceptions).

Prohibition was held to be 'at once simple and effective' whilst Regulation was 'essentially complicated and less certain in its results'[105]

Medical expertise indicated that lead-laden dust was by far the biggest cause of danger. The measures adopted to regulate other lead processes under the Factories Act were evaluated for applicability to housepainting. Measures for the removal or avoidance of dust or spray were held to be of greatest importance. The chief sources of airborne lead were held to be the dry rubbing down of old paint prior to repainting, and the dry rubbing down of newly painted surfaces to prepare them for applying subsequent coats. Whilst the former could be (and frequently was) carried out with pumice stone and water, which released little dust, most painters believed that this could not be used for the latter, since, especially in the damp British climate, it would cause substantial delays in applying coats of paint, or interfere with the process of drying and impair the quality of the painted surface. Rubbing had to be done with sandpaper, which was not water resistant. Damping the painted surface with organic solvents (e.g. white spirit) when sanding, was held to be impracticable or unenforceable.[105]

Control Measures

There was little evidence of attempts by the paint industry to apply measures to prevent inhalation of this dust.

Thus the committee found impracticable the suggestions by some witnesses for the installation of local exhaust ventilation (on the grounds that the conditions of work would be too variable, and that electricity for extractor fans would not always be available) or for requiring workers to wear respirators (on the grounds that the committee could not find any respirator that was both efficient and that could be worn for any length of time).

Since the dust could not be removed at source/prevented, precautions would be needed to prevent accumulation and transfer of dust that might lead to lead absorption. Thus a code of regulations would need to include provision for :

- washing accommodation (including preferably hot water)
- mess rooms
- overalls (and then laundering - since paint spattered overalls had been found to carry and readily release sufficient lead dust to cause poisoning of workers and their families)
- storage for clothing
- limitation of working hours
- periodical medical examination
- compensation for those suspended from work.[107]

The experience of the Admiralty Dockyard in Portsmouth was cited. Although many of the above measures were provided for and presumably enforced, cases of lead poisoning still occurred. This raised questions about the effectiveness of the Regulation strategy even had it been rigorously adopted.[108]

The provision of the above amenities and precautions in the widely varying circumstances of housepainting was seen to be very difficult, if not impossible.

Moreover these precautions would incur costs which Master Painters were frequently unwilling to bear. For example most of the employers of housepainters giving evidence were unwilling to pay for replacement and laundering of overalls. A substantial minority were opposed to bearing the cost of medical examinations and compensation for suspended workers.[109]

Enforcement

The lack of voluntary adoption of hygiene precautions and the resistance by the painting employers to their compulsory requirements drew attention to the problems of enforcing a Code of Regulations.

The evidence from witnesses from Germany, Austria and Switzerland, where Regulations had been introduced, indicated that, whilst incidence of poisoning had to some extent been reduced, progress was slow, and poisoning rates were still unacceptably high. Regulations were very difficult to enforce in the large number of domestic premises being painted and their rapid turnover of work. Proponents of Regulation suggested that between 50 and 450 inspectors would be needed to carry out inspection and enforcement (compared to the complement of 200 in the whole Factory Department at that time). The cost of such inspection for the state was felt to be "too extravagant" for the committee to recommend.[110]

Attitudes of Painting Trade to Regulation

A bare majority of employers of housepainters giving evidence stated their preference for Prohibition rather than Regulation. Their views are summarised in Table 4.9.[111]

In addition, two resolutions were presented to the committee, one supporting Prohibition from the Liverpool Master Builders' Association and one from the National Association of Master Painters of England and Wales, which called for Regulation rather than Prohibition. The latter appears to have limited impact on the committee which concluded that those who voted "were not in possession of all the evidence that was laid before the committee".[112]

A significant component of the painting employers' opposition to Regulation was a strong "laissez-faire" attitude, expressed in resistance to the administrative and financial burden of following hygiene

TABLE 4.9. 1911 Painting of Buildings Committee : Preference by Painting Employers for Regulation or Prohibition

Evidence of 36 Painting Employers Specifically Questioned about their preference for Regulation or Prohibition

Source: 1911 Painting of Buildings Report p.90.[111]

(Not including 6 Master Painters brought before the committee by the White Lead Corroders, of whom 5 opposed Regulation the other was ambiguous.)

precautions stipulated by a Code of Regulations. This attitude predominated in the evidence of those painting employers who supported Prohibition in favour of Regulation. Thus the Liverpool Master Builders' Association had resolved unanimously that "They would rather vote for total prohibition of white lead than be hedged in with any regulations or restrictions".[113] A similar attitude is evident in the statements of individual witnesses.[114] In some cases this appears to have been a spontaneous reaction to the realisation that legislation was being proposed, and the precautions that would be involved under Regulation, rather than a considered opinion.[115]

In contrast to Regulation, Prohibition was seen as involving no direct costs to painters (though the customer might be affected by inferior paints) and ensuring equality of competition (i.e. preventing non-compliant employers from gaining an advantage).[116]

The witnesses from the painters' unions were wholehearted in their support for prohibition.[117]

The Rejection of Regulation

The committee concluded that it was impossible to deal with lead poisoning by Regulation "for four principal reasons :

- i) the inadequacy of regulations to cope with the [lead poisoning] evil,
- ii) the difficulty of prohibiting dry rubbing down,
- iii) the cost and difficulty of complying with the various precautionary measures,
- iv) the insuperable (sic) difficulty of enforcing regulations by adequate inspection."[118]

Thus the rejection of Regulation appears primarily as a consequence of its inadequacy as a means of controlling lead poisoning in painters not only for technical reasons but also because of the economic and administrative costs of its enforcement. The enforcement costs to the state were a major consideration.

(In contrast, difficulties in enforcing prohibition were not seriously considered.)

This decision was taken against a background of a painting industry that lacked a coherent position and was internally divided. Moreover there was no basis of voluntary compliance in the industry, which accentuated concern about the feasibility of enforcing Regulation. This situation contrasts sharply with the 'normal' process of consensual regulatory development described earlier.

The lack of consensus and voluntary compliance and the strong laissez-faire tendency amongst Master Painters can be related to the nature of the painting trade - the variable and seasonal nature of the work, its constantly changing location and circumstances of operation, and above all its decentralisation with 20,000 small painters, spread between Master Painters', Decorators' and Builders' Trade Associations.

The Efficacy of 'Lead Free' Substitutes for White Lead and Other Lead Pigments

Introduction

Bearing in mind these difficulties of controlling the hazards of using lead paints by means of regulations to enforce hygiene precautions, the committee felt that it was "evident that theoretically the prohibition of the use of lead would be by far the preferable policy to adopt, but the question arises whether or not its abolition can be carried into effect without causing undue detriment to the Trade". Since lead was the principal pigment for oil paints, especially for exterior use, the committee asked two questions :

1) "Is there a reasonable certainty that leadless paints would be efficient for all purposes?
2) Would the supply of such materials be sufficient to meet all the requirements of the trade?" [119]

The first of these questions was a critical issue in the 1911 Departmental Committees, and became even more contentious in the subsequent regulatory debates. At the 1911 committee, the overall finding was that efficacious substitutes existed or could readily be developed. Subsequently, the major thrust of opposition to prohibition of white lead attempted to refute this.

The opinions of the paint trade which in 1893 had barely considered the possibility of substitutes, shifted radically at the 1911 enquiry. After World War I the balance of opinion had shifted back again, to support the continued use of white lead. It is therefore worth considering the evidence submitted by the painting trades to the 1911 Departmental Committee in some detail.

The evidence of the witnesses is highly contradictory even on readily ascertainable questions such as cost (and sometimes internally contradictory). Although more developed since the 1893 Departmental Committee, there was a marked lack of systematic knowledge of the issues under discussion, and even of standards for defining the properties of paint and pigments (e.g. terms used such as covering or spreading power, durability, etc.).

Substitutes Considered for Lead Pigments

The principal substitute for White Lead referred to is Zinc Oxide. Though reference was made to Antimony Oxide and Zinc Hydrate, there was little experience with the use of these materials. Lithopone, surprisingly was not specifically referred to, although it was noted that distempers had largely replaced lead paints for painting ceilings and other plasterwork (these were typically based on lithopone). Lead Sulphate was seen as preferable to white lead on account of its lower solubility in hydrochloric acid (and presumably its lower ease of absorption into the body). Grey and black paints (used in industrial work and civil engineering) based on silica, graphite and bitumen were referred to.

For coloured paints, 'a variety of lead-free materials had been available for many years'. The significant uses of lead based colours were Lead Chromate - for red-yellow paints and in greens; Lead Oxide - for red paints. Both were used (especially the latter) in rustproofing and anti-corrosion paints. (Their substitution by red Iron Oxide was proposed). However, the main point of issue was the substitution of white lead, primarily because it was the most widely used pigment in the painting of buildings, both as the sole pigment in white paint and as a significant component of coloured paints. The coloured lead pigments were not a major issue,

i) because they were used in much smaller quantities in housepainting,

ii) because of the wide variety of substitutes that were in use. Although some of these were 10-50% more expensive than lead colours, their low concentration of usage would result in a marginal increase in cost of paint (1-5% for yellow paint).

iii) the exemption of paints with below 5% soluble lead by weight from prohibition allowed the continued use of Lead Chromate (and a proportion of Lead Sulphate).[121] This exemption was based on the precedent of controlling lead in potteries, and was adopted primarily to allow the use of 'direct' Zinc Oxide as well as lead based driers.

The regulatory debate thus focused on the possibility of obtaining substitutes for white lead pigment. The views of the various witnesses on the relative efficacy of white lead and zinc pigments (in most cases, zinc oxide is specified, however some witnesses may also be referring to lithopone) is analysed in detail.

<u>The view of the Different Parties on the Efficacy of Zinc Pigments as Substitutes for White Lead</u>

The views of the various groups of witnesses to the 1911 Committee on Painting of Buildings are summarised in Tables 4.10 to 4.12.[122]

Table 4.10 Summarises the overall views of witnesses on the performance of zinc pigments relative to white lead, for all witnesses and also distinguishes between witnesses supporting and opposing <u>Prohibition</u>.

Table 4.11 Distinguishes the views of the different parties giving evidence on the performance of zinc pigments relative to white lead.

Table 4.12 Shows the Relationship between the propensity to give evidence on pigment efficacy and attitudes to prohibition of the major groups of witnesses.

TABLE 4.10. 1911 Painting of Buildings Committee: Summary Views of Witnesses on Performance of Zinc Pigments Relative to White Lead, for All Witnesses Supporting and Opposing Prohibition.

The witnesses giving evidence on efficacy were made up as follows:

THOSE OPPOSING PROHIBITION: 6 Master Painters, 2 Paint Makers, 1 Ship Painter and 7 Witnesses, presented by the White Lead Corroders (including 5 Master Painters).

THOSE FAVOURING PROHIBITION: 12 Master Painters, 5 Painting Workers, 12 Paint Makers and 2 Consultants, 4 Master Ship Painters and Witnesses from Cadbury Painting Department, Home Department, Office of Works (2), RIBA (2).

THOSE AMBIGUOUS ABOUT PROHIBITION: 1 Master Painter presented by the White Lead Corroders and 1 Paint Consultant were ambiguous or did not specify their views.

TABLE 4.11. 1911 Painting of Buildings Committee :
Views of Different Parties on Performance of Zinc Pigments Relative to White Lead.

Royal

Aston University

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Source: 1911 Painting of Buildings Report. pp.4-74 [122]

NOTES TO TABLE 4.10

a) Not including Consultant to Paint Makers and White Lead Corroders Witness (Master Painter) ambiguous about Prohibition.

b) "Covering Power worse but Spreading Power better". sic

c) "Spreading Power worse".

d) "External durability worse, but same if varnish added".

e) "Durability worse in sulphurous fumes".

f) "Durability same or better if varnish added".

g) 2 witnesses noted poor internal durability in damp conditions.

STATEMENTS BY OTHER GROUPS

2 Bridge painters favoured Prohibition and substitutes for red lead paints.

3 Manufacturers of 'lead free' coloured pigments gave evidence in favour of Prohibition.

2 Lead Pigment Manufacturers opposed Prohibition

None of these witnesses presented evidence about the efficacy of Zinc Pigments.

TABLE 4.12 1911 Painting of Buildings Committee:
Relationship between Propensity to Give Evidence on Pigment Efficacy and Attitude to Prohibition of Major Groups of Witnesses

Source: 1911 Painting of Buildings Report pp. 4 - 74.

All Groups

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Aston University
Illustration removed for copyright restrictions

For the purposes of this comparison, witnesses whose evidence related solely to industrial hygiene, and those who referred only to coloured pigments and paints (e.g. Bridge Painters, Coloured pigment manufacturers), are excluded. The remainder are therefore affected parties and 'expert' witnesses concerned with the use of white lead/substitutes in the painting of buildings. Though included in the above tables, the views of the ship painters represent an untypical case because of the different requirements of marine paints, which were frequently repainted because of the physical abrasion to the paint. The ship painters were largely in favour of zinc paints, but their requirements for paint performance were very different.[123]

Table 4.10 demonstrates a wide range of opinions on all aspects of the performance of zinc pigments/paints relative to white lead. This is so for easily ascertained matters (e.g. pigment price) as well as those which could only be determined on the basis of experiment and experience (e.g. overall cost of painting job, durability of paint). Indeed, on the topic of covering power, the majority of opinion falls into contrary positions, that zinc pigments were superior (10 witnesses) or inferior (10 witnesses) to white lead, with only a small group (4 witnesses) arguing that the two were comparable.

Differences can be noted between those favouring and those opposing Prohibition in both the assessment of performance of zinc pigments and in the homogeneity of assessments. Where the opponents of Prohibition gave evidence, they unanimously held zinc pigments to have inferior performance to white lead in all characteristics (covering power, ease of application, pigment cost, overall cost of painting work, and durability of paint in exterior applications) except for interior durability of paint whose performance was held to be comparable. In contrast the supporters of Prohibition had a much more varied assessment of relative performance, which included more favourable assessments of zinc pigments. Table 4.11 shows that the different groups of witnesses not only exhibited divergent attitudes to prohibition, but also a varying propensity to give evidence regarding relative performance of zinc pigments to white lead.

The relationship between assessment of the relative performance of zinc pigments, attitudes to Prohibition, and the experience, policy and interests of the different groups of witnesses is very complex. However the existence, in the evidence to the 1911 Committee on Painting of Buildings, of a detailed survey of these views in 84 witnesses provides a valuable opportunity to assess the significance of knowledge, experience and interest in determining attitudes to Prohibition

A detailed analysis has been undertaken to elucidate the relationship between these factors. Given the degree of ambiguity and indeterminacy in these relationships, interpretation can be little more than speculative.

The diversity of opinion on aspects of paint performance requires consideration of the ways in which the properties of paints and pigments were understood at that time and currently.

Terms Used in Judging the Relative Performance of White Lead and Zinc Pigments

The properties of pigments/paints discussed at the 1911 Committee on the Painting of Buildings were covering power, ease of application, pigment cost, overall cost of painting, external durability (of paint applied to exterior surfaces), and internal durability (of paint applied to interior surfaces of buildings).

Durability of paints (particularly in exterior applications) was by far the most frequently discussed property, followed by covering power and then pigment costs - indicating the relative importance of these factors in the regulatory debate. These properties will be examined in turn.

Durability of Paint : The effects of substituting white lead by zinc pigments on the durability of the painted surface was the most keenly debated aspect of pigment performance. Opposition to prohibition centred around the inferior durability of zinc based paints. However this view of pigment properties as determining the durability of the paint requires further consideration in the light of subsequent changes in paint technology.

The changing understanding during the Twentieth Century of the role of pigments in paint performance is described in Chapter 3.

The traditional view, which saw pigment properties as the key to paint durability has been replaced by a more complex understanding of the contribution of a paint to paint performance. A wider range of materials are currently used in formulating paints, to provide greater control over paint properties.

Generally the effect of pigments on performance depends on the matching of pigment properties (e.g. alkalinity) to the vehicle system being used. In addition some alkaline pigments impart corrosion inhibiting properties and are used in certain protective paints for metal surfaces.

With the benefit of hindsight, many of the problems in the early Twentieth Century in formulating durable lead free paints can be seen to have stemmed from the lack of knowledge about how to formulate paints in the zinc pigments compared to the white lead pigments traditionally used.

Even in 1911, some of the proponents of zinc pigments drew attention to the need for changes in vehicle formulation to make durable 'lead free' paints.[124] For example, the addition of varnish to zinc/linseed oil paints to make gloss paints known as enamels or varnish paints. (Zinc Oxide was traditionally used in such enamels). Experiments with changes in the drying oils used and the dryers had also been undertaken.[125]

The views expressed on paint durability at the Committee On Painting of Buildings can be summarised as follows:

i) Amongst witnesses opposed to <u>Prohibition</u>, external durability of zinc paints was the property most frequently commented on and was unanimously held to be inferior to lead paints.

ii) Witnesses favouring <u>Prohibition</u> showed a wide spread of opinion, with a majority holding zinc paints to be equal or better than lead. They frequently pointed to the importance of vehicle composition (e.g. by adding varnish). In contrast such observations were wholly absent from the evidence of opponents of Prohibition.

iii) Internal durability of zinc based paints was less frequently commented on than external durability, and was generally held to be broadly equivalent to lead based paints. A significant number found that zinc had superior internal durability since it did not blacken in the presence of hydrogen sulphide fumes (unlike white lead which was converted to black lead sulphide in these circumstances). Conversely some witnesses held that zinc white would not perform adequately internally in damp conditions.

Although the statements by the different parties appearing before the 1911 Departmental Committee were highly contradictory, and an unambiguous systematic comparison of the <u>relative</u> durability of lead and zinc based paints was absent, the committee was able to collect a large body of reports from users of leadless paint, in which not only the durability, but also the colour, finish, pigment cost and overall cost of painting with leadless paints had been comparable or better than lead based paints.

Covering Power : As noted above, this was the second most frequently cited property of pigments at the 1911 Painting of Buildings Committee, and opinion on the relative performance of white lead and zinc pigments is polarised. The opponents of Prohibition unanimously stated that zinc pigments had inferior covering power, whilst the supporters exhibited a range of views - most judging the hiding power of zinc to be superior.

However, the very existence of different opinions on the subject is remarkable, since covering power is presumably a constant physical property of a material. Though neither authoritatively defined, nor in current use, the term covering power seems to describe the same characteristics as the current term - hiding power. A pigment's hiding power is determined by its colour, refractive index (constant for a given crystalline form) and particle size [127] (though in the case of white pigments, colour is of minor significance).

As noted in Chapter 3, measurements of hiding power conducted since 1922 have always shown zinc oxide to have greater hiding power to white lead though the relative advantage has ranged in magnitude in assessments from 15% (1922) to 76% (1931).[128] This difference in scale was attributed to changes in the criteria and equipment used to assess hiding power, although other factors such as changes in particle size and crystalline form could not be ruled out (e.g. changes in particle size, crystalline form and chemical composition). Around 1911, 'expert assessments' of pigment hiding power were unsystematic and frequently ambiguous, however the view that zinc oxide covers as well or better than white lead appears to predominate.[129]

This is a marked reversal of expert and trade opinion in the Nineteenth Century (e.g. the 1893 Departmental Committee). From the available evidence, it does not appear that the view that zinc oxide had inferior hiding power to white lead (in 1893 and by a substantial minority in 1911) can be attributed to changes in the chemical and physical properties of the pigments.

One possible explanation for the disagreement between witnesses at the 1911 Departmental Committee is the lack of a precise definition of the term covering power. Whilst hiding power is defined as the ability of a given weight of pigment mixed into paint to obscure the surface being painted, covering power is used to describe the opacity of a coat of paint as it was applied (usually without specifying the thickness of the paint layer or the concentration of pigment used in the paint).

Munby, representing the Royal Institute of British Architects, stated at the 1911 Departmental Committee that "the covering power of zinc is worse, but its spreading power is better"[130] than white lead. Such a statement could be consistent with scientific assessment of hiding power (zinc greater than lead) if the zinc paint was being applied at a lower concentration than white lead (i.e. due to its greater spreading power). Because of its lower density (70-90% that of white lead) a given weight of zinc oxide had to be mixed with a larger amount of linseed oil to produce a paint of workable consistency than white lead. (For example, zinc oxide required 19% by weight of linseed oil to make a stiff paste as opposed to 7-9% for white lead,[131] a greater volume of zinc paint, with lower pigment concentration would be produced. This suggests an explanation for the discrepancy of views on the covering powers of zinc oxide and white lead - that those believing zinc white had inferior covering power were referring to the performance of a given volume of paint while those believing the opposite were referring to a given mass of pigment.[132] However, if this explanation is correct, one would expect those witnesses finding zinc to have a lower covering power than lead to assess the other properties of these pigments/paints on a 'paint volume' rather than a 'pigment weight' basis - and in particular, to state that they found zinc paints to cost less than lead paints. In fact there is no relationship between the statements of witnesses on covering power and on the cost of pigment/paint or the overall cost of painting work with zinc and lead pigments.

Thus if the divergent assessments are due to differing definitions of covering power (by volume or weight) there is a discrepancy with witnesses statements regarding the cost of paints/pigments.

It is interesting to note that paint manufacturers' assessments of covering power corresponded more closely to current scientific assessments than master painters' assessments. The only paint manufacturers stating that zinc had inferior covering power to lead were a lead paint maker presented by the White Lead Corroders and an independent witness from a firm that made mainly lead paints. The other paint makers (who were partly or wholly involved in zinc paint manufacture) held zinc oxide to have equal or better covering power.

Whilst a mechanistic relationship between trade interest/attitude to prohibition and assessment of hiding power cannot be demonstrated, there is clearly an interesting and striking fit between these factors, for which no satisfactory alternative explanation is available.

Cost : There was a wide spread of opinion regarding the simple question of cost of pigment (8 witnesses held that zinc cost more, with 3 saying that it cost less and 6 that it cost the same). However this spread does not seem to be a result of attitudes to Prohibition (since 16 out of the 17 witnesses giving evidence of pigment cost were in favour of Prohibition. Several witnesses commented that the cost of specialised pigments such as zinc pigments was flexible, with the larger consumers (e.g. the Office of Works) being able to obtain them on more favourable terms.[133]

A similar spread of views is found regarding the overall costs of the job with different pigments. It must be remembered that labour was the single largest cost in a painting job, exceeding materials costs by a factor of between 2 and 3.[134] Pigment cost was therefore less significant than questions of covering power (affecting the number of coats of paint needed) and durability (affecting the frequency of repainting). Despite this, ease of application does not seem to have been a major matter of debate.

The failure of the opponents of Prohibition to comment on paint/pigment costs (in contrast to those supporting prohibition) may reflect a lack of information on these matters - that would be consistent with their having less experience of lead-free pigments/paints.

The Views of the Different Groups of Witnesses

These are detailed in Table 4.11, which also distinguishes between those Master Painters supporting and opposing Prohibition.

Of the different groups giving evidence, the painting workers' union representatives and the White Lead Corroders' witnesses stand out by virtue of the unanimity of their viewpoint not only regarding the outcome of the enquiry (they gave unanimous support and opposition respectively to Prohibition) but also regarding their evidence on efficacy.

The painting workers held durability to be the same for zinc as lead - this was the only aspect of efficacy they addressed and the technical aspects of their evidence were limited.

The witnesses presented by the White Lead Corroders focused on the alleged inferior durability of zinc to white lead paints on exterior applications (durability on interior application was held to be the same) with additional comments on cost, ease of application and covering power of zinc pigments (which were held to be inferior).

It could be argued that for these groups of witnesses an examination of the technical etc. problems associated with Prohibition was secondary to the group's direct interests, and that the viewpoints of the witnesses were unanimous due to the internal coordination of policy amongst the painting unions and the selection of witnesses for the White Lead Corroders.

The views of the other two major groups : Paint Makers and Master Painters are of greater interest.

Paint Makers : These included 3 representatives of the Colour, Paint, Oil and Varnish Trades Association (one of whom worked for a zinc paint maker and the other two were not associated with a particular kind of paint), and two Zinc Oxide manufacturers (from Belgium and France respectively). The remainder represented paint making companies of which 5 were described as dealing with zinc paints alone, whilst the other 5 made both lead and zinc paints. The views of the paint makers have been broken down according to their involvement in making lead and/or zinc paints, in Table 4.13. This table does not include the maker of white lead paints

Views of Paint Makers on Performance of Zinc Pigments Relative to White Lead

According to attitude to Prohibition and involvement in making Zinc or Lead Paints.

		All Paint Makers	Lead and Zinc Paint Makers	Zinc Oxide Manufacturer	Zinc Oxide Manufacturer	Paint Makers Supporting Prohibition	Paint Makers Opposing Prohibition
Total Number of Witnesses		15	7	6	2	11	4
No.of Witnesses Favouring Prohibition		11	4	6	1	11	
Witnesses Giving Evidence about Efficacy		14	6	6	2	11	3
Covering Power	Better	5	2	2	1	5	
	Same	2		2		2	
	Worse	1	1				
Ease of Application	Better						
	Same						
	Worse						
Pigment Cost	More	4	2	2		4	
	Same	4		3	1	3	1
	Less	2	1	1		2	
Overall Cost	More	2	2			1	1
	Same						
	Less	3		2	1	2	1
Durability in External Use	Better	1		1		1	
	Same	4	1	2	1	4	
	Worse	3	3			1	2
	Better if Varnish Added						
	Same if Varnish Added	2	1	1		2	
Durability in Internal Use	Better						
	Same	4	2	1	1	4	
	Worse						

presented by the White Lead Corroders, nor a manufacturer of lead sulphate pigments. It is clearly not representative of the paint making trade as a whole, due to the significant number of firms represented who made only zinc paints.

Not surprisingly, the paint makers provide the most frequent comments on pigment/paint performance - especially regarding cost and covering power. Their assessments, are generally more favourable to zinc than those of the master painters and this is most marked amongst both those manufacturers supporting prohibition and amongst those involved only in making zinc paints. However several firms making both lead and zinc paints were in favour of prohibition (4 out of 7). Mr. Carson, giving evidence for the now renowned firm of Berger argued that "prohibition ... would give an impetus to manufacturers to find efficient substitutes" and would not hurt them.[135]

It is important to remember that Prohibition of white lead would have potential benefits for paint makers, particularly those with experience of mixing 'lead free' paints, by increasing the demand for ready-mixed paints (as opposed to paints mixed 'on site' by craftsmen, who had less opportunities to develop the technology of zinc paint formulation). Though the conversion to 'lead-free' paints would involve technological problems (of paint formulation) they would not increase capital costs. However the paint making industry (as a separate entity from pigment manufacture) was small in 1911 and had relatively little influence.

The Master Painters: The views of the Master Painters on paint performance are presented in Table 4.11, distinguishing those supporting and opposing Prohibition.

Master Painters opposing Prohibition gave uniformly negative assessments of the performance of zinc paints relative to white lead (regarding external durability and covering power). Master Painters supporting Prohibition exhibited more heterogeneous assessments of relative performance with a greater tendency to produce favourable assessments of zinc paint. However, an explanation of Master Painters' attitudes to Prohibition as a simple consequence of their assessment of relative performance of zinc and white lead paints as many supported Prohibition despite critical evaluations of zinc paint.

A more significant difference between Master Painters supporting and opposing Prohibition appears to be their amount of experience with zinc paint. Only 6 out of 17 Master Painters partly or wholly favouring Regulation could refer to experiences with leadless paints compared to 12 out of 19 favouring Prohibition (If the Scottish Master Painters are excluded these figures become 2 out of 10 and 11 out of 18 respectively). The Master Painters favouring Regulation only referred to one aspect each of paint performance whereas those supporting Prohibition referred to an average of two aspects (covering a much wider range of aspects of paint performance).

This indicates that those Master Painters favouring Prohibition were more likely to have experience of leadless paints and had apparently carried out a more systematic or extensive trial of these paints.

The Master Painters supporting Prohibition may have been an atypical self-selected sample of employers in the industry. Several had conducted experiments in 'lead free' paints over an extended period because of their concern about the health hazards of lead paint. One referred to "a prejudice in the painting trade against anything new".[136]

Miscellaneous Paint "Users" : In addition to the various sections of the paint industry, a number of witnesses concerned with the maintenance of buildings gave evidence regarding the efficacy of 'lead free' paints, namely : Munby and Wonnacott of the Royal Institute of British Architects, Mr. G.D.Patterson (Clerk of Works) and Sir Henry Tanner (Principal Architect) of the government's Office of Works, and Morley of Cadburys. Their experience, as 'disinterested users' had special significance at the enquiry. They exhibited a range of opinions on pigment performance - arguing in particular that the overall costs of zinc paints were comparable with those of lead, whilst the interior durability of lead was superior (since it did not blacken on exposure to hydrogen sulphide). These witnesses all supported Prohibition.

The Relationship between attitude to Prohibition and Evidence Regarding Performance of Lead and Zinc Pigments

The relationship between attitude to Prohibition and extent and content of evidence regarding relative performance of zinc and white lead paints, identified amongst Master Painters appears also to exist amongst all groups of witnesses as a whole. (See Table 4.10). In particular this shows that the opponents of Prohibition gave evidence on relative performance of zinc and white lead paints less frequently, covered a narrower range of issues and produced uniformly negative assessments of zinc performance. The superficial explanation for the latter observation - that these witnesses opposed Prohibition simply because of the inferior performance of zinc paints - is inadequate since it does not explain the behaviour of supporters of Prohibition and since knowledge about paint performance at that time was limited or ambiguous and could not sustain (and even in some cases such as covering power directly refuted) the 'unanimous' views of the opponents of Prohibition.

The relationship between attitude to Prohibition and propensity to give evidence about pigment performance of the major groups is shown in Table 4.12. The exceptional group amongst the opponents of Prohibition is those witnesses presented by the White Lead Corroders - who were selected on the basis of their expertise and their opposition to Prohibition. Amongst the other groups there appears to be a correlation between support for Prohibition and propensity to give evidence on efficacy of zinc and lead paints. Applying the 'chi-squared' test to this relationship amongst 'all groups except white lead witnesses' showed this relationship to be highly significant at a level of less than 1%.[137] (If the witnesses presented by the White Lead Corroders are included, the relationship lies just outside the 5% level of significance).[138]

There is evidence of a significant correlation between ability to give evidence regarding relative efficacy of zinc and white lead paints and support for Prohibition amongst most of the groups of witnesses (in this, as suggested earlier, painting workers' and the white lead corroders' witnesses may be exceptional). This does suggest that the opponents of Prohibition had a weaker knowledge base than the supporters. The position of the supporters of Prohibition could be characterised as acceptance, based on critical awareness of the problems of applying substitutes for white lead paints.

The Conclusions of the Committee Regarding 'Lead Free' Substitutes for White Lead

The 1911 Committee on Painting of Buildings, recommended that the sale or use of paints containing (over 5% soluble) lead should be banned three years from the publication of its report.

This recommendation was based on a number of findings about the relative performance of zinc and white lead paints.

1) "it was quite possible to dispense with lead paints for the painting of interior surfaces"

2) that although there had been problems in the performance of leadless paints on exterior surfaces, there were many examples where "with only a moderate persistence", Master Painters had been able to discover leadless paints with "satisfactory" exterior performance. A wide range of leadless paints were available from Paint Makers, and a large body of reports from the users (i.e. customers) of these paints corroborated their claims of efficacy. The evidence of the Office of Works, which had been using leadless paints since 1907 was particularly influential .

3) the committee noted the lack of any "systematic attempt" to discover lead substitutes by the painting trade - which they attributed to "lack of interest" in the question of lead poisoning and "a real prejudice in the trade" against new materials.

4) the committee judged that "legislation affecting the amount of lead permissable in paints would give a great impetus to the manufacture of non-poisonous substitutes".[139]

Thus the regulatory strategy recommended by the committee rested not on a proven technology, but on one which was at that time imperfect. In reaching this recommendation, they had prioritised the views of those who argued that substitution of white lead was feasible over those who argued that (at least for exterior surfaces) 'lead free' paints had inadequate durability. Such a recommendation was clearly related not only to the number of witnesses on either side, but to their "technical credibility". The views of the opponents of Prohibition were thus over-ruled. However, the subsequent collapse of the Prohibition strategy can be largely attributed to the success of the White Lead Corroders in re-opening this debate. It is useful therefore to examine their strategy emerging at the 1911 Departmental Committees and subsequently victorious.

The Position of the Opponents of Prohibition

As already noted, the painting employers were strongly divided, both in their evidence regarding substitution of white lead (which had a limited, and highly variable technical base) and in their policy regarding Prohibition.

The White Lead Corroders presented their objection to Prohibition not only on the grounds of protecting their industry and interests, but also on the basis of the interests of the painting trade and customer (and the national economy). In particular they attempted to project a position for the painting trade. Six of the eight witnesses presented by the White Lead Corroders to deal with technical aspects of the regulatory strategy were themselves Master Painters (mainly from European Painters Federation - the other two being a consultant to and an employer from the White Lead industry). In addition, through the London Chamber of Commerce, the Corroders conducted a survey of practices and attitudes to lead and zinc paints amongst Master Painters.[140] This indicated that only a minority of the painting trade felt that white lead could be substituted for exterior paints.[141] Though it had little influence on the outcome of the 1911 Departmental Committees, it does indicate that the balance of opinion amongst Master Painters giving evidence at the committee was not reflected amongst the industry. Moreover there is evidence of a hardening of attitudes in the trade against substitution/ prohibition.[142]

The other aspect of the opposition to Prohibition was an attempt to refute or discredit the evidence that supported the feasibility of substituting zinc for white lead pigment in paint. This was most marked in Sutherland's dissenting Memorandum to the Committee's report, almost half of which was devoted to this question.

Sutherland's Memorandum sought in particular to undermine the evidence of the successful use of leadless paints claimed by the Office of Works,[143] which, he suggested had 'coloured the whole enquiry'. The evidence of Patterson, (Clerk of Works) was held to be 'unsystematic', 'inadequate' and 'worthless from a scientific point of view'.

The crux of this criticism rested on the Office of Work's use of proprietary, ready mixed paints, which were not 'impersonal products' but were made according to secret formulae. The durability of these paints was not questioned, but rather the addition of varnish etc. to the paint vehicle. In contrast Sutherland attempted to impose a traditional definition of a paint which "in the generally accepted use of the term is a substance mixed from ordinary pigments, to which are added oil, and turpentine for thinning purposes and dryers to make it dry". Sutherland noted that "the great bulk of the paint used in this country is entirely innocent (sic) of varnish".[144]

Thus Sutherland's criticism rested on the association between the use of varnish and inferior quality paints and the insistence that changes in pigment should not be associated with changes in the methods of paint formulation.

Though Sutherland's position was rejected by the rest of the Committee on Painting of Buildings, the arguments he raised were to be a major factor in the subsequent debate.

Consequences of Prohibiting White Lead

The third major area of debate concerned the economic consequences of prohibiting white lead.

The London Chamber of Commerce, representing the White Lead Corroders, presented evidence on the economic costs of prohibition of white lead.[145]

The British white lead industry produced 57,946 tons of white lead in 1910. Imports amounted to 14,436 tons and exports 20,219 tons leaving total home consumption of some 52,000 tons, of which 3,000 were estimated as being used for purposes other than painting. Prohibition would thus reduce the scope for production of white lead in Britain to 23,000 tons (although this might be further reduced by enhanced competition for the export market).

This move would substantially affect the white lead industry which employed 2,489 workers, with a capital value of £1,234,000. In addition there would be a 25% reduction in consumption of pig lead in Britain which would affect the prospects of the lead mining and smelting industry which employed respectively 2,678 and 730 workers.

Since there were only three zinc pigment manufacturers in Britain, which would not be able to produce the additional 34,000-50,000 tons of zinc pigment needed if Prohibition were introduced, the Lead Corroders argued that Britain would be dependent on importing pigments for painting. The increasing consumption of zinc pigments would inflate the price of zinc and therefore the costs of substitution.[147]

The committee's deliberations made light of these obstacles. They noted that the British Empire was a major producer of zinc ore and metal as well as lead (see Table 4.14)[148] and that there was a current surplus of zinc production, which had risen by 30% between 1903 and 1910 (whilst prices

TABLE 4.14. Production of Zinc and Lead in Britain, the British Empire and the rest of the World 1909.

	Zinc Production Thousand Tons	Lead Production Thousand Tons
Great Britain	4	23
British Empire	151	204
Rest of World	701	826

Source: Painting of Buildings Report *op.cit.* p.68.

fell by about 6%). They concluded that there were plentiful supplies of materials for leadless substitutes and moreover that Prohibition would stimulate the development of a domestic zinc pigment market as well as 'lead free' pigments from other materials (e.g. Antimony Oxide).

The economic impact of Prohibition was judged by the committee as "by no means large". Moreover it considered that "such questions might well be regarded as outside its terms of reference".[149] Thus despite the availability of (albeit imperfect) evidence about the relative costs of the difference regulatory strategies, this was not a major component of the deliberations of the committee - which was primarily concerned with the feasibility of the different regulatory strategies.

Whilst this concern with feasibility did include economic considerations (e.g. costs of enforcement of Regulations, a requirement that lead free substitutes were not substantially more expensive than white lead), it was the ability of the strategies to control lead poisoning in housepainters that predominated.

The Coach painting Committee

As noted earlier, the Committee of Painting of Buildings overlapped in terms of personnel, activities and matters considered with a Departmental Committee on the Use of Lead Compounds in Painting of Coaches etc.[150] Rather than analyse the proceedings of this committee in detail, the key aspects relevant to housepainting and the regulatory debate will be noted.

Though this committee considered questions relevant to industrial painting as a whole (and even considered evidence from safe making) the main emphasis was the painting of vehicles including the railway wagon, tram, motor car and perambulator trade as well as 'coaches'. This was a small trade involving directly some 18,866 workers in 1911 (as opposed to 181,000 housepainters) which had been responsible for an average of 72 cases of lead poisoning per year during 1900-1913, approximately 4 of which were fatal.[151] Moreover the rate of poisoning had been increasing or static in contrast to the other lead processes which were subject to specific Regulations under the Factories Acts with the result that by 1909, coachpainting contributed more to lead poisoning figures than any other single industry under the Factories Acts.

White lead was used in painting and as a putty like paste (jointing) to fill cracks between (especially wooden) panels. As with housepainting, the biggest danger was determined as arising from dry rubbing with sand-paper of lead painted surfaces - in particular of wheels, releasing airborne dust. As noted earlier, the Factory Inspectors were able to directly determine lead exposure in the coachpainting factories they inspected.[152]

Following the Committee on Painting of Buildings, the Coachpainting Committee considered the alternative regulatory strategies of Prohibition or Regulations/

Feasibility of Regulations

Since coachpainting was conducted on factory premises, health precautions in use of lead paint were held to be technically, economically and administratively possible to enforce - in contrast to the housepainting industry (e.g. enforcing wet pumicing of surfaces, or installation of engineering controls and in particular local exhaust ventilation). In addition, ancillary precautions (such as the provision of washing facilities etc.) were held to be more feasible.[153]

Prohibition of White Lead

Nine representatives of coachpainting etc. employers gave evidence. Most expressed surprise at the level of poisoning in coachpainting. When given details of the Code of regulations that would be required 7 said they would prefer prohibition to regulation and only 2 supported regulation. Ten witnesses including craftsmen and employers gave evidence or were visited by the committee to investigate their successful use of leadless substitutes in painting and jointing. 'Leadless' pigments considered included Zinc Oxide, Lithopone, Whiting (with Japan varnish), Lakes and were found to be as durable and in some cases cheaper than lead paint. A major factor facilitating the adoption of these materials was the different finish required for coach paints than house paints. The use of colours was more frequent, and coach paints were typically finished by several layers of varnish.

The advantages cited of adopting 'leadless' substitutes for white lead in painting or jointing are summarised in Table 4.15.

As Table 4.15 shows, one half of the firms who had adopted substitutes for white lead claim to have done so because of the discovery of lead poisoning amongst their workforce (a degree of 'voluntary compliance' with Prohibition that far exceeded that in housepainting). Whilst humanitarian concern may have played a more important role amongst vehicle painting than housepainting (backed up by the differing market, production and industrial relations etc. situation in these industries) there are indications that informal regulatory pressures may also have played a role (including the threat of compensation and informal visits/encouragement from the Factory Inspectorate). Daimler cars for example had converted to leadless materials following visits by the Factory Inspectorate to investigate cases of lead poisoning there.

TABLE 4.15. 1911 Coachpainting Committee:
Advantages Cited by Coachpainting Employers who had adopted Lead Substitutes in Painting and Jointing

Visited by Committee	Operation for which leadless materials adopted	Name of Witness	Industry	Page of [Cmd 630]	Reason for Substituting	Benefits from Substituting
✓	Painting and Jointing	Jordan	Railway	3	-	Cost less. Successfully resisted compensation claim.
✓	Jointing	Steinitz	Tramworks	4	Cases of lead poisoning	
✓	Painting and Jointing	Swain	Motor Cars	4	*	
✓	Painting and Jointing	Spencer	Tramworks	5	Case of poisoning	
	Painting	Allen	Motor Cars	18		Better health of workers Not more expensive
	Painting (top coat)	Mr.X (Worker)	Motor Cars	19	Risk to own health led to development of substitute	
	Painting (Decorative lining)	Robbins	Motor Cars	19		Zinc paint keeps colour better
	Jointing	Ball	Safemaking	22	Cases of poisoning	
	Painting	Baker	Perambulators	22	Cases of poisoning	Cost no more
✓	Painting	Guy & Brown	Motor Cars	37	Case of poisoning	Cost the same

Source : Coachpainting Committee. pp.3-37 [154]

* No reason given but the firm, Daimler, had been encouraged by the Factory Department to adopt precautions following cases of poisoning.

The Committee unanimously decided to make the same recommendation as the Committee on the Painting of Buildings, for the Prohibition of the use of materials containing over 5% of lead (soluble in Hydrochloric Acid) three years after the publication of its report. It made this recommendation even though the technical, economic and administrative obstacles to the effective enforcement of Regulation were considerably less in coach than housepainting. Conversely, the opposition from the trade to Prohibition was much less, and significant steps had been taken towards compliance by a number of firms in advance of formal regulation.

The Coachpainting Report was drafted prior to 1915, but was not published because some of its members were drafted overseas in the First World War. When the Committee met again after the War, they noted concern about the feasibility of substituting white lead on the grounds of the poor performance of the 'lead-free' materials used in paints as a result of the war-time shortages. The committee decided to discount this evidence, and affirm its earlier recommendation on the grounds that the painting conducted during the war was conducted as hurriedly as possible, only where absolutely necessary, with whatever materials were available. However it did make additional recommendations for the establishment of quality standards for 'lead-free' paints (comparable to those existing for white lead) and that the paint industry should be provided with information to help them to comply with the new legislation.[155]

The Postwar development of the Debate about Prohibition of White Lead

After the war, the debate about prohibition continued at national and international level. The publication of the Coachpainting Report in 1920 rekindled interest in the subject, and the poor performance of many 'lead free' paints, improvised during the war, added fuel to a backlash against prohibition of white lead. A further Departmental Enquiry was formed in

1921 to reconsider these decisions of the 1911 Committees.

This Enquiry began its investigation after a protracted debate at the International Labour Conference in 1921 had culminated in a Convention on the Use of White Lead in Painting, which adopted a compromise position of prohibiting use of lead paints in internal painting whilst allowing use of lead paint under regulations in painting the exterior of buildings and certain other applications (e.g. certain public buildings such as railway stations). This compromise was accepted by the 1921 Departmental Enquiry (known as the Norman Committee).

These two debates overlapped. However it is convenient to start by examining the debate at the International Labour Conference.

The International Labour Conference and Convention on White Lead

The history of the development and application of the convention on the Use of White Lead has been recorded in detail by the International Labour Office.[156] This will be briefly outlined, since its conduct is central to an understanding of the continuation of the British Regulatory debate.

The International Labour Organisation established under the auspices of the newly formed League of Nations took over the activities (and even the library) of the International Association for Labour Legislation. It also took over the latter's interest in lead paint hazards.[157] The question of lead poisoning in painters was raised (by Dr.Legge) at the first annual meeting of the International Labour Congress in 1919, which was concerned with the employment of women and young persons. As a result the issue was put on to the agenda of the 3rd Congress in Geneva in Autumn 1921.

In January 1921 the International Labour Office addressed a questionnaire to establish the views of member states on the prohibition of White Lead. The questions and subsequent replies are summarised in Table 4.16.[158]

TABLE 4.16. <u>International Labour Office Questionnaire to Member States on Prohibiting the Use of White Lead in Painting 1921</u> and summary of replies to the principal question.

<u>Source</u>: International Labour Office, 1921, <u>op.cit.</u>

The International Labour Office noted that the replies from the States using white lead to the 'greatest extent' had called either for prohibition to be limited to internal painting or to specific industries (Austria, Belgium, Czechoslavakia, Germany, Netherlands) or for further investigation into lead substitutes to be carried out before acting (Britain, Switzerland).[159] (Although not mentioned by the I.L.O., other factors, such as involvement in lead production also appear to have played a significant role).[160]

The International Labour Office, noting that a number of governments seemed prepared to give approval to total prohibition of all use of white lead, proposed a Draft Convention for the Conference prohibiting the use of white lead in painting with certain exceptions, which were to be strictly regulated, notably artistic painting and the painting of objects (other than buildings) continually exposed to the open air.

At the start of the 3rd International Labour Conference on 25th October 1921, a Commission on White Lead was formed to consider the report of the International Labour Office.[161] The Commission comprised 8 representatives each of governments, (painting) employers and painting workers, accompanied by technical advisers (6 for government and 5 for employers).

It was notable that many members or consultants to the English White Lead manufacturers had succeeded in getting represented at the Conference, and were members of the White Lead Commission as employers' representatives or technical advisers.[162] Thus Mr. Cookson (a Newcastle White Lead manufacturer) was the employers' representative for Australia, accompanied by two technical advisers)Mr. J.H.Smith - an English White Lead manufacturer, and Professor Armstrong - who had been a witness at the 1911 Departmental Committee for the White Lead Corroders). Whilst the British employers delegation (of painting employers) included Sir Kenneth Goadby (the medical consultant who had raised the theory of turpentine as an alternative source of poisoning when he gave evidence as as a White Lead Corroders' witness at the 1911 Departmental Committee). C.A.Klein (Chemist to another English Lead Corroder) was an Australian government technical adviser though not on the Commission.

The White Lead Commission dealt with four points:

i) The diagnosis of lead poisoning

ii) The importance of lead poisoning in the painting industry

iii) The technical value of the substitutes for white lead

iv) The social and economic consequences of such substitution.

The content of the Commission's deliberations were substantially similar to those of the 1911 Departmental Committee.[163]

The first two questions were referred to a separate Medical Sub Committee following a protracted dispute about diagnosis of lead poisoning (along the same lines as the views of Goadby and Sutherland described above). Eventually the Medical Sub Committee agreed to a position on the nature of the risk to painters that was identical to the conclusions of the 1911 Departmental Enquiry (focusing on airborne dust as the major hazard, in particular from sanding painted surfaces).

There were sharp differences of opinion within the Commission:

i) on the efficiency of lead substitute pigments for both internal and external painting,

ii) on the effectiveness of regulation and in particular the possibility of introducing wet rubbing of painted surfaces,

iii) on the economic consequences of prohibiting white lead (particularly on the lead mining industry), the likelihood of an adjustment in production and of the priority that should be given to these costs relative to human health.

After 9 sessions, the White Lead Commission discussed and voted on a range of possible recommendations to the Conference. Total prohibition of white lead was rejected (by 14:9), while prohibition for internal painting was rejected by a narrow margin (13:10). Eventually a draft Convention was proposed for Regulations which defined precautions to be adopted for the continued use of white lead paints. This was accepted by a majority (14), whilst the minority (10) abstained. A minority report was also submitted to the International Labour Conference, supported by 7 workers' representatives (all except the Australian workers' representatives), and by the French, Belgian and Italian government technical advisers. The minority report "would have preferred complete prohibition" but called "at least .... for [prohibition of using lead paint] in the interior of buildings".

The Commission reported back to the broader conference where the debate continued. The views of the various delegates, regarding the regulatory strategy appropriate for white lead, have been ascertained from their speeches at the conference and resolutions at the commission, and are summarised in Table 4.17.

Three positions are identified :

1) Support for total <u>Prohibition</u> (or opposition to <u>Regulation</u>)

2) Support for <u>Regulation</u> (or opposition to total <u>Prohibition</u>

3) A new strategy which emerged at the Conference was of partial <u>Prohibition</u> - of the use of lead paints on the interior of buildings. This is described as <u>Internal Prohibition</u>.

A number of points can be made regarding the distribution of opinion amongst the different delegations :

1) The workers' representatives were strongly supportive of total <u>Prohibition</u> (with the exception of the Australian delegate who

TABLE 4.17. Views of the Delegates to the 1921 International Labour Conference on Prohibition or Regulation of Lead Paint

Aston University

Illustration removed for copyright restrictions

Aston University

Illustration removed for copyright restrictions

Source: International Labour Office, 1927, *op.cit.*

argued that Regulation was sufficient and that internal use of lead paint could be avoided by collective agreement between painting worker and employer).

2) Though the employers overwhelmingly opposed complete Prohibition, two distinct positions could be noted according to their particular trade interest:

   a) The Master Painters, who were opposed to Prohibition because of its impact on paint durability; however some were prepared to accept Internal Prohibition (notably the Belgian delegate, in whose country Internal Prohibition had already been introduced).[164]

   b) The lead producers, in particular from Spain, Australia and South Africa opposed Prohibition because of the impact it might have on the lead, zinc and gold markets.

3) The government representatives from the major lead mining countries (Spain, Australia) also opposed Prohibition for the same reason.

   Whilst several governments did not have a clear position, a significant group of governments favoured some form of Prohibition (especially those who had already had experience of the failure of Regulation or had introduced a degree of Prohibition.)

At the final stages of the International Labour Convention the majority report of the White Lead Commission was accepted as a draft Convention and then immediately substituted by an amendment which implemented Prohibition of white lead in painting buildings but allowed white lead to be used (under Regulation) for other industrial painting. This amendment was accepted by a vote of 45 to 44.

Thus the balance of opinion at the Conference was marginally in favour of Prohibition whilst that on the Commission on White Lead was marginally opposed to it. Opinion at the International Labour Conference was still sharply divided. The conference was due to end on the following day, 19th November 1921, and since the substantive motion was the product of Commission's minority report, it was open to discussion article by article. A stalemate threatened, since any convention required a 2/3rds majority.

At this stage, the British workers' delegate proposed a compromise amendment - for Internal Prohibition of use of white lead paints on the interior surfaces of houses (to ensure that the conference "at least achieved something"). This received immediate support from a number of representatives. During an adjournment, the Commission on White Lead reached agreement on the wording of a draft Convention based on this compromise which was accepted by the Conference by 90 votes with none against and one abstention (based on a technicality). The British government representative (Sir Montague Barlow) agreed to cast the British government vote in its favour on the basis that it was a "compromise, agreed to by all parties". His statement was to achieve great significance in subsequent years. To ratify the Convention, Member States were required to take action by 1924 and implement by 1927 the prohibition of the use of white lead in interior painting of buildings (with the exception of railway stations or industrial establishments) and regulated the use of white lead paint in other applications. The text of the Convention is reproduced in Table 4.18.[165] However it was open to states not to ratify the Convention. Subsequent progress in ratifying the Convention is recorded and discussed in Chapter 7, (Tables 7.1 and 7.2).

TABLE 4.18. Text of the 1921 International Labour Convention on White Lead

The Post-War Debate in Britain

Factors Leading to the Appointment of the 1921 Departmental Committee (the Norman Committee)

The First World War interrupted the impetus of the 1911 Departmental Committees and gave the opponents of Prohibition a breathing space and new evidence to attempt to re-open the debate and reverse the Committees' recommendations.

A wide range of the issues that had predominated at the 1911 Departmental Committees came under scrutiny and criticism wherever a forum was presented. A notable aspect of this is the use made by the white lead manufacturers (or rather their scientific consultants) of the key industrial/technical avenues available. C.A.Klein (Chemist to Brimsdown Lead Co.) and H.E. Armstrong (academic chemist and witness for the White Lead Corroders at the 1911 Departmental Committees) produced a series of papers and journal articles.[166] Klein himself became president of the Oil and Colour Chemists' Association in 1926.[167]

The main areas of attack by the White Lead Manufacturers and other opponents of Prohibition are briefly summarised below.

Efficacy of Leadless Substitutes : The lead industry had been under government control during the war, and white lead production was reduced and finally ceased for the year of 1918 (a move which had dramatic benefits for workers health).[168] As a result less painting was carried out and there was an increased use of whatever substitutes for white lead were available. Much of this paintwork had performed very poorly.

As noted above, the Coachpainting Committee judged this experience of 'lead-free' paints to be of little practical value in assessing the efficacy of lead substitute pigments, and re-affirmed its commitment to

Prohibition in 1920.[169] The Home Office continued to support the 1911 Committees' recommendations and issued the report of the above committee with a memorandum drawing attention to the satisfactory results obtained with non-poisonous paints and calling on employers to discontinue the use of lead paints. At the same time they issued a memorandum by the Office of Works on an extended test of non-poisonous paints for priming iron and steel, conducted at Kew Gardens between 1912 and 1919.[170] A further Home Office memorandum was circulated to government departments suggesting that they implement the 1911 Committee recommendations in advance of legislation.[171]

However, attitudes amongst Master Painters had been hardened by the war-time experiences against lead substitutes and by the time of the International Labour Conference they were united in their support for Regulation rather than Prohibition. (Regarding the former, it was held that the invention of waterproof sandpaper had eliminated the difficulties of wet rubbing which, it was claimed, had underlain their opposition to Regulation).[172] After the war Master Painters quickly reverted to using lead paints. Another factor that may have encouraged this was the post-war drop in the price of white lead. Zinc pigments did not fall in price to the same extent and this was suggested as an obstacle to further substitution of white lead.[173]

Criticism of the Conduct of the 1911 Departmental Committees continued along the lines that had been spelt out in Sutherland's dissenting Memorandum. Particular significance was placed on the lack of scientific expertise on the Committee. The only "scientific man", the Medical Inspector of Factories, was deemed to be "incompetent either to deal with the issues raised or to appreciate the evidence offered".[174]

When in 1921 the new Director of H.M.Office of Works issued a circular seeking financial savings in the cost of maintaining buildings by less frequent painting he was informed by his officers that this was impossible with zinc based paints because of their poor durability. The Office of Works sought to reverse its policy on using lead free paints. This development played a major part (coming on top of Sutherland's allegation about Patterson's role at the 1911 Committee) in provoking a re-examination of the issues.[175]

Turpentine poisoning not lead? : Although the two theories regarding organic emissions from painted surfaces had been decisively countered at the 1911 Departmental Committee, there was still an attempt to promote the idea that many cases of "so-called lead poisoning [amongst painters were] due to the inhalation .... of the vapour of turpentine" and further, that "the dangers of the painter's work have been exaggerated - his occupation is not unhealthy".[176] The promotion of this theory was facilitated by the growth of concern during the war about the dangers of acute poisoning from the use of quick drying lacquers containing thinners such as benzene, tetrachlorethane in the wartime production, in particular of aeroplanes. Toxic jaundice from exposure to benzene and other solvents for example became a notifiable industrial disease in 1915.[177]

Effects of Prohibition on Mining Interests : Finally, and very significantly in the political arena (and eventual implementation of policy formation) the opponents of Prohibition attempted to mobilise the support of (lead) mining interests in the colonies (and thus colonial 'interests' within the state) against Prohibition which it was alleged "would cause the closing down of the lead mines" of New South Wales, Burma and Rhodesia. For example, following the dissemination of the Coachpainting Report and memoranda described above, Captain Bowyer M.P. (a vociferous opponent of

Prohibition) addressed a "Written Question" to the Secretary of State for the Colonies, expressing the "alarm" of the New South Wales government and urging that the British government delegates to the forthcoming International Labour Conference be instructed to "consider carefully" the possibility of Regulation rather than Prohibition. (The Colonial Secretary's reply was non-committal).[178]

The development of a close alliance between the "White Lead" lobby and colonial/mining interests was further demonstrated by the ability of the representatives of the British White Lead Corroders to gain access to the 1921 International Labour Conference, as technical advisers to the Australian government and employers' delegations (see previous section).

The Appointment of the 1921 Departmental Committee

In contrast to the Home Department, the government was becoming increasingly uncertain about the question of Prohibition (as demonstrated by its response to the International Labour Office questionnaire in February 1921 which called for "further investigation before any move towards total prohibition" see Figure 4.15). Action followed a further "Written Question" from Captain Bowyer, which suggested that the Home Office withdraw its circulars that urged government departments and the public to use leadless paints since "the use of leadless paints during the war has shown them to be defective in point of durability". In a written reply, Mr. Shortt the Home Secretary, announced that he was appointing a new Departmental Committee "to examine the new information, which appears to throw some doubt on the conclusions arrived at by [the 1911 Departmental] Committees".[179]

What is most surprising about the establishment of this fresh Departmental Committee is the fact that it overlapped with the International Labour

Conference. The conference had been known about for two years (and indeed would already have been completed by July 1921 had the original timetable not been delayed) and its findings presumably would have been seen as authoritative. The new Departmental Committee was appointed on 31st August 1921 but did not meet till 8th December 1921 after the results of the International Labour Conference. Of the members of the 1911 Departmental Committees, only Dr.Legge the Medical Inspector of Factories was invited to serve on the 1921 Departmental Committee, which did not have representatives of painting workers or employers,[180] which instead was dominated by medical, architectural, civil engineering and chemical specialists.

The Departmental Committee was known as the Committee on Industrial Paints or the Norman Committee (after its chairman). It met and reported very rapidly.[181] It saw 26 witnesses in 13 days deliberations (compared to 181 witnesses and 49 days of the Committee on Painting of Buildings alone). Of the witnesses to the 1911 Committee, only 4 were heard by the Norman Committee.[182]

The Proceedings of the Norman Committee

The chairman, Sir Henry Norman, proposed that the enquiry "might start from the position that practically the decisions of the Geneva conference will be accepted by the government".[183]

The "Norman Committee's" deliberations included a review of the 1911 Committees and issues that had arisen since then, most of which have been dealt with in the preceding sections. It will therefore suffice simply to review its findings and recommendations.

Extent of Harm from Use of Lead Paints and Substitutes

1) Lead poisoning figures had fallen dramatically amongst housepainters

during the war (poisoning cases fell to 25% and deaths to 50% of their pre-war levels) and had not reverted to their pre-war levels by that stage.

2) The percentage of lead poisoning cases classed as 'severe' amongst housepainters (29%) was almost threefold that of other lead workers (10.2%) implying that a substantial number of 'non-severe' cases of lead poisoning were failing to be reported under voluntary notification (of poisoning in housepainters compared to compulsory notification for factory workers).

3) Investigations by the Medical Inspectorate revealed that the rate of 'misdiagnosis' was much lower amongst housepainters (up to 4.2%) than other workers (up to 14%).

4) Figures for Standard Mortality Rates from the Registrar General's Office showed that housepainters had excess mortality from the same diseases prevalent amongst other lead workers, but different to (e.g. varnish) workers exposed to turpentine and other organic solvents. The suggestions by Goadby and others that a significant portion of the death and disease amongst housepainters ascribed to lead was due to turpentine poisoning or otherwise incorrectly diagnosed were thus demolished by the availability of rigorous state statistics.

5) The toxicity of lead substitute pigments was considered. The reduction in lead poisoning in those railway works that had converted to zinc paints (and the absence of other industrial disease) refuted another of Goadby's suggestions to the 1911 Departmental Committee.

Antimony Oxide pigments were held to be 'industrially non-toxic', apart from its ability to cause dermatitis. The lack of information on the physiological effects of the recently introduced Titanium Dioxide was noted.

Experience of Leadless Paints

Sir Frank Baines, director of the Office of Works, gave evidence about inadequate performance of zinc based paints. He repudiated the views of Sir Henry Tanner, who had given evidence at the 1911 Committee as principal architect of the Office of Works, as being based on only four years experience. He argued that Zinc Oxide was leached out of the paint surface due to the action of sulphurous fumes and noted its reduced ability to react with linseed oil compared to white lead.

Sir Frank supported the Geneva Convention position, of prohibiting internal painting by lead paints, on condition that a wide range of exemptions for industrial establishments was allowed.

The position of the white lead industry could be summarised that no one paint [i.e. pigment] "is the most suitable for all purposes .... and circumstances", "a substitute for lead in external use .... does not exist".[184]

New substitutes for lead were considered, notably those based on Antimony Oxide and Titanium Dioxide. The former was held by the Lead Corroders to have insufficient durability for exterior applications, whilst the latter though 'of interest' had been on the market for only 12 months and its life was unproven.

Significantly, the only paint mixing firm presenting evidence (Manders Ltd.) argued that "they would not mind the prohibition of lead for external work .... According to the work you can find a substitute for white lead .... I do not think it would cost more, [it would create] hardships only to those who make white lead".[185]

Wet Rubbing of Painted Surfaces

A major factor behind the Master Painters opposition to Regulation at the

1911 Departmental Committee was the increased cost, technical difficulty and impaired quality of work that would be associated with wet rubbing of painted surfaces. This was the corner stone of the Regulation strategy since dry rubbing of new and old surfaces painted with lead paint had been identified as the major source of risk due to the high levels of airborne lead dust it created. Klein, witness for the White Lead Manufacturers, proposed a method of wet rubbing using waterproof sandpaper (which reduced the time and money cost of using conventional sandpaper and sponges).[186] Results of measurements of airborne dust levels using this process were presented as follows:

	Total Dust	Lead Dust	
Dry Rubbing	45.3	5.7	milligrams per
Wet Rubbing	20	0.1	cubic metre of air

N.B. the ratio of lead to total dust is approximately 1:8 for dry rubbing and 1:200 for wet rubbing. This might be due to high background levels of (lead free) dust in the workplace. However, this contradiction was not discussed.

Waterproof sandpaper had been developed in the U.S.A., where its use was claimed to be increasing. There was little experience of it in Britain. The viability of this method became of central importance to the White Lead lobby's posit with the subsequent debate.

Despite the small number of witnesses addressed, and their conflicting assessments on a number of issues[187] the committee came to the following conclusion :

> "We are satisfied that for outside painting and for certain kinds of internal painting, there is at present no efficient substitute for white lead. At the same time the statistics of lead poisoning arising from lead paint in its production and in its use are unquestionably sufficiently serious to make it most desirable to limit its use as far as practicable and where it is used, to make its use subject to statutory regulations as is already done in its production.

.... These needs are adequately met by the agreement embodied in the Geneva .... Convention. We accordingly recommend that legislation should be passed to give effect to the principles therein contained".

However they pointed out that "any prohibition is likely to involve an increase of cost" of maintaining buildings.[188]

In line with the Geneva Convention, the Committee recommended that Internal Prohibition be deferred until 1927 to allow time for adjustment, whilst Regulations to deal with the continued use of lead paints should be brought into force at the earliest possible moment. A code of Regulations, following the Geneva agreement, had already been prepared by the Home Office in collaboration with Painters and Decorators Joint Industrial Council (Master Painters Federation and Painters Unions) and agreed by the trade. It was therefore suggested that these regulations should be enforced by the state in the housepainting industry (backed up by a requirement to notify lead poisoning in housepainters).

Though the committee concentrated almost exclusively on the painting of buildings, it recommended that the 1911 Coach Painting Committee's proposal for Prohibition of lead paint in coach painting be overturned and replaced by Regulation of the use of lead paint for industrial painting (under the Factories Act) as well as a requirement that ventilation be used in ship painting.

Thus in its recommendations regarding regulatory strategy the 1921 Committee on Industrial Paints served to bring official policy in line with the International Labour Convention (in the case of coach painting, this move was not even sustained by an evaluation of the views of industry or the obstacles to Prohibition).

However, the Norman Committee also came up with a significant recommendation which the International Labour Conference had not dealt with, for an "authoritative investigation" of paint technology.

Thus although the committee opposed total Prohibition on the grounds of the current lack of suitable substitutes for white lead paint in some applications it considered that there had been too little testing of these to warrant a final conclusion. The conflicting views about the relative merits of lead and leadless paints was seen as a consequence of the lack of "authoritative scientific information as to the relative behaviour and economy" of the various pigments and vehicles, and the unsystematic and often 'ex-parte' nature of the testing that had been carried out.

All but one of the witnesses had agreed the need for further investigation. The committee therefore proposed that a technical commission be established under the Department of Scientific and Industrial Research, including representatives of government paint users, the painting industry (employers and workers), Paint Manufacturers architects and chemists. The establishment of this Commission was deemed a matter of utmost urgency if Internal Prohibition was to be introduced by 1927. It was proposed that the Commission should deal with, inter alia, the formulation and standardisation of paints, and the testing of new materials.[189]

These recommendations represent an attempt to develop reliable knowledge about the major remaining area of uncertainty surrounding regulatory strategy - regarding the technology of production itself. Thus, in sharp contrast to the view of the 1893 Departmental Committee, a role for the state in coordinating changes in production technology was proposed as a means whereby the states remaining information needs could be met. This proposal will be discussed in the final chapter.

A Note on Internal Prohibition

Internal Prohibition was adopted by the International Labour Convention solely as a political compromise, and subsequently accepted by the Norman Committee on the basis of scant information. This regulatory strategy had little technical underpinning, although its promulgation had implications for the technical legitimacy of both Prohibition and Regulation. The possibility of such a strategy had been broached by Sir Thomas Oliver in 1914, on the basis of the preference by Master Painters for lead paints for external work, while a significant number preferred zinc for inside work. Oliver presented figures from Vienna, where it had been found that the use of 80 tons of white lead in interior painting had caused 163 cases of lead poisoning amongst housepainters, whilst 237½ tons of white lead used in external paints had only caused 50 cases of lead poisoning - the implication was that internal painting with lead paint was 10 times more dangerous than external painting.[190] Apart from this observation, there appears to have been little information on the relative risks of internal and external painting, and none was examined at the 1921 Departmental (Norman) Committee. Equally the technical and administrative obstacles to the effective enforcement of such a hybrid strategy received little consideration (especially considering the importance attached to these at the 1911 Committee on Painting of Buildings).

The main technical factors underlying the acceptance of Internal Prohibition by the Norman Committee appear to have been :

i) the possibility of using waterproof sandpaper in (external) Regulation of lead paint for exterior surfaces, and

ii) the fact that this overcame the technical objections to Prohibition of lead paint for exterior surfaces.

The adoption of the compromise solution of Internal Prohibition led to the rapid development within the painting trade of a developed Code of Regulations for the implementation of Regulation for external painting with lead paint (and for internal painting prior to Prohibition). Thus following the International Labour Convention, the Painters and Decorators Joint Industrial Council (comprising the National Federation of Master Painters of England and Wales and of Scotland, the National Operative Painters Society and the Scottish Painters Society) held a conference at the Home Office with the Factory Department (Bellhouse, Price and Legge).[191] An outline Code of Regulations was drafted and agreed. This was formalised by the Home Office after discussion with the Federation of Building Trades Employers in June 1922[192] and presented to the Norman Committee.

As will be seen in the next chapter, the acceptance of Internal Prohibition as a regulatory strategy gave the opponents of Prohibition significant opportunities to push for its total abandonment by both implicitly conceding the technical economic and administrative feasibility of Regulation and by making available and legitimating a developed Code of Regulations.

CHAPTER FIVE

THE HISTORY OF REGULATION OF WHITE LEAD PAINT II

POLICY IMPLEMENTATION

THE HISTORY OF REGULATION OF WHITE LEAD PAINT II: THE POLICY IMPLEMENTATION PROCESS

Introduction

The Norman Committee report was completed in 1922 and published in 1923. Its conclusions in the main supported the agreement reached at the International Labour Conference for Internal Prohibition (of the use of white lead paint in the interior of buildings). Most of the recommendations of the committee could only be implemented through legislation.[1]

The focus of this study at this stage shifts from the process of policy formation, to the process of legislative implementation. Whilst both stages of this wider regulatory debate have involved both public (e.g. discussion in the media, parliament or scientific circles) and private (e.g. approaches by affected groups to the Home Office) representation of interests, policy formation had been conducted primarily through public fora - including open political activity, public government enquiry. In contrast the implementation stage took place primarily behind closed doors (through the administration and cabinet).

Analysis of the latter stage has been facilitated by the availability of some of the relevant Departmental files on this subject, lodged at the Public Records Office. These allow access to certain Cabinet papers, and series of correspondence kept by the Home Office, and within this the Factory Department (after 1938, the Safety, Health and Welfare Department of the Ministry of Labour). The relevant files available are summarised in Table 5.1. Through these files, supported by published sources, it is possible to document the political process in detail, starting from the International Labour Convention, and leading to the adoption of state controls over the use of lead paint.

The continuation of the open controversy on this question, the fervour

TABLE 5.1. Home Office files on the Implementation of Legislation on the Use of Lead Paint. 1922-1936

Files available at Public Records Office.

Public Records Office Identification Code	Home Office File Reference No.	Period Covered	Topics Covered
LAB.14/211	428004	13.11.22-25.4.24	Discussion of implementation of Geneva Convention - legislation probiting internal use of lead paint.
LAB.14/218	428004	5.3.24-9.4.25	Discussion of implementing legislation leadin to 1926 Lead Paint Act (based on Regulation not Internal Prohibiti
LAB.14/226	428004	21.7.22,25.5.27-29.7.27	Discussion and Mackenzie enquiry leading to Lead Paint (Protection Against Poisoning) Regulations 1927
LAB.14/215	481945	14.8.23-12.3.26	Discussions leadin to 1926 Vehicle Painting Regulatior This file began as Item 43 of file 428004, initiated following a deputation from the Vehicle Trader to the Home Office on 27.7.23.
LAB.14/28 This file derives from Item 62 of file 428004.	496133	21.7.26-1936	Discussion of Research into Paint Technology - possibility of finding lead substitutes i the event of prohibition being introduced.

It will be seen that the original Home Office file (No.428004) has been sorted into 3 files, as the focus of the debate shifted over time. Some of the relevant correspondence is missing, but there is sufficient duplication to allow a comprehensive picture to be built up.
Because the original order of the files has been disturbed, contents will be identified not by their sequence number, but by the current file (e.g.LAB. 14/211)

with which the different parties attempted to influence the process of implementation controls, and the ultimate resolution of these pressures by the introduction of Regulation alone (i.e. the rejection of Internal Prohibition - the strategy which had been agreed by the International Labour Convention and the Norman Committee) provide an exceptional demonstration, (writ-large) of the complex process by which state intervention is determined. The lack of consensus around one strategy accentuated by the inability of scientific knowledge to provide convincing technical underpinning for either control strategy (which might have allowed decisions regarding regulatory strategy to be conducted in technical terms, without expressing their political component) exposes the ways in which conflicts at the level of society and within the state (administration and government) are resolved. Since the policy options had already been formulated at the International Labour Convention and the Departmental Committees, we shall refer to this process as policy implementation.

The description and discussion of the process of policy implementation will be highly detailed. It is therefore useful to start by outlining the positions of the different parties at the beginning of the process, and then summarising the implementation process, before going on to examine this process in depth.

The Situation following the Norman Report

The publication of the Norman Committee's Report in 1923[2] did not end the controversy over the control of paint hazards, but rather led to renewed lobbying by the different interested groups to try and gain advantage in the political process of implementation. The White Lead Corroders immediately contacted other employers organisations, seeking their support in urging the government not to ratify the prohibition clauses of the Geneva Convention, but to implement the rest (i.e. Regulation).

The Master Painters (whose separate national organisations had worked together on this question since the Geneva Convention through the International Materials Committee of the Master Painters Federations of England, Scotland and Assembly of Ireland) rejected this approach by the white lead interests and declared their intention to stay loyal to the compromise accepted at Geneva.

The Painters Unions also adhered to this compromise position and criticised the White Lead Corroders for breaking their word, which they saw as part of a continuing rearguard action against prohibition focusing on whatever justification was available.[3] The White Lead Corroders justified their shift in position at two levels:

i) at a technical and administrative level, they extended their arguments about the feasibility of Regulation (due to the development of waterproof sandpapers and the existence of developed Regulations agreed by the trade).

ii) they refuted their commitment to Internal Prohibition at Geneva, which they justified at a 'moral/political' level by two arguments :

a) the fact that their commitment at the International Labour Convention was based on a misleading assurance that only 10% of white lead was used on internal painting, whereas they claimed this figure was in fact 40%.

b) they claimed that the International Labour Office had adopted a partisan role on this question and were pressing for Internal Prohibition.[4] (Whereas their agreement to Internal Prohibition was in order to "bury the controversy in a deep grave".)

Summary of the Political Process in Implementing Legislative Controls

The White Lead Corroders succeeded in winning the support of industrial paint users outside the painting industry, and were able to lobby the government and administration through the auspices of the National Confederation of Employers Organisations. Even the workers in white lead firms were brought in to pressurise the government to introduce Regulation and abandon Internal Prohibition.

Against this pressure stood the Painting Trade (comprising Master Painters and Painters Unions), who were reinforcing the active support by the Factory Department and the Home Office, to adhere to the Norman Committee/Geneva Convention recommendations. The White Lead Lobby appears to have had little effect on the Home Office, but did succeed in influencing Parliament and Governments.

In May 1923, Baldwin's Conservative Government, took the first step away from implementing the Geneva Convention. Montague Barlow, the Minister of Labour (who had headed the British government delegation to the International Labour Conference) attempted to redefine the British government's commitment at the Convention, arguing that it was contingent on agreement existing between the different parties which had since broken down. Despite opposition from the Home Office, this view was presented in Parliament. However, no decision was taken, and consideration of the matter was deferred.

Following the General Election of December 1923, the Labour Party was pushed into forming a minority government. As the deadline for ratifying the Geneva convention approached, the Home Office pushed the Cabinet to introduce legislation. A Bill was drafted to give effect to the Convention. The first reading of the Bill (3 April 1924) was in the House of Commons rather than the Lords (where the White Lead interests were firmly established). Opposition in the Commons was greater than expected and the Labour Home Secretary (Henderson) appeared to lose confidence in the measure. At the Second Reading, rather than appointing a Select Committee on the subject, Henderson proposed that the Bill should continue and that if Section 1, (dealing with Prohibition) was defeated, the remainder could be introduced to give effect to Regulation. We can but guess the outcome of this process since, with the fall of the Labour Government in October 1924, the Bill was abandoned.

During this period there was an intensive process of lobbying by the various affected parties, directed to different sections of the state. The painting industry were providing material to help the Home Office answer the criticisms of the White Lead interests. The White Lead Corroders, with their allies from other industries, had lobbied the Board of Trade, and succeeded in getting them to make an approach to the Home Office (which the latter sharply rebuffed). Meanwhile the Home Office had convinced the Office of Works to adopt Internal Prohibition voluntarily and approached other Government Departments to do the same. This period provokes three observations:

i) The policies of the various government Departments are linked to their area of responsibility - e.g. the Board of Trade for industrial promotion and the Home Office for regulation of Factories etc.

ii) The administration undertook highly active roles in the process of negotiation and had a degree of autonomy from ministers; whether the Home Office from Barlow (anti-prohibition Conservative Home Secretary) or the Board of Trade from Sydney Webb (Labour, President of Board of Trade, supporting prohibition).

iii) The impact of administration policies had relatively little effect on Government or Parliamentary deliberations IN THIS CASE, where political and economic interests directly represented to government appear to have predominated.

The election of a Conservative government in October 1924 with a massive majority sealed the fate of the Prohibition strategy. Though a Bill introduced in April 1925, implementing Regulation of lead paint, did not reach the statute book, a similar Bill was introduced on 4 June 1926 and finally passed on 15 December 1926. The Lead Paint (Protection Against Poisoning) Act 1926 became law in the New Year, giving the Home Secretary the right to introduce Regulations in the painting industry. The Home Secretary justified the move, stating that it was an experimental measure, necessitated by the high costs of prohibition. The government undertook to introduce Prohibition later if Regulation failed to deal effectively with the problem of lead poisoning amongst housepainters.

After an initial protest about the proposed Bill from the Master Painters, when the 1925 Bill was introduced administrative and political activity on the subject was subdued - (this is not surprising since there was little likelihood of it having effect). The Home Office ceased its espousal of Prohibition, and in 1925 began preparing a code of Regulations to implement Regulation under the Lead Paint Act (consideration of which had been suspended during the Norman Committee 3 years earlier).

Draft Regulations on housepainting were circulated after the Lead Paint Act became law. Negotiations between the Home Office and affected parties continued during 1927, though it was necessary to have a formal enquiry to resolve points of disagreement between employers and the Home Office (the Mackenzie enquiry). Following this, the Lead Paint

(Protection Against Poisoning) Regulations were introduced and came into force in October 1927. These implemented Regulation in the painting of buildings.

Previously between June 1925 and March 1926, discussions had taken place with industrial paint users, leading to the introduction of the Vehicle Painting Regulations under the Factories Act, which implemented Regulation in the painting of vehicles.

The conduct of these two sets of negotiations reveal a number of conflicting concerns of painting employers regarding stringency of regulation which throw light on both the debate about Prohibition and more general attitudes amongst employers to regulation. In particular, the industrial painting employers who in 1923 had called for stringent Regulation as opposed to Prohibition subsequently sought to dilute and gain exemption from the codes of Regulations. Other sections of painting employers sought more stringent Regulations apparently in order to establish a monopoly over painting activities, or to avoid being undercut by unregulated establishments.

Despite the Government's commitment, that Prohibition would be considered if Regulation did not succeed, there was no serious evaluation of the effectiveness of Regulation.

Notified cases of lead poisoning amongst housepainters did decline steadily following the introduction of Regulations, and interest in the question evaporated.

Chronology of Events and Exchanges involving the Government and Administration in the Policy Implementation Process 1923 - 1927.

Table 5.2 records the actions of the government, parliament and the administration in the implementation of legislation on the use of lead paints, and the major exchanges conducted within the state and between the state and the affected parties ('external' political developments are also recorded - in upper case characters). The main source is Home Office files (listed in Table 5.1) supplemented by records of Parliamentary debates and miscellaneous publications.

The source of the information is recorded as follows:

i) Where Home Office files are the source, the date of the Memorandum/correspondence and (Public Records Office) file identification number ([LAB.14]/211, 218, 225, 226, 28) are given.

ii) Parliamentary debates are recorded in Hansard (Great Britain, Parliamentary Debates, House of Commons [or Lords] Official Report) and are recorded by the date and, where relevant column number (e.g. H.C.Debs 4 June 1926 Col. 1053 et.seq.).

iii) Other sources are referenced normally.

This account is unbalanced insofar as it offers relatively complete access to formal exchanges between the administration [particularly the Home Office and Factory Department) and 'interest groups' and other sectors of the state. In contrast, informal exchanges are less well covered. Moreover, in this particular case, it was the explicit political apparatus of the state (Parliament, the Cabinet) that was determinant in the eventual regulatory policy adopted. Representation of the interests of the different parties in these sectors of the state is only indirectly documented. There seems little prospect of correcting this imbalance. This problem does not invalidate this analysis, since, it will be argued, the primacy of the formal political arena is largely a consequence of the lack of consensus and indeed the open conflict that existed within the state and industry regarding the regulatory strategy to be adopted.

Table 5-2: REGULATING THE USE OF LEAD PAINTS.
Chronology of Events and Exchanges involving Government and Administration in the Policy Implementation Process. 1923 - 1927.

1 9 2 3

3/2/23	RED CROSS SOCIETIES DEMONSTRATION IN BRUSSELS IN FAVOUR OF IMPLEMENTATION OF GENEVA CONVENTION FOLLOWED BY SIMILAR EVENT IN PARIS (26/4/23)
27/4/23 <211>	Deputation to Home Office by National Confederation of Employers Organisations, including White Lead Manufacturers, Paint and Varnish Manufacturers and Industrial Painting Trades (including Vehicle, Ship and Building Employers organisation) to present their resolution of 4/5/22 that it was unnecessary to prohibit white lead. Request by Vehicle painters to be represented in any discussion of painting that went beyond the building trade. Statement from White Lead Manufacturers to Home Office outlining their reasons for opposing the Geneva Convention and criticising the role of the International Labour Organisation.
30/4/23 <211>	Letter from International Labour Office refuting allegations by White Lead Manufacturers about the speech by the ILO Director at the above Demonstration.
30/4/23 <211>	Deputation to Home Office by Master Painters Federations in support of Geneva Convention
3/5/23 <211>	Letter from Home Secretary to Home Office suggesting statement to Parliament, that if the compromise between different parties breaks down the Government would no longer be committed to implementing the Geneva Convention, and that the matter should merely discussed in Parliament pending a decision. Reply from Home Office opposing this statement as misleading.
9/5/23 HC Debs Col 2426	Home Secretary makes statement on above lines to Parliament.
16/5/23 <211>	Deputation to Home Office by Painting Workers' Unions in suppport of Geneva Convention.
2/8/23 <211>	Home Office Memorandum on need for Britain to ratify Geneva Convention. Summarises progress in ratification in other countries. Argues for G.B. to ratify to give lead to other countries and avoid a revival of agitation on the subject.

Table 5-2:2

14/8/23 <215>	Memorandum by Home Office summarising the implications of the Norman Committee recommendations for the Vehicle Painting Trade in the light of the deputation of 27/7/23. 30/8/23 Home Office Letter and Memorandum sent to National Federation of Vehicle Trades proposing to implement Norman Committee recommendations by issuing draft Regulations on coachpainting though no steps had yet been taken. NFVT reply referred to Factory Department. No action was however taken until 1925. Because of pressure of work and illness amongst the Inspectorate and the loss of the relevant file, a decision was deferred depending the outcome of the lead in buildings question (according to note dated 9/3/25 <215>).
14/8/23 <211>	Memorandum from Home Office to Home Secretary summarising situation, and refuting objections by Board of Trade and Colonial Office to prohibition as using "exaggerated figures".
27/8/23 <211>	Draft Memorandum for Home Affairs Committee based on above document for amendment and circulation to Cabinet)
6/9/23 <211>	Note from Home Office to Home Secretary stating that the materials are now available for a decision on ratifying the Convention. Summarises positions of Master Painters, Painting Unions and White Lead manufacturers; supports the former and disagrees with the case of the latter.
8/11/23 <218>	Home Affairs Committee proposes not to take a final decision regarding ratification of convention, but to introduce regulation immediately. They would give a PRIVATE UNDERTAKING TO THE I.L.O. that 12 months later, if they were not satisfied with the adoption of wet rubbing, they would bring in Prohibition by 1927. (According to a memo of 28/1/24 at the cabinet meeting the Board of Trade argued for postponing the decision on ratifcation. A decision was deferred beause of the election.)

DEC. 1923 FALL OF CONSERVATIVE GOVERNMENT. MINORITY LABOUR GOVERNMENT.

Table 5-2:3

1924

1/1/24	DATE BY WHICH GOVERNMENTS SUPPOSED TO RATIFY CONVENTION
28/1/24 <211>	Home Office Memorandum to (the new) Home Secretary, stating that a decision on the Convention is long overdue. Subsequently Home Secretary sent Memorandum to Cabinet Home Affairs Committee supporting ratification.
20/2/24 <211>	Bill drafted prohibiting use of white lead paint in painting the interior of any building after 19/11/27.
20/2/24 <211>	Master Painters and Painting Unions (represented through the Painters and Decorators Joint Industrial Council - P&DJIC) send Home Office a resolution supporting intrnal prohibition. Letter offers help to Home Office in its attempts to bring in internal prohibition. Reply, thanking them, from Home Office 18/3/24.
28/2/24	Cabinet approves introduction of Lead Paint Bill
29/2/24 - 5/3/24 <211>	Correspondence between Home Secretary and Cabinet members about strategy for introducing Lead Paint Bill into Parliament. Resolved to introduce into Commons because of possibility of White Lead Manufacturers organising opposition in the Lords (through the 'White Lead interests' - Lords Cedby and Askwith).
8/3/24 <211>	Deputation to Home Office by Painters Unions to present information on deaths amongst their members from lead poisoning which exceeded those notified officially.
3/4/24	Lead Paint Bill introduced In Commons.
15/4/24 <218>	Home Secretary letter to Office of Works, enclosing copy of Bill, asking them whether they will enact prohibition at once or whether they will be regulated (memo from Office of Works said that they would prohibit interior lead at once. Letter 13/5/24 states that Office of Works "is acting as though internal prohibition was already operative").
1/5/24 <218>	Home Office requests Master Painters and Painters Union to to provide information on adoption of waterproof sandpaper, to reply to claims being made by opponents to prohibition, ready for debate at 2nd reading of Bill. Replies from above on 6/5 and 5/5 respectively state that method is little used. 24/5/24, Painters Union submits results of questionnaire on the matter - only 43 firms using waterproof sandpaper.

Table 5-2:4

7/5/24 <218>	Deputation to Board of Trade from White Lead Corroders, Building Trades Employers, and Federation of British Industry, focussing on the adverse effects of prohibition on employment in the White Lead industry.
13/5/24 <211>	Deputation to Home Office from P&DJIC states that 40% of white lead is used in industrial paints. Estimates that internal prohibition would reduce demand for white lead paint by 15% (cf White Lead Manufacturers claim of 40%).
16/5/24 <211>	Deputation to Home Office from National Union of General Workers representing workers in white lead works, to oppose prohibition. (N.B. As a result of this, the Housepainters' Union arranged a meeting with the <NUGW> Lead Workers. An agreement was reached that six years warning should be given prior to the introduction of prohibition.) 5
20/5/24 <218>	Home Secretary letter to Government Departments asking them to follow example of Office of Works (GPO, Armed Forces) by introducing Internal Prohibition.
22/5/24 <218>	War Office suggests extension of prohibition to lead colours as well - rejected after communication with Factory Department.
23/5/24 <211>	Deputation from P&DJIC to Home Office discusses growing opposition to internal prohibition from White Lead Manufacturers and their employees. P&DJIC undertakes to canvass MPs.
30/5/24 <218>	Letter to Home Office from Board of Trade urging that prohibition be dropped, in view of facts raised by deputation of 7/5/24 and that regulation only be introduced.
6/6/24 <218>	Home Office reply that they are unable to accept the statements or the recommendations. (This follows correspondence between the Home Office and Ministers, criticising the Board's position - namely their lack of expertise, their failure to invite the Home Office to the meeting, and their open disagreement with the position of the Home Office and the President of the Board of Trade.
20/6/24 HC Debs col 2503	Second Reading of Lead Paint Bill in Commons. Bill meets substantial opposition. Home Secretary (Henderson) agrees that if clauses relating to prohibition were defeated in comittee, the remainder would still be introduced (giving effect to regulation) and on this basis, opponents withdrew suggestion that Bill should go to Select Committee.
21/7/24	Committee Stage, discusses amendments - chiefly to delete clause introducing internal prohibition. Comments from Home Office criticising above attempts. Committee Stage not completed.

SEP 1924 FALL OF LABOUR GOVERNMENT. ELECTION BRINGS CONSERVATIVE GOVERNMENT.

Table 5-2:5

1925.

7/1/25	War Office issue instructions prohibiting the use of lead paints for internal painting (except existing stock). Objection by Federation of British Industry/White Lead Corroders on the basis of the degree of oppostion to such a move in the previous debate in the Commons. The War Office then cancelled its instructions.6
3/4/25 <218>	Draft Lead Paint (Protection against Poisoning) Bill approved by Home Secretary which would give effect to Regulation only 'in line with the recommendations of the previous Conservative Home Affairs Committee'. Bill subsequently approved by Home Affairs Committee and Cabinet.
9/4/25 <218>	House of Commons Debate on the International Labour Organisation. Criticism of Government for failure to ratify Geneva Convention. Home Secretary (W. Joynson Hicks) statement to Commons that because of the "difficulty of getting prohibition through Parliament", regulation would be introduced, and that further powers would be sought if this "did not reduce mortality and morbidity very considerably". He claimed that "arrangements (for regulation) amounting almost to an agreement, have been made between the users and manufacturers of White Lead".
17/4/25 <218>	Protest to Home Secretary from Painters Union at above speech, refutes suggestion of existence of such an agreement, and presents resolution (23/1/25) from Joint Industrial Council of Painting Trade that "they cannot support any Bill which confers less protection than the (Geneva convention) provides."
1/5/25	Home Secretary introduces White Lead (Protection Against Poisoning) Bill into Commons to bring regulation into effect by 1/1/26
June 25	Factory Department issues draft regulations for use of lead paint in House, Vehicle and Ship painting respectively. 7
17/7/25 <215>	Letter from Harney (Liberal M.P.) to Home Office about draft Regulations for Painting Vehicles. Complains about inclusion of clause prohibiting lead paint in interior of vehicles as being in conflict with government position on Housepainting.
20/7/25 <215>	Conference between Home Office and Vehicle Painting Trade representatives about draft Regulations for the painting of vehicles. Home Office agreed to deletions requested by the employers - namely of the requirement for messrooms, and the excemption of small firms. Spraying of lead paint no longer prohibited - but allowed only under local exhaust ventilation. Interior painting now only prohibited where surface is subsequently to be scraped.

Table 5-2:6

10/8/25	Home Secretary certifies Vehicle Painting as a "dangerous trade" under the Factories Act (thereby empowering him to make regulations to control the hazards.
25/8/25	Draft Vehicle Painting Regulations circulated (as amended on 20/7).
6/9/25	TUC Debate on Geneva Convention addressed by Gibson (Housepainters' Union). TUC condemns government's failure to ratify the Convention. TUC opposes the Lead Paint Bill, and calls for the introduction of internal prohibition. 6
23/9/25 <215>	Letter to Home Office from Scottish Vehicle Builders Association and National Employers Association of Vehicle Builders objecting to the regulations as unnecessary. The former in addition objected to requirement for wet rubbing and requested that all vehicle painting be conducted in authorised premises (SIC). Letter from Engineering and Allied Employers Association with objections to Vehicle Painting Regulations - requests excemption of occasional painting of vehicles in factories not engaged in vehicle painting. Objections also submitted by Railway and Pram Painting Employers.
24/9/25 <215>	Objection submitted by White Lead Corroders to proposal in draft Vehicle Painting Regulations for prohibition of painting interior of roofed vehicles.
26/10/25 <215>	Deputation from National Union of Vehicle Builders to Home Office, requests stricter control of spraying lead paint.
2/12/25 <215>	Conference between Home Office and Employers Representatives from Engineering, Vehicle and Pram Industries. Agreement reached on amendments to Vehicle Painting Regulations (in particular to delete reference to internal painting).

Table 5-2:7

1926

16/2/26	Home Office circulates final draft of Vehicle Painting Regulations
12/3/26	Vehicle Painting Regulations made (SR&O No.299) effective from 1/5/26
15/3/26	Lead Paint (Protection Against Poisoning) Bill comes before Commons for First Reading.
4/6/26 HC Debs. Col 1053	Second Reading of Lead Paint Bill. Extended debate. Carried by 131 to 56.
3/8/26	Report stage of Bill. Labour proposes amendment introducing internal prohibition. Under Secretary of Home Office opposes prohibition as being more difficult to enforce than regulation. Amendment defeated by 198 - 74, Bill passes third Reading and proceeds to House of Lords. Becomes law on 15/12/26.
31/12/26 <226>	Draft Lead Paint Regulations published in London Gazette and circulated to 36,000 concerned bodies.

1927

25/5/27 <226>	Home Office enquiry into draft Regulations under Sir W.W.McKenzie set under the factories Act up to seek agreement on terms of the regulations - after 16 objections to the draft had been submitted on which it had not been possible to reach agreement through informal discussions with the Home Office.
22/6/27 <226>	Hearing of McKenzie enquiry - leads to agreement on Lead Paint Regulations (enquiry re-opened to examine question of wire-brushing metal structures.
6/9/27	Lead Paint Regulations introduced; come into force on 1/10/27.

The British Political Situation

It is useful to begin this discussion of the policy implementation process with an examination of the wider political situation in this period and in particular (given the importance of government and parliament in the resolution of this process) the state of the major political parties and their representation in parliament and government. Table 5.3 shows the number of Members of Parliament elected and the composition of the government over the period 1910-1929. This shows that government and parties were in a state of transition, with four elections and five governments in the six years after the First World War. The Liberal Party was fragmented and in the process of being displaced as the alternative governing party to the Conservatives, by the infant Labour Party. In this period of shifting political loyalties the 'equilibrium' between two dominant parties (which characterises the British Parliamentary situation) had been upset.

It has been suggested that in the post war elections, the 'politics of negation' prevailed.[8] Bonar Law's 1922 government promised government economies and non-interference as its domestic policies. When Law's successor, Baldwin, went to the country in 1923 to gain support for economic Protectionism, the overall Conservative majority was lost and the government was defeated in Parliament. Constitutional precedent required the next largest party to form a government. Thus the first Labour Government was appointed, though it had less than 1/3rd of the Members of Parliament.

The minority Labour government "in office, but not in power" was thus unable to make fundamental changes. Moreover they lacked experience in government. "Inevitably they relied on the civil servants in their departments".[9] The Labour cabinet was politically moderate and largely lacking in concrete alternative policies. There was little prospect

TABLE 5.3. Composition of British Governments and Parliaments 1910-1929 (with leading cabinet members).

Aston University

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Aston University

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Source: A.J.P.Taylor, 1965, op.cit.

here for a radical programme of change even had the government lived on for more than 10 months.

Though the Labour government was brought down on an 'anti-communist' wave, the effect in the subsequent election was mainly to undermine the position of the Liberal Party, whose voters shifted to the Conservatives.

Baldwin's second Conservative government, despite its overwhelming majority, did not attempt to roll back the social reforms that had been introduced by earlier Liberal and Labour governments for example; differences between Tory and Labour on unemployment insurance were over the detail of benefit rates, not the principle.

A.J.P.Taylor, comparing these governments concluded that "the difference between Conservative and Labour was more rhetorical than real".[10]

Whilst this may have been true in terms of broad social policies adopted, the Lead Paint question would clearly be an issue on which Labour might be expected to take a stand. More than half their M.Ps at this time were trade union officials (and the unions provided most of the party funds). The interests of the painting unions would have a great opportunity of direct representation with the Labour M.Ps.

In contrast the 1924 Conservative Cabinet, like the Premier Baldwin, were 'cultivated businessmen', whilst the 1922 Conservative Government was markedly aristocratic (including 5 hereditary peers).

The Labour Movement

The other aspect of the British political situation which requires consideration is the position of labour. The years under examination saw substantial changes in the size, activity and political complexion of the labour movement.

As shown in Table 5.4, trade union membership experienced sustained and rapid growth in the 1910-1920 period.[11] During the First World War, a powerful rank and file shop stewards movement had emerged in many industries. The immediate pre- and post-war years were marked by increasing working class militancy (as indicated by the number of days lost in industrial disputes - see Table 5.4.) and broadening political aspirations (marked by the formation of the Labour and Communist Parties, and the survival of the revolutionary regime in Russia). The growth of the labour movement was put into reverse in the 1921-3 period when a sharp slump resulted in rising unemployment, wage cuts and a 44% fall in trade union membership.[12]

The next turning point was the 1926 General Strike. Although the strike itself sparked off a remarkable degree of solidarity and self-organisation amongst the working class, both the prelude to and defeat of the strike demonstrated major problems of strategy and leadership. In retrospect, the General Strike can be seen as a reaction to an offensive on the part of capital. Its defeat was a marked set back to the labour movement and reasserted the political dominance of capital.

Whilst the post-war movement was characterised by polarisation and struggle between reformist and revolutionary strategies, the aftermath of 1926 and the growing depression saw the entrenchment of a corporatist model of trade unionism (Mondism), particularly in the official movement.

It would be misleading to attempt to correlate particular events in the process of regulatory development to these overall changes in the position of labour overall. The painting unions had a sectional, craft outlook and were on the margins of the waves of labour militancy which centred around heavy industry. However, in the policy implementation process, the broader industrial relations situation was on occasion expressed as a

TABLE 5.4. Trade Union Membership in Britain 1910-1932 and number of days lost in stoppages of work.

Source: Henry Pelling, 1976, *op.cit.* [11]

direct consideration (e.g. by the desire of Master Painters to maintain the compromise agreed with the painters' unions).

The implementation of regulatory policy regarding lead paints involved choices about the allocation of "costs" to sections of labour and capital. It would seem significant that the eventual rejection of Prohibition occurred at a period when the position of labour was coming under attack.

Analysis of the Policy Implementation Process

The policy implementation process, described and documented above, will be analysed in the light of the theories of the state and its relationship to society that were discussed in Chapter 1. Policy implementation here involves the selection of a particular regulatory strategy in the context of sharply opposed interests and policies between the different affected social groups which in turn were reproduced within and by different sectors of the state.

The state is seen as contradictory and divided. In the implementation process, the interests of different social groups are unevenly represented by different sectors of the state. This is obviously so in the explicitly "political" representative arenas of the state (i.e. Parliament and Government) whose composition varies over the period in question with the wider political/electoral changes described earlier. However this is also the case with the administration, which is internally differentiated according to administrative function. This analysis focuses on the role of divisions and alliances between social groups and sectors of the state in determining the outcome of policy implementation. Alliances between social groups will be underpinned not only by the material interests of the groups but also by their strategy and in particular the extent to which one group is able to articulate and integrate its interests and strategy with that of another group.

A comparable situation exists through alliances with sections of the state. Whilst it would be misleading to conceive sectors of the state as pursuing their own material interests[13], different sectors of the administration have specific areas of concern and responsibility (e.g. regulation of hazard, promotion of industry) which will be reflected in the internal ideology of the agency, its structure and relationship with other groups/agencies etc. Success in winning support of an agency for a particular policy will be particularly influenced by the impacts it presents on the central concerns of that agency.

Thus the policy implementation process involved the pursuit by different parties of legitimacy and support for a particular policy option in society and within the state. The ability to win support in this process was not a simple consequence of the policy involved, its 'impacts' and the power of the group involved, but was significantly influenced by the ability of the proponent to elaborate the policy and project its implications for the interests and concerns of other social groups and state agencies. Given the degree of uncertainty that remained about many aspects of the regulatory strategies, a significant factor in this process was the ability of a group to develop and legitimate its view of the impacts of the regulatory options.

The development of the key divisions and alliances, and their effects on the policy implementation process, are examined below (in an order which approximates to their chronological order). These are:

1) alliances within society
2) the representation of these alliances within the administration; alliances between sections of the administration and sections of civil society.
3) alliances and divisions within the administration; their development in the attempt to resolve the implementation process.

4) the relationship between the administration and governments,

5) the relationship between government (and parliament) and social forces.

Alliances and Divisions within Society

The Lobby for Internal Prohibition

This comprised two groups, the Master Painters and the Painting Workers' Unions.

The Painting Workers' Unions, (the National Operative Painters' Society and the Scottish Painters' Society) had agreed to forgo their claim for total Prohibition of white lead paint on the basis of the Geneva compromise, and (at a meeting with employers and the Home Office on 4 April 1922)[14] had discussed and agreed a code of Regulations which could be applied to external painting with lead. If Internal Prohibition was abandoned they threatened to obstruct Regulation, and fight once more for total Prohibition. However, while the compromise endured they gave their wholehearted support for Internal Prohibition stating that "it was the only way".[15]

The Master Painters, now jointly represented on the (International) Painting Trade Materials Committee, also supported Internal Prohibition, but in a more contradictory way. They maintained their belief in the position outlined by Sutherland's minority report to the 1911 Departmental Committee, in the adequacy of Regulation to deal with lead poisoning. However they had accepted the Geneva convention "as a satisfactory compromise between conflicting claims" that "would end a long and embittered controversy". Internal Prohibition "applied to that section of painting where the danger was greatest and the economic loss would be least" whilst "the right to use lead would be retained for those purposes for which lead is most essential."[16] They would not revoke their commitment to this compromise because "it would be considered a breach of faith", which might imperil the agreement on the code of Regulations with the workers [N.B. it must be remembered that the craft basis of painting made the cooperation of the workforce in any changes essential]. Moreover, such a move "might have the unfortunate result in reviving the controversy between the parties .... who at present are working together", especially since following the Geneva Convention "the agitation for total prohibition has ceased".[17] The Master Painters thus were seeking stability by maintaining this compromise which, it was noted by the Home Office "safeguards the Master Painters against complete prohibition."[18] The Master Painters therefore opposed the White Lead Corroders who by reneging on the compromise, were attempting to avoid their burden of costs, and threatened thereby to "throw everything back into the melting pot".

Thus the lobby for Internal Prohibition, though strongly politically united, had divergent motivations, and held internally contradictory technical positions, especially regarding the adequacy of Regulation. (This contradiction was seized on by the White Lead Manufacturers.[19]) However, both Master Painters and Painting Workers agreed in their scepticism about the adoption of waterproof sandpaper which the White Lead Makers had proposed as overcoming the problems of Regulation.

The Lobby Against Internal Prohibition

The White Lead Corroders were described by a senior Home Office official as "leading, or perhaps it would be more correct to say engineering, the attack on the (Geneva) Convention".[20]

The White Lead Corroders were highly successful in winning support from a wide range of other industries to join them in the lobby against prohibition. Thus following their circular to other industries (described earlier), their first lobby to the Home Office was under the auspices of the National Confederation of Employers Organisations and also included representatives of the following organisations:[21] the Shipbuilders Employers Federation, the National Federation of Building Trades Employers, the White Lead Manufacturers, the Lead Employers Council, the British Ship Repairers Association, the Engineering and National Employers Federation, the National Federation of Associated Paint, Colour and Varnish Manufacturers of U.K., the Institute of British Carriage and Automobile Manufacturers, the National Federation of Vehicle Trades, the National Employers Association of Vehicle Builders.

The Confederation had resolved on 5 May 1922, that it was unnecessary to prohibit white lead. The deputation claimed to "represent .... the industries most affected by any action taken in the matter of white lead",[22] and, in particular, the National Federation of Building Trades Employers claimed to employ 2/3rds of operative painters, in 11,000 firms, and therefore to speak with more weight than the Master Painters Federations (with only 3,750 firms).[23]

The main presentation at this meeting was made by J.Hugh Smith, who submitted a memorandum by the White Lead Manufacturers.[24] This portrayed the continental zinc manufacturers as the source of the campaign to prohibit lead paint, aided by the International Labour Office.[25] It noted that the Master Painters only supported the Convention because of their general policy towards the operatives. The memorandum argued that the government should consider "both the means of preserving the health of the painter and the important economic interest of the state involved in the question of what paints should be used in the protection of buildings".[26]

The cost of prohibition of white lead paint would fall on 'certain Imperial industries' (i.e. leadmining), the community at large and the white lead industry (whose manufacturing process was totally different to the preparation of zinc oxide, and therefore could not be converted). The slump in demand for white lead in Britain with Internal Prohibition would reduce prices and lead to undercutting from the U.S.A. (the world's largest producer of white lead, which was not party to the Geneva Convention), further damaging the 'British Lead industries'.

Finally, it argued that "there was not precedent in this country for any industry to be treated in this way", - and by implication that Internal Prohibition went beyond the legitimate involvement of the state.

The Differences between the Alliances Supporting and Opposing Internal Prohibition.

Marked differences can be noted in these various delegations between the strategy and action undertaken by the Painting industry in support of Internal Prohibition and by the White Lead Makers, in opposition.

The White Lead Makers conducted a broad campaign, focusing not only on the direct impacts of Prohibition on themselves, but also on a wider range of broader effects. In this way they succeeded in enlisting the support of a wide range of economically powerful industrial interests, including industrial paint users and paint makers. The support of the latter is even more remarkable since, as described above, paint making firms had supported total Prohibition at both the 1911 and 1921 Departmental Committees, and the impact of Prohibition would be expected to enhance the sales of ready made paints. At the same time the White Lead Makers attempted to undermine the credibility of the proponents of

Internal Prohibition and to characterise some of these as being based on narrow self interest .

Many of the claims made by the White Lead Makers appear tenuous. For example they claimed that 40% of white lead was used in interior painting of houses. In contrast, the Master Painters, on the basis of a survey of their members, estimated that 40% of white lead was used in industrial painting, only 25% in painting the interior of buildings - reduced to 10-15% with the exemptions of industrial and public buildings embodied in the Geneva Convention.[27] The latter figures seem far more credible[28]. Whilst definitive information on this matter was (and still is) not available, what mattered was not the 'truth', but the political impact of such figures. The state's lack of reliable information about this and related issues was of central importance to the policy formation and implementation process.

In contrast to the 'White Lead Lobby', the painting industry had a much more inward looking approach and appears to have made little attempt to seek external allies to support its position.[29] Its contribution to the debate was little more than a restatement of the compromise accepted at the Geneva Convention and the Norman Committee. This may be partly a consequence of the level of resources which they were able or willing to devote to this matter (especially given the contradictory position of the Master Painters on this question). Whilst the level of public activity of the Painting Operatives Union in support of Internal Prohibition rose substantially towards the end of 1924, this only took place after the fall of the Labour government and after considerable opposition to Prohibition had been established. In 1924 it published a pamphlet supporting Prohibition and attacking the White Lead Manufacturers.[30] In September 1925 the union introduced a resolution at the Trades Union Congress (unanimously supported) calling on the government to implement

Internal Prohibition under the Geneva Convention and opposing the recently introduced Lead Paint Bill which embodied only Regulation.[31] However, by this stage the union's protests to the Home Secretary about this legislation were not even supported by the Master Painters, and did not succeed in stopping its introduction.

The demonstrations organised in 1923 by the Red Cross Societies in Brussels and Paris indicate that in some countries, Prohibition was a matter of broad social concern and still commanded the widespread support of 'disinterested parties'. (Rather than an internal matter to be settled in the trade - as it seems to have been considered by the British painting industry.) Despite the ongoing controversy about Prohibition during this period in Britain, it is clear that the impetus of social concern and support for this had been lost.

The White Lead Makers' allegations about the 'continental zinc interests' would appear to have a degree of truth insofar as the compaign for Prohibition appears to have been stronger in those countries with an established Zinc pigment industry that could provide a counter-weight to the strength of the White Lead industry, and broaden the alliance in support of Prohibition.

Thus the White Lead industry, though substantially smaller than the Painting employers, succeeded in building a broad and powerful alliance against Internal Prohibition. A major difference between these two sections of capital is the extent to which Prohibition affected their interests. The White Lead industry was thus more highly motivated to oppose Prohibition, and were willing to devote a greater degree of resources to this end, than the Master Painters to support it. As noted in Chapter 4, the White Lead industry seems to have been better coordinated in its responses, and to have made greater use of public, industry representative and in particular, technical avenues to promulgate its position, than the interests supporting Prohibition. These factors are clearly interlinked. Their net result was to guarantee a substantial difference in the economic and technical strength, and public visibility of the social forces supporting and opposing the implementation of Internal Prohibition.

Representation of these Divisions in the Administration

The divisions between the different sectors of industry regarding regulation of lead paint were represented ACTIVELY by sections of the state Administration in ways that were consistent with their administrative function. Thus the Home Office, which incorporated the Factory Department, not only "presented the case for ratifying" the Geneva Convention to both the 1923 Conservative and 1924 Labour governments, but under the latter played a much more active role, that could almost be described as a campaign, liaising with and coordinating the social forces supporting Prohibition.

Conversely, the White Lead Lobby was able to gain representation through the Board of Trade and the Colonial Office - which had responsibility for promoting the interests of industry/commerce and the Empire respectively - by promoting its argument about the effects of even Internal Prohibition on employment in lead mines in Britain, Australia and Canada.

The relationship between the administration and the various industrial interests (employers and workers in pigment and paint manufacture and paint use) will be examined in the cases of :

i) the Home Office

ii) the Board of Trade.

The Relationship between the Home Office and the Lobbies for and against Internal Prohibition

The White Lead Manufacturers, with their allies from the paint making building and coachpainting industries, were the first group to lobby the Home Office following publication of the Norman Report.[32] The Home Office did not accept the claims by this group to be the major representative of housepainters and questioned their technical legitimacy on the subject.[33] The visit seems to have had little impact on Home Office views regarding Internal Prohibition. Indeed, in the subsequent visits by delegations from the Master Painters and Painting Operatives' Unions, the Home Office concentrated on collecting information that could be used to undermine the White Lead Lobby's objections, particularly regarding the proportion of lead paint used in interior decoration[34] and the applicability of the method of wet glass papering.[35]

During the 1923 Conservative government, the support by the Home Office for Internal Prohibition in its dealings with the different affected parties takes a relatively low profile and was primarily of a reactive nature (which may be related to the equivocation of the government about implementing the Geneva Convention).

A different picture appears after the Labour Government in 1924 decided to introduce legislation to implement Internal Prohibition. The Master Painters and Painting Unions (through the Painters and Decorators Joint Industrial Council) sent a resolution to the Home Office in support of Internal Prohibition on 20 February 1924 with a letter offering their help in enacting this legislation.[36] This was followed by a period of close cooperation between the painting trade and the Home Office with ministerial support. Thus during the course of the 1924 Lead Paint Bill the Home Office wrote, at the Home Secretary's behest, to the Master Painters and Painters Unions "to ascertain the adoption of wet rubbing down with waterproof sandpaper since it is expected that at the second reading .... the opponents of prohibition will lay great stress on the use now made of this new method".[37] Replies were received from both, indicating that the method was not being widely adopted.[38, 39.]

In contrast to the frequent and close collaboration with the painting trade, countervailing groups were received less sympathetically. Thus a letter from the National Union of General Workers, requesting that the Home Office receive a delegation from workers in lead factories to oppose prohibition,[40] was initially resisted by the Home Office.[41]

During 1923 and 1924, the Home Office were willing to make critical observations on the White Lead Manufacturers' position. Thus in a memorandum to the Home Secretary (16 September 1923) they were described as "engineering the attack on the convention". The Home Office concentrated on undermining the factual basis of their arguments[42] (as well as their claim to represent the affected parties).

The estimate of the impact of Internal Prohibition on consumption of white lead (and thus lead production and prices and employment in Australian lead mines) produced by the White Lead Manufacturers, and supported by the Board of Trade and Colonial Office, were described as based on "exaggerated figures".[43]

The position adopted by the Home Office in actively supporting the ratification of the Geneva Convention primarily reflected its responsibility for protecting the health of workers (as the Government Department which included the Factory Department). However a secondary motivation is evident, stemming from the Home Office's responsibility for liaising with the International Labour Organisation.[44] Thus it argued that Britain had a moral obligation and, as a leading force behind the League of Nations, a political duty "to give a lead to other countries".[45]

Additional arguments were advanced:

i) that the compromise at the Geneva Convention shared the burden amongst the different parties and, having been agreed should be adhered to, especially since

ii) "failure to ratify will revive the agitation" for total prohibition in an industry (i.e. painting) in which employers and unions were working together.[46]

Thus, in addition to protecting workers' health, a separate concern can be noted that the state be seen as acting fairly and avoiding confrontation.

The Relationship between the White Lead Lobby and the Board of Trade and the Colonial Office

As noted earlier, the White Lead Manufacturers had approached the Board of Trade and the Colonial Office (in particular the Imperial Mineral Resources Bureau) and enlisted their support against Internal Prohibition on the grounds of its economic consequences.[47] In particular it was suggested that the Australian lead mines would be affected by the reduction in demand for lead.[48]

Under the 1923 Conservative government these bodies had opposed the introduction of Internal Prohibition. When the question of ratifying the Geneva Convention came before the Conservative Cabinet Home Affairs Committee it was the President of the Board of Trade who argued for postponing the decision.[49]

As the 1924 Labour Government began to introduce legislation to implement the Geneva Convention, the White Lead Lobby pursued these avenues more strongly. On 7 May 1924 the Board of Trade received a deputation from the Federation of British Industry, the Federation of Building Trades Employers, the White Lead Makers and their employees, at which the White Lead Corroders reiterated their position.[50] Subsequently the Board of Trade wrote to the Home Office stating that they were "impressed with the evidence as to the possible adverse effect upon employment in the white lead industry of the proposed (interior prohibition) and as to progress since 1921 with wet rubbing ...." The Board acknowledged that it was undesirable not to ratify an International Labour Convention to which it had been party and that a Bill to implement internal prohibition had already been introduced. It therefore suggested that the Home Secretary (Henderson) should consider an amendment to make the Bill 'purely regulative' in the event of strong opposition in the House of Commons to the 'prohibition section'. This was seen as 'a reasonable compromise' which "in all circumstances could not be regarded as a failure by the government".[51] This intervention is surprising since the President of the Board of Trade (a member of the Labour Cabinet) had rejected this position at the Home Affairs Committee in February of that year.[52] Indeed the Board's position in 1924 was very much a continuation of the policy that it had adopted, with the support of its President, under the previous government.

The Relationship between Sections of the Administration in the Policy Implementation Process

The Home Office response to the Board of Trade

The Home Office attacked the Board of Trade's intervention as being procedurally incorrect and beyond the Board's area of expertise. Thus a Home Office note attached to the Board's letter states that "They are not qualified to judge on the latter parts" dealing with the technical problems of regulation.[53] A Home Office memorandum comments "This is an extraordinary letter from the Board of Trade. The facts, or rather mis-representations in the enclosure have been known for many months",[54] and moreover, the Board should have voiced its attitude before the Cabinet discussed the question, rather than prior to the 2nd Reading of the Bill.

The Home Office enlisted the (Parliamentary) Under Secretary of State for the Home Office, who commented that "We cannot object to the Board of Trade receiving deputations from traders who think they will be adversely affected by a Home Office Bill, but they ought to give us an opportunity of being represented and they should certainly be careful to refrain from expressing views in conflict with the responsible department".[55]

As a result a letter was written to the Board of Trade that "the Secretary of State is unable to accept the statements made by the deputation, (moreover) .... dropping prohibition would make it impossible to ratify the Geneva convention".[56]

The Home Office thus fought to establish its primary legitimacy within the government to deal with this matter as well as to constrain the activities of the sections of the administration that might run counter to it.

The Home Office activities with other Sections of the Administration

When the Home Office was preparing a position on the Geneva convention for the 1923 Conservative government, the views of other government departments were canvassed (mainly regarding the exemptions that should be allowed for certain government painting activities). These had little relevance to whether Internal Prohibition should be introduced.

Following the Labour Government's introduction of the Lead Paint Bill (embodying Internal Prohibition) the Home Office, in conjunction with Rhys Davies, M.P., (Under Secretary of State) asked the Office of Works (the body responsible for painting government buildings) whether they would "enact prohibition at once" or "be regulated".[57] The Office of Works replied only a month later that "this Department is acting as though the prohibition of lead paint for internal work, as foreshadowed by .... the Bill, was already operative. Where Lead Paint is used (i.e. external work) the Regulations prescribed by the Secretary of State will be followed".[58] The speed of this change in practice is as striking as the completeness by which it reversed the 1921 Office of Works position.

This move was welcomed by the Home Office as being "of considerable assistance in demonstrating that it is quite practicable to comply with the convention".[59] Rhys Davies requested that a note of this fact be made for the 2nd reading of the Lead Paint Bill,[60] and as a result other government departments were informed of this position stating the "strong hope (of the Secretary of State that they) will find their way to take action similar to that taken by the Office of Works".[61]

The War Office responded enthusiastically[62] and eventually in January 1925 issued instructions prohibiting the use of white lead paints in its operations for internal painting, except to use up existing stocks.[63] However by this stage the political climate had shifted and a new government was in power. When the Federation of British Industries and the White Lead Manufacturers protested, pointing to the strong opposition expressed in the House of Commons to the Labour governments Lead Paint Bill, the War Office withdrew this instruction.[64]

Thus a distinct strategy emerged under the Labour Government, with the Home Office seeking with Ministerial encouragement, to establish the technical feasibility of internal prohibition through its political influence over the productive activities under its direct control, and then to extend this to other areas of the state's activities. In addition to administrative consistency, this endeavour was underpinned by a philosophy that state enterprises should "set a good example to employers" by adopting best practice in advance of legal requirement to do so.[65]

Relationship between the Administration and Government in the Policy Implementation Process

The discussion about divisions within the administration has already covered some aspects of the relationship between the government (the cabinet, ministers etc.) and administrative departments.

As noted earlier, the Board of Trade continued to promulgate the White Lead Manufacturers' position in 1924 despite the fact that the President of the Board under the newly appointed Labour Government (Sydney Webb) had already made clear his support for Internal Prohibition. Similarly, the Home Office attempted to bring about a decision to ratify the Geneva Convention despite the ambivalent statement in Parliament by Sir Montague Barlow, Minister of Labour in the 1923 Conservative Government. There is clearly a degree of autonomy between the views of a department and of its Ministerial head/the government. That autonomy has to be seen as constrained, both by explicit control and informally.

An example of explicit control is the argument between the Home Office and the Board of Trade in 1924. The Home Office rebuff at departmental level was strengthened by a direct approach from the Secretary of State for the Home Office to the Board.[66] After this point, the Board of Trade appear to have refrained from further intervention.

The model of informally 'constrained autonomy' can perhaps best be illustrated by the changing tenor of the activities of the Home Office in support of Internal Prohibition, which went through three broad stages depending on the government in office, without any explicit ministerial control taking place.

Thus under the 1923 Conservative government, Home Office activity took the form of presenting in a factual manner the case for Prohibition, criticism of the opponents' case and the obligation on the government to ratify.

Under the 1924 Labour Government, the Home Office worked in conjunction with the responsible minister to secure technical and political support for Internal Prohibition. Under the subsequent Conservative government, whose opposition to Internal Prohibition was marked, Home Office activity in the matter is negligible (after passage of the Lead Paint Act 1926, the Home Office devoted its primary attention to developing a code of Regulations).

The role of the Home Office under the 1923 Conservative government is particularly interesting. When the Minister of Labour proposed to make an announcement to Parliament which opened the possibility of not ratifying the Geneva Convention he met strong opposition from the Home Office (which was, however, not successful in altering Barlow's statement).

Sir Montague Barlow (Minister of Labour) had written to W.C.Bridgeman (Home Secretary) about a statement he proposed to make to the House of Commons on the International Labour Convention. Since the convention only required that the matter be brought before the competent authority within 18 months, he suggested that 'it merely be discussed in Parliament' - and that a decision be deferred while the government considered the implications of the Norman Committee report.[67] Barlow's proposed statement drew a rapid protest from Sir M.Delevingne in the Home Office, in particular that the obstacles to ratification that Barlow mentioned "were of a minor character .... the main difficulty was the opposition of the White Lead Corroders".[68]

Barlow did not amend his statement in the light of this intervention, however, his position was cautious, and couched in 'diplomatic' terms. He stated that when he had cast the British government's vote at the International Labour Convention in support of internal Prohibition, he had done so "on the basis of the compromise which had been reached, agreed to by all concerned".[69] Since this compromise appeared in 1923 to be breaking down, he claimed that he and the government clearly "had a free hand".[70] The statement by Barlow's Parliamentary Assistant clung to an even slimmer justification - that the Norman Committee recommended "that legislation should be passed to give effect to the principles contained [in the Convention]; it does not say that the Convention itself is to be adopted"(sic).[71]

The Home Secretary pleaded that it would be "precipitate to urge ratification" whilst consultation was proceeding with the affected parties. The tentative and convoluted phraseology of these statements reveal the difficulty that faced the government in not implementing policy recommendations to which it had been part at both the Geneva Convention and the Norman Committee, as well as the seriousness attached to failure to ratify an International Convention.

Despite (or possibly because of) the fact that the government was generating an option NOT TO ratify the Convention, the Home Office embarked on a period of intensive activity to lay the ground for a decision on implementing Internal Prohibition. Following representations from the affected parties, a memorandum on the need for Britain to ratify the Convention was initiated on 2 August 1923, it was augmented by a criticism of the opposition from the Board of Trade and White Lead Manufacturers and submitted to the Home Secretary on 14 August. After circulation for amendment to the Home Affairs Committee on 27 August, a final case was prepared,[72] and presented to the Home Secretary on 6 September 1923.

This Home Office memorandum to the Home Secretary states that "the materials are now available for a decision on the question of ratification". It strongly supported ratification, arguing that "the communication from the Master Painters is important" whilst the arguments of the White Lead Manufacturers "cannot be accepted".[73]

The main thrust of this argument rested on political rather than technical grounds i.e. administrative appropriateness and avoiding controversy and conflict. Thus the memorandum states that "the chief considerations in favour of ratification ...." were,

i) the adherence to a compromise suggested by one of the British delegates and supported by all the U.K. delegates at the Convention

ii) the compromise had led to an end to the controversy about total Prohibition. "The Master Painters of this country, who are the employers organisation mainly concerned, are strongly in favour of ratification .... it is they who will have to face the trouble if the workers join battle again over this issue"

iii) the Convention was supported by the Home Office committee (the 'Norman' Committee on Industrial Paints).

Finally, the memorandum suggested a method of avoiding difficulties in interpreting the Convention that had been raised as a potential obstacle to ratification.[74]

The endeavours of the Home Office did not, in the event, succeed in winning the 1923 Conservative government to ratify the Geneva Convention. Equally, that government was unable to reject ratification.

Thus the Home Affairs Committee (a sub-committee of the Cabinet) discussed the Convention and came to a curious proposal on 8 November 1923 "that it should be announced that the British government did not propose to take any final decision on the question of ratification at present but that an undertaking should be given that if the British Government was not completely satisfied that the new process (wet rubbing) had been adopted and was being properly carried out .... they would take steps to secure that full effect was given to the Convention on the appointed day of 1927.. An understanding, not for publication, would be reached with the International Labour Office to decide on the question of ratification 12 months after Regulations become operative".[75]

According to a Home Office Memorandum to the subsequent Labour Administration,[76] it was the Board of Trade who had pushed for postponing the decision on ratification, pending a trial of wet rubbing (i.e. Regulation), while the Home Office continued to support ratification. After debating the question at length, the matter was brought before the full Cabinet. However, in view of the declaration of a General Election, and the dissolution of Parliament, the Cabinet decided to postpone a decision until after the election.[77]

Notwithstanding their limited success under the 1923 Conservative government, the Home Office took advantage of the 1924 Labour government to push its case, arguing that, since the deadline for ratification had arrived on 1 January 1924, a decision was long overdue.[78] The Home Secretary was rapidly won to support ratification.[79] A Bill was drafted, Section 1 of which prohibited the use of lead paint in painting the interior of any building from November 1927.[80] On 28 February 1924 the Cabinet approved its introduction. This was one of the first questions that the Labour Government had to deal with, and the rapidity of the decision making process (which took apparently a single month) stands in contrast to the failure of the previous government to take any action in more than seven months of deliberation. Arguably, the 'synergistic' relationship between the Home Office and the Labour Government facilitated a rapid decision. Equally, it has been noted that the Home Office, with Ministerial support, and in liaison with the painting trade, attempted to demonstrate the feasibility of, and undermine opposition to, the introduction of Internal Prohibition (in particular from the Board of Trade and the White Lead Lobby). The failure of the Labour government's Bill however was a consequence of the political weakness of the government, and the opposition it faced in Parliament.

The role of the Home Office under the Conservative Government which took office in November 1924 was different yet again. The new Home Secretary Joynson-Hicks, noting the opposition that had met the Labour government's Bill (which included Internal Prohibition) chose to adhere to the policy determined by the previous Conservative Home Affairs Committee (of introducing Regulation on an experimental basis), apparently without any discussion with the Home Office of the policy implications of such a move.[81] For its part, the Home Office does not appear to have initiated any attempts to promote Internal Prohibition in painting buildings. The only activity of the Home Office/Factory Department in housepainting under this government seems to have been development of a code of Regulations to implement Regulation under the Lead Paint Act (particularly in the first half of 1927 - see below).

However the Factory Department presumably with the involvement of the

Home Office did attempt to develop a code of Regulations for Vehicle and Shipbuilding which included similar elements to Internal Prohibition of lead paint in housepainting. In particular a clause prohibited the use of lead paint in the interior of roofed vehicles. This clause was dropped after opposition from industry and M.Ps. (The development of these Regulations is discussed below).

The contrast between the Home Office role in the first and second Conservative government suggests that Departmental autonomy was highly constrained in the latter period where there had been clear expression of opposition from Parliament and government to Internal Prohibition (and, possibly, when the scope/need for a departmental role in policy development had been largely exhausted).

This overview of the role of the Home Office, and other government Departments, in the policy implementation process under three governments has indicated the varying degree of Departmental autonomy from government policy according to the political context (particularly according to the policy of government and Parliament and the intervention by external bodies).

It also suggests an interaction between departmental and government policies in the policy implementation process. Thus the form and extent of Departmental activity to support or oppose Internal Prohibition varied according to the governments' position. In the case of the Home Office support varied from active coordination of the forces supporting the Geneva Convention, to attempting to invalidate the opposition.
The facility of governments to implement their preferred policy seems also to have been affected by the extent to which it coincided with the policies generated by the relevant government departments and the earlier policy development process.

Relationship between Government, Parliament and Social forces in the Policy Implementation Process

The study of the articulation of different interests within the administration has shown a complex pattern of representation marked by sharp internal divisions. The resolution of these problems took place through Parliament and Government. This was necessitated by the historical fact that an Act of Parliament was required to extend the terms of the Factory Acts to the painting of (non-industrial) buildings, and more fundamentally, by the political context of the policy implementation process.[82] The fact that all the Bills on Painting Buildings presented to Parliament, in one way or another, determined whether Internal Prohibition was to be introduced reflects the continuing controversy on the subject (within the administration, parliament, and society).

In contrast to the bulk of regulatory development of workplace hazards in the Twentieth Century, in this case study, determination of the outcome of the policy implementation process fell to the representative/public decision making arena of the state, which was polarised, largely along party political lines. Neither the policy development process nor the administration seem to have had a decisive influence at this stage.

This situation focuses attention on to the representation of the different industrial/social interests at the level of government and Parliament. These will be examined in the 1924 Labour and Conservative governments (since policy implementation by the Conservative government in 1923 was interrupted).

The 1924 Labour Government

As stated earlier, it was not surprising that the Labour government gave more weight to the position of the painting workers than the White

Lead Employers. Half the Labour M.Ps. were former trade union officials. For example, Rhys Davis, Parliamentary Under Secretary for the Home Office, who was very involved in the introduction of the 1924 Lead Paint Bill, had been an official of the Distributive Trade Union.[83]

From the outset, the minority Labour government was very aware of the developing campaign against Internal Prohibition. However, their main concern was with the House of Lords, where it was felt that "the lead interests (Lords) Cedby and Askwith, will concentrate their efforts to stop or emasculate the Bill, and might very possibly succeed." The Cabinet therefore decided to introduce the Bill into the House of Commons where, it was hoped, it would be "almost sure to be carried by a very large majority and would go to the Lords with a backing that they could not ignore".[84]

The Home Secretary argued that an early introduction of the Bill was important to 'show willing' and that there was no advantage in delaying introduction "because the interests who oppose the bill are already working busily".[85]

The Lead Paint Bill, including a measure for Internal Prohibition, was introduced on 3 April 1924, but did not get its 2nd Reading until 20 June 1924. It was during this period that the activities of the government, Home Office and painting trade in support of Internal Prohibition reached their highest peak. However it was noted that opposition was also growing. To offset this, the painting trade undertook to canvass M.Ps.[86]

Events showed the Labour government to have misread the opinions of Members of Parliament. At the 2nd Reading of the Lead Paint Bill there was strong opposition to the clause prohibiting the use of lead paint in painting the interior of buildings from both Conservative and Liberal M.Ps. (although there was general agreement to the remaining sections which dealt with Regulation), who argued that it should be sent to a Select Committee. Henderson, the Home Secretary, was only able to get agreement for the 2nd Reading to be completed by giving an undertaking that if Clause 1 (dealing with Prohibition) was defeated in subsequent stages of parliamentary procedure he would still go on to implement the remaining clauses which implemented Regulation.[87] Only with this assurance was the Bill able to proceed. The Bill then went to the 'Committee stage' for detailed discussion. The only amendment of any note proposed for consideration was to delete Clause 1 (requiring Internal Prohibition).[88] The defeat of the Labour government and the dissolution of Parliament prevented further progress.

The rapid collapse of the Labour government's policy deserves comment. Rather than let the measure be defeated in hope of subsequently being able to get ratification implemented, the Home Secretary acceded to a move that would almost certainly have lead to introduction of Regulation alone. It is worth noting that this was indeed the option that the Board of Trade had proposed as a way of letting the government off the hook. However, as a minority Party, they could only govern with Liberal support. With sections of the Liberals opposing Internal Prohibition, it could not succeed.[89]

When the matter was debated again in Parliament in 1926, the Labour Party now in opposition were able to be outright in their support for Prohibition, and voted against the Conservative Lead Paint Bill - which introduced Regulation alone - the very position that Henderson had effectively conceded in 1924.

The Conservative Government 1925-6

Having drafted a Lead Paint Bill, which introduced Regulation only

(3 April 1925), the Conservative Home Secretary took the unusual step of announcing the Bill in a Commons debate on the International Labour Organisation (9 April 1925) before introducing it in the House of Commons (1 May 1925). The Home Secretary's statement claimed that it was based on "arrangements, almost amounting to an agreement [that] have been made between the users of white lead and the manufacturers of white lead".[90]

When the Labour opposition protested about the government's failure to frame legislation on the lines of the Geneva convention, the Home Secretary replied that there would be difficulty getting such a Bill through Parliament, and that it was best to implement Regulation now, and to "ask [Parliament] for further powers" if this "did not considerably reduce mortality and morbidity".[91]

The government seems to have adopted a strategy of distancing itself from responsibility for failure to ratify the Convention, while delaying a decision on the question, in the hope that the controversy might die down. Though the Lead Paint Bill was introduced in 1925, it was not allocated debating time. The Bill was reintroduced before Parliament the following year (15 March 1926) and the 2nd Reading took place on 4 June 1926.

Although the outcome of the Parliamentary Debate on the 1926 Lead Paint (Protection Against Poisoning) Bill was never in question, it is useful to examine the contents of this debate for the insights it gives into the perspective of the government and Members of Parliament and the overt factors underlying this.

Joynson-Hicks, Home Secretary, introducing the debate, claimed that the Conservative Party, like the Labour Party, wanted Prohibition, but that there was "a very great demand for lead paint". Although the use of lead substitutes was increasing he claimed that employers said that these "were not satisfactory".[92] This and other government speeches supporting the Bill did not directly discuss the economic costs, to white lead makers and the lead industry in general of Internal Prohibition, but were based on assertions about the technical obstacles to substitution that had little factual justification from the policy formation process and the policy of painting industry employers.

Though the Conservative government was following the policy and technical justifications of the industrial interests that made up the 'anti-Prohibition' lobby, the importance of these interests was obscured in the government's contribution to the debate.[93]

The Labour opposition was quick to take up the accusation of vested interest. Rhys Davies, opposing the Bill, claimed that the "Home Secretary had been influenced by the White Lead Corroders of Australia and this country". This accusation even received support from the Liberal bench. Lord Henry Cavendish-Bentinck, who had served on the 1911 Departmental Committee argued that "there is always the question in this Parliament of a struggle between vested interests and the interests of the workers, and, as far as I can see so far, the vested interests have got an upper hand".[94]

The supporters of Regulation made the counter-claim that the International Labour Convention had been influenced by the French and Belgium zinc lobby.[95]

The government's position in the debate was notable for its tentative nature and its lack of technical justification. Joynson-Hicks claimed that Regulation would "reduce [rather than eliminate] the possibility of poisoning by lead paint" and repeated his offer to "make further Regulations" if this measure was "not sufficient".[96] The only piece of evidence cited for abandoning the findings of the policy formation process was "the invention of waterproof sandpaper".[97]

In contrast, the opponents of the Bill were able to draw on the material and recommendations of the Departmental Committees and a range of their sources (including the [increasing] levels of lead poisoning reported amongst house painters, noted by Rhys Davies in support of Prohibition, but, astonishingly, not mentioned at all by the proponents of the Bill).[98] Though the opponents of the Bill may have won the debate, they lost the vote which followed by 131 to 56.

There was a similar performance at the Report Stage of the Bill, when the opposition moved a clause to insert Internal Prohibition into the Bill, which was defeated by 198 to 74 votes. The Bill then 'passed its Third' reading and was sent to the Lords. The Lead Paint (Protection Against Poisoning) Act 1926 became law on 15 December 1926 and its clauses came into operation on 1 January 1927.

One immediate result of the government refusal to ratify the Geneva White Lead Convention was the resignation (on 29 November 1926) of the Medical Inspector of Factories, Sir T.M.Legge, because of his role in bringing about the compromise agreement at Geneva, and because "he could not bring himself to administer a method of prevention from which he could not forsee satisfactory results".[99]

This examination of the final stages of the policy implementation process provokes some observations:

The Labour government prioritised the question of painting workers health, and by so doing, the policy of the painting trade as a whole, over that of the economic arguments of the alliance of industrial interests in the 'white lead lobby'. In so doing, it was following both the preceding policy formation process, and its own institutional links with the trade union movement. While some vacillation was apparent in the government's position, this can primarily be related to the political weakness of the government (particularly its lack of a Parliamentary majority), and the lack of support for Internal Prohibition from other political sections in Parliament.

The Conservative government, with support from its own and Liberal M.Ps, by implementing Regulation, was acting to secure the policy objectives of the 'white lead lobby'. It thereby prioritised the claims of the white lead lobby about the economic impact of Internal Prohibition (over other interpretations), and adopted a regulatory strategy, which, it was equally agreed, would have an uncertain and probably limited impact on the health of painting workers. However, in its public proclamations, the government did not acknowledge the role of these economic considerations, but sought to obscure them (behind counter claims of the role of vested zinc interests) and to resort to scanty technical justifications about the feasibility of Regulation.

This concealment of 'economic' motivation would appear to be related to the government's need to appear 'disinterested' in its actions. However the government faced substantial problems in legitimating its actions which contradicted its own policy formation process, the views of key sections of the Administration and its commitments at the International Labour Convention. This was expressed in delays to, and the tentative manner of the government's introduction of Regulation and its attempts to sidestep responsibility for such a move.

It would be misleading to see the eventual outcome of the policy implementation process as based on a comprehensive assessment of the economic and health effects of the different regulatory strategies available, and the determination that Internal Prohibition involved unacceptably high costs to capital. Instead, it would appear to have been the political influence of the white lead lobby on Parliament and government that prevailed, in a situation in which many of the impacts of the regulatory options were uncertain.

It is important to note that substitution of white lead by zinc pigments was taking place at a surprisingly rapid rate during this period. As shown in Chaper 3, between 1910 and 1924, U.K.consumption of lead fell from 52 to 33.3 thousand tons. Consumption of white lead in interior paints was estimated as having fallen even more rapidly, from 16 to 6.5 thousand tons (only part of which would have been eliminated under the International Labour Convention).

There was thus little credible evidence from the information available, at the time or subsequently, that would demonstrate Interior Prohibition as having a substantial economic effect either on the painting trade or on lead and white lead manufacturers.

In the face of uncertainty about, and strong political opposition to the alleged economic consequences of Prohibition, the government adopted the policy that involved least intervention in industrial development.

Summary of Policy Implementation Process

The highly detailed discussion of the policy formation and implementation process has been at the expense of clarity of exposition of the salient points in this process. It is perhaps useful to summarise these.

The eventual decision by the state was in conflict with, and ignored, the policies generated by the Departmental Committees of 1911 and 1921 (the policy formation process). Resolution of the policy implementation process was projected into the explicitly 'political' representative arena of the state (government, parliament). This contrasts with other areas of state control over technological hazards which were frequently seen as 'technical' rather than 'political' issues, and in which the administration was frequently the most significant arena for resolving/implementing policy.

The 'politicisation' of the implementation process can be attributed to the breakdown of consensus over the control strategy to be adopted (as defined in the policy formation process) both within the administration and society.

This breakdown of consensus was in turn a consequence of the uneven power and differences in strategy and organisation of the 'affected parties' as well as specific problems for regulatory development based on Prohibition. Thus Prohibition posed particular problems for the development of regulation on a consensual basis because of the uneven distribution of costs and benefits, across a wider range of affected parties than the traditional regulatory strategy. In addition, Prohibition involved a new form of state intervention and required state competence over new areas (industrial/technological development). There was a shortage of reliable information and expertise about the feasibility and impacts of the regulatory strategies under examination (for which state sources of information were little developed), that was needed to legitimate the state's regulatory activity. This became particularly problematic during the policy implementation process, as the focus of the controversy shifted from the protection of health to the economic costs of regulatory strategies.

Policy implementation was taking place in a period of changing political terrain in Britain, as the Labour Party began to replace the Liberal party as the alternative governing party to the Conservatives. The balance of political power was thus disturbed. (Equally the counter-position of agricultural and industrial interests, represented in Parliament by the Tories and Whigs, which had been instrumental in the establishment of Nineteenth Century Factory legislation, was also broken down).[100]

Governments were uncertain as to the position to adopt on policy implementation in the face of controversy and division in society and the administration, which was expressed partly in terms of delay in implementation, and partly by offloading responsibility for the outcome to Parliament.

The strength of the White Lead Lobby was not counterbalanced by the Prohibition lobby in the U.K. Given the political balance in Parliament, it would have been necessary for significant numbers of Liberal and Conservative members to be won over to support Prohibition (on the basis of humanitarian concern, in breach of class and party alignment) in order to win a Parliamentary majority for a measure of Prohibition. However, the climate needed for such a development did not exist by the time the final decision on policy implementation was made.

The salient features of this implementation process will be examined in greater detail focusing on the organisation and strategy of the different interest groups, information constraints in the policy implementation process, the role of the administration and of governments and Parliament.

The (Internal) Prohibition Lobby

The Internal Prohibition lobby was based on an explicit compromise (at the Geneva Convention) - its policy was, as a result, internally contradictory. It had an inward looking approach (representing mainly Master Painters and Painters Unions) and failed to ally with or neutralise other groups (e.g. the Paint Makers - who it must be remembered supported total Prohibition in 1911). This may reflect its defensive orientation (around the Geneva Convention and Norman Committee recommendations), its lack of foresight of the opposition, lack of resources and (in the case of the Master Painters) lack of commitment to the policy being propounded. The latter two factors appear to have contributed to a weakening of the lobby in the final stages of policy implementation - the prolonged delay in policy implementation seems to have resulted in a dying down of public concern about poisoning in housepainters and the Master Painters commitment to the alliance seems also to have waned.

The White Lead Lobby

At the heart of the 'White Lead' lobby were the White Lead Manufacturers. Though substantially smaller than the painting industry (in terms of turnover, number of workers or establishments), it was highly centralised, with strong links both internally, and with other industries. The White Lead industry responded to the threat to its livelihood not by focusing on its narrow interests, but by devoting its considerable economic and technical resources to winning a wide range of industrial allies and projecting a claim to represent the general interest. It conducted activity within industrial, public and scientific circles and concentrated on the wider impacts of Prohibition (total or internal), particularly its economic and employment effects, as well as questioning the legitimacy of state involvement of this nature and the proponents of Prohibition.

A Note on the Internal Contradictions of Internal Prohibition

In retrospect it can be seen that the adoption of the compromise strategy of Internal Prohibition at the Geneva Convention and Norman Committee had particular effects on the legitimacy of the case for and against Prohibition. The 'White Lead Lobby' attacked Internal Prohibition along the same lines as it had attacked total Prohibition. In contrast, the alliance supporting Prohibition accepted the compromise without apparently considering the implications for its policy. It had thereby conceded the economic and technical feasibility of Regulation and the administrative possibility of enforcing it - though this had been a major plank of the case for Prohibition as a means for reducing lead poisoning amongst lead painters. Moreover, in their attempts to implement the Geneva Convention, the painting trade and Factory Department developed and agreed a code of Regulations to be applied to external painting, thereby making available a credible, detailed programme for Regulation that could be extended to internal painting.[101]

Lack of Knowledge and Expertise in the Policy Implementation Process

The debate about policy implementation was conditioned by the lack of knowledge and expertise regarding key aspects of Prohibition and Regulation of lead paints (and by the location of areas of information and expertise within sectors of private industry).

Whilst the state, through the Factory Department, was able to propose the Prohibition strategy on the basis of its knowledge of industrial hygiene and experience of regulating other industries it could not conclusively demonstrate the inefficacy of Regulation for housepainting, which was outside its administrative scope. Equally, the debate about Prohibition shifted onto the terrain of the technical feasibility and economic consequences of substituting zinc pigments for white lead. There was considerable uncertainty about these areas. The state had limited expertise in paint technology (other than through its role as a paint user) and systematic study of this was not available. Industrial assessments of paint performance were highly contradictory. The state was beginning to develop reliable sources of information about the economic impacts of Prohibition - for example, trade and census of production statistics, (ironically, these were under the administration of the Board of Trade, which was hostile to Prohibition) but the main source of such information were the industries to be regulated.

The terms of the debate about policy implementation shifted to those areas where uncertainty was greatest and away from health, onto the economic impact of the regulatory strategies. The debate was thus forced onto the terrain chosen by the White Lead lobby. Whilst the latter's claims about the effect of Internal Prohibition had a dubious factual basis there was no authoritative alternative source of information and the White Lead Makers had prima facie legitimacy on this matter.

The Failure of the Administration to Resolve the Policy Implementation Process

The administration were unable to resolve the problems and conflicts over the policy implementation, and played only a secondary role in determining the consequences of this process. Whilst this would appear to be mainly a result of the strength of the social divisions it is also linked to the internal divisions within the state. The policy of administrative departments differed according to their administrative function (particularly between industrial promotion and industrial regulation), and had a degree of autonomy from ministerial control. There was conflict within the state for legitimacy/domination over a policy area involving differences as to which private interests and which objectives should be prioritised. The position which prevailed varied under successive governments. However the differences were never resolved.

The terms of the debate within the administration increasingly concentrated on economic and political grounds rather than health - with the Home Office stressing the political need to adhere to the compromise embodied in the Geneva Convention and the Board of Trade stressing the economic consequences of Internal Prohibition.

The Role of Government and Parliament

Given the lack of consensus and the uncertainty surrounding the regulatory strategy to be adopted, resolution of this process fell to the government and Parliament. However there was considerable vacillation and delay in the implementation of policy.

The eventual outcome of the process was determined by the political balance of forces in Parliament and government, including both the failure of the minority Labour Government's attempt to introduce Internal Prohibition and the eventual success of the Conservative government in introducing Regulation in 1926.

Despite its overwhelming majority, the Conservative government faced marked difficulties in implementing a policy which conflicted with policy commitments of previous governments, and the Parliamentary debate on the implementation of Regulation was marked by its lack of technical justification, its attempt to deny responsibility for the course of action adopted and its failure to acknowledge the role of economic considerations in the action taken.

Final Stages in the Process of Regulatory Development

The provisions of the 1926 Lead Paint (Protection Against Poisoning) Act were as follows:

i) It applied the terms of the 1901 Factories Act to the Painting of Buildings (including the notification of lead poisoning cases by employers and medical practitioners, and the right of Factory Inspectors to inspect workplaces).

ii) It required painting employers to register with the Factory Inspectorate and keep (and make available for inspection) details of painting work undertaken.

iii) It enabled Factory Inspectors to take samples of paint for analysis

iv) It enabled a set of Regulations to be issued (by the Home Secretary at that time) to require certain health precautions to be adopted in the use of lead paints and to require medical examinations.

Thus the detailed provisions to implement Regulation were to be developed through a code of Regulations. The process of development of these Regulations for housepainters, and similar Regulations for vehicle painters is discussed in the next section.

The Lead Paint Act had been introduced with government assurances that Internal Prohibition would be introduced if Regulation was not successful in reducing lead poisoning amongst housepainters to an acceptable degree. However, and this is a reflection of the strength of the governments opposition to Internal Prohibition, no systematic examination of its effects on industrial practice and lead poisoning was initiated. The 'impact' of the Act on lead poisoning will be discussed in the next Chapter, however, as Figure 4.2. indicates, lead poisoning in housepainters remained at level for the immediately succeeding years.

Research into Paint Technology

The last vestige of discussion of Prohibition comprised a sporadic correspondence about research into paint technology between the Factory Inspectorate and the Home Office.

The Norman Committee had called for urgent research into lead substitutes, possibly under the Department of Scientific Industrial Research (DSIR). Implementation of this recommendation was postponed when the British Engineering Standards Association established a Sub-committee on Paints and Varnishes (which from 1925 included a representative from the Factory Inspectorate).[102]

This committee undertook the task of drawing up standard specifications for paints (its first standard was for white lead paste). In 1926, the DSIR provided funds for the establishment of a Research Association for the Paint and Varnish Industry, which started work in 1927. The painting trade had "the controlling influence" on its activities.[103] As a result it was noted the research undertaken "served the interests" of the affiliated companies and was "not pursued from the standpoint [of] the Norman Committee", only one of the 23 projects carried out in the first two years work of the committee had "any relevance for the control of lead poisoning" (an investigation into durability tests for paint).[104,105]

This state of affairs provoked a debate within the Home Office and

Factory Department. Since Regulation was only provisional, it was suggested that the Home Office should "initiate research through the Office of Works into the comparative protective properties of different paints" in case Regulation failed.[106] Against this, it was argued that the Norman Committee's recommendations were based on the anticipation that Internal Prohibition would be rapidly introduced.[107] With no immediate prospects of such a move, it was suggested that the work of the Paint Research Association might "ultimately" furnish accurate information on lead substitutes, "in which case independent research would be unnecessary". Moreover, since the formation of the DSIR, the Office of Works would probably not be willing to undertake such research, but would refer its problems to the Paint Research Association.[108] Consideration of the matter was deferred, noting that levels of lead poisoning were beginning to fall.

Though the decision was reviewed annually, by 1933, in the light of continued reductions in lead poisoning amongst painters, the Chief Inspctor of Factories held that "the Norman Committee recommendations were becoming of less moment as time goes on",[109] and by 1936 it was agreed within the Inspectorate that "the subject could fairly be regarded as closed".[110] The Home Office file on Lead Paint itself was closed 10 days later. (17 February 1936).

These deliberations indicate the rapid shift in policy of the Home Office and the Factory Inspectorate (lacking Legge's influence) that followed the political defeat of Internal Prohibition. The administration failed to initiate the research into paint technology that could have sustained Internal Prohibition had this again been placed on the agenda. The position that prevailed within the administration accepted that responsibility for the development of paint technology should remain in the hands of the industry, noting that the Factory Inspectorate lacked the technical expertise to be involved in this area.[111] This change of attitude was apparent not only in other sections of the administration,[112] but also in the concerns of the painting trade itself (as indicated by the areas of research initiated by the Paint Research Association).

The Development of Regulations for Using Lead Paint

The final stage in policy implementation consisted of the development of codes of Regulations for the use of lead paint, in vehicle painting (under the Factory Acts), and subsequently for housepainting (under the Lead Paint Act). These will be examined in turn, as they provide additional insights into the debate about Prohibition as well as into the dynamic of Regulation itself.

The Vehicle Painting Regulations

The Norman Committee had suggested Regulation rather than Prohibition for the industrial use of lead paints. Following its report, the Home Office were approached by representatives of vehicle building and related employers' organisations, who noted that they had not been involved in the Norman Committee and asked to be involved in any discussions that "went beyond" the Building trade.[113] The Home Office assured them that this would take place.[114] The matter was referred to the Factory Inspectorate but (because of pressure of work, illness of the relevant Inspector and the loss of the Home Office file) "no steps were taken pending the outcome of the lead in buildings question".[115]

The Conservative government introduced the Lead Paint Bill to implement Regulation for housepainting in May 1925. Though it did not reach the statute book (a similar Bill was successfully introduced the following year) its introduction seems to have stimulated the Factory Inspectorate into action. In June 1925 draft codes of Regulations were issued to cover the use of lead paint in House, Vehicle and Ship painting.[116]

The draft Regulations provided for:

i) White Lead pigment to be provided as a paste (rather than as dry pigment),

ii) Paint to be labelled as containing lead,

iii) Where dry white lead was used, in the preparation of stopping, local exhaust ventilation to be provided,

iv) Floors to be smooth and kept clean and dry,

v) Messrooms and washing facilities to be provided,

vi) Arrangements to be made for medical examination of workers if required,

vii) Inspectors empowered to take samples of paint,

viii) Dry rubbing of painted surfaces prohibited,

ix) Spraying with lead paint prohibited,

x) The use of lead paint in the interior of a roofed vehicle was prohibited,

xi) Firms employing 3 painters or less were exempted.

The draft Regulations were subject of a conference between the Factory Inspectorate and representatives of Vehicle Trade Employers Organisations on 20 July 1925, which proceeded as follows:[117]

1) The employers wanted the prohibition of spraying lead paint to be lifted and replaced by a requirement for local exhaust ventilation where lead paint was sprayed. They admitted that lead paint was not currently applied by spray but justified their request by claiming that some paints contained a (small) percentage of lead which might bring them within the Regulations. Legge, for the Factory Inspectorate, accepted that it might be possible to spray lead paint safely under ventilation, and this amendment

2) The employers were opposed to the exemption for small firms, and it was agreed to delete this.

3) The employers opposed the provision of messrooms for meals on the grounds that this would create problems with their other workers not involved in painting. Subsequently, and after further discussion, it was agreed simply to require that meals be taken outside the painting shop, with the justification that small firms, now to be covered by the Regulations, might have difficulty in complying.[118]

4) The employers opposed the prohibition of the use of lead paint in the interior of roofed vehicles arguing that this could be done safely since 'wet rubbing' was to be adopted. Primer coats of lead paint were also needed, which could not be rubbed down. The clause was modified to prohibit lead in painting the interior of roofed vehicles only if the surface is subsequently to be rubbed down (thereby allowing priming).

5) On the grounds of the difficulty of applying this to wagon shops the employers wanted deletion of the requirement for floors to have an even surface and they wanted an alternative method to "daily cleaning by a damp process" allowing debris to be removed while it is wet. This modification was accepted.

Following this conference, the draft Regulations, as revised, were published and circulated for comments with a request that organisations submit objections, as the first stage in formally implementing Regulations.[119]

Seven organisations submitted objections to the draft Regulations, some of which took part in a second conference with the Factory Department/ Home Office on 2 December 1925.[120] The objections and their outcome are summarised below:

1) The National Association of Perambulator etc. Manufacturers (N.A.P.M.), the National Employers Association of Vehicle Builders (N.E.A.V.B.), and the Scottish National Vehicle Builders Association (S.N.V.B.A.), opposed the Regulations altogether, claiming that their cost, especially for small firms, would be excessive, and that lead poisoning in their trade was unknown.[121]

   The S.N.V.B.A. also opposed 'wet rubbing' of painted surfaces as being impracticable on wooden surfaces since it would leave a 'hairy surface', and made the (contradictory) request that the Regulations require all vehicle painting to be carried out in authorised and inspected premises.

   The Factory Inspectorate were able to disprove the claims about the lack of lead poisoning in the trade, and these objections were over-ridden.

2) The Engineering and Allied Employers' Federation (E.A.E.F.) requested the exemption of factories not engaged in vehicle manufacture and repair, which occasionally painted their own vehicles, and the Railway Carriages etc. Makers Association objected to the requirements for washing and eating accommodation in workplaces employing less than six painters.[122]

   An exemption from the Regulations was consequently agreed where not more than two painters were employed or for occasional painting of vehicles for use in a company's own business or factory.

3) E.A.Harney (the Liberal M.P. noted for his support of the White Lead lobby) had written to oppose the prohibition of internal painting, a provision which, he claimed "though confined to vehicles, (was) not only wholly incompatible with the position the government (had) taken up (i.e. of introducing Regulation not internal Prohibition of house-painting) but would be used as a strong lever by those who desire prohibition in the case of painting of buildings".[123] This letter illustrates the strength of the opposition to Prohibition and the importance of ideological and political issues as well as technical considerations in the highly polarised regulations debate. Though Harney's objection was rejected on the grounds that this clause had already been amended, the White Lead Makers submitted an objection to the provision. The Home Office noted that "these people have no 'locus standi' on this question, but all their points have been adopted by the E.A.E.F.".[124] At the second conference, the industry representatives claimed that the previous conference had agreed to delete the clause prohibiting lead paint in the interior of vehicles altogether (rather than amend it). The Home Office eventually agreed to withdraw this clause.

4) The National Union of Vehicle Builders, representing the employees, who had not been consulted earlier, sent a delegation to express concern about "the dangers of spraying", which was then being "largely substituted for brush work". They noted that lead primer and coloured paints were being applied by spray, "often without exhaust" ventilation. The union was concerned that ventilation

might not be effective in capturing drift and rebounded spray, especially if the worker was required to stand between the spray and the fan. The union and the Factory Inspectorate agreed that respirators were unsatisfactory because of their discomfort.[125]

Subsequently, when the employers (at their second conference) requested that the requirement for extract ventilation be replaced by general workplace ventilation, this was rejected as inadequate to prevent poisoning. The provisions regarding ventilation were strengthened by a Factory Inspectorate amendment stipulating that it should also be "unnecessary for the workman operating the spray to stand between the fan and the spray". This was agreed after discussion.

Following this conference, a second draft of the Vehicle Painting Regulations were issued and circulated on 16 February 1926. A month later the Home Office noted that "the whole of the organisation of employers and operatives have accepted (the Regulations) without question.[126] The Regulations were issued by the Home Secretary as the Vehicle Painting Regulations 1926 on 12 March 1926 and came into force on 1 May 1926.[127]

The Lead Paint Regulations 1927

As noted earlier, a draft code of Regulations had been worked out in 1922 between the Master Painters and the Painters' Unions (through the Painters and Decorators Joint Industrial Council [P.D.J.I.C.]) and the Home Office. These had subsequently been approved by the National Federation of Building Trades Employees. The code was presented to the (Norman) Committee on Industrial Paints, which recommended their adoption.

for painting work not covered by Internal Prohibition and prior to the introduction of Internal Prohibition.)[128]

It was agreed by the Home Office not to ask the P.+ D.J.I.C. to voluntarily adopt the Regulations as this would penalise their members in competition with 'non-federated' firms.[129] No progress was made in introducing these Regulations due to deliberations over Internal Prohibition. Though the code was re-issued in 1925, discussions did not start until the Lead Paint Act was introduced.

On 31 December 1926, 16 days after the Lead Paint Act came into force, the draft Lead Paint Regulations were issued [published in the London Gazette and circulated to 36,000 concerned bodies].

Despite their consensual beginnings and their long vintage, implementation of the Regulations was not to be an easy process.

16 objections were submitted to the draft Regulations. In particular the Iron and Steel, Shipbuilding and Engineering employers met Bellhouse, the Chief Inspector of Factories, to argue that workers involved only occasionally in the painting of buildings (e.g. factory maintenance workers) should be covered by the Regulations controlling the painting process (e.g. forbidding dry rubbing, use of lead as paste, prohibition of spraying) but should be exempted from the ancillary health precautions (draft Regulations 4-10 dealing with washing facilities, medical records etc.). Whilst Bellhouse was 'personally sympathetic', the P.+ D.J.I.C. "put up strong opposition to the proposed concessions". "It became evident that there was no possible hope of an agreed code and that an Enquiry was necessary".[130]

As no agreement could be reached by informal discussions, an enquiry was called under Section 80 of the 1901 Factory Act, under an independent referee (Sir William W.MacKenzie) to adjudicate between the different objectors.

The Enquiry was held on 22 June 1926 (and reopened on 29 July to consider the application of regulations to wirebrushing iron and steel structures). A report was subsequently issued.[131]

The objections to the Regulations fell into three main classes:

1) application of the proscription of dry rubbing to Iron and Steel structures,

2) application of the Regulations to those occasionally involved in painting,

3) drafting amendments.

Five main groups of affected parties were represented:

1) painting operatives - wanted prohibition of the use of lead paint,

2) Master Painters - satisfied with the existing code,

3) Home and Women decorators,

4) The lead paint manufacturers who "desired rigid enforcement of the regulations in order to establish a case for the continuance of white lead",

5) Railway, Shipbuilding and Engineering Employers "mainly concerned in other industries, but who employ workpeople in painting operations (chiefly for maintenance)".

The principle points of difference are dealt with in turn.

Iron and Steel Structures

The code of Regulations prepared were concered with painting of buildings (wood, plaster, stone, brick etc.) and forbad dry sandpapering of painted surfaces (which had to be smoothed by wet processes using waterproof sandpaper or pumice stone) Iron and steel structures were typically scraped by wire brushing, and Railway and other employers argued that a wet process could not be adopted (since it would cause rust). This process had not been considered in the original code of Regulations. The enquiry was reopened a month later, to consider a report by the Factory Inspectorate into this process.[132] They concluded that dry wire brushing in the open could be regarded as safe but if carried out indoors or under cover it could generate levels of lead bearing dust able to cause poisoning in a short spell (levels in measurements of lead in air were up to 0.6mg/m³ for outside work and 9-18mg/m³ inside). 'Wetting' the job with linseed oil was not effective while the use of turpentine was unpleasant and involved a fire risk. Ventilation or respirators might provide a solution. Since there was insufficient experience to deal with the question, they recommended that dry rubbing be allowed, but kept under review. Problems could be dealt with by using the powers to suspend workers if necessary, or further Regulations could be adopted. The Lead Paint Regulations in consequence forbad dry sanding of painted Iron and Steel surfaces, but allowed dry wire-brushing.

Exemptions for Occasional Painting

The Engineering and Shipbuilding industry sought exemption from the requirement to provide washing etc. facilities for workers employed only intermittently in painting buildings (e.g. factory maintenance). While larger works employed regular painting staff, in many smaller works, general labourers are used for some painting work. The P.+ D.J.I.C. argued that any use of lead paint carried a risk of poisoning (even occasional) and that the Regulations were not highly onerous. "If exceptions are allowed for occasional workers there is a danger of abuse".

Bellhouse, the Chief Inspector of Factories argued at the Enquiry that if dry rubbing were prohibited, the risk of contracting poisoning in occasional painting is small. He believed that "the P.+ D.J.I.C. are looking at the question not from the point of view of health but from its economic aspect. They want all painting to be done by the painting industry and not by general labour."[133] Bellhouse supported granting the concession (thereby freeing the engineering industry from the onerous task of providing a bucket, nailbrush, soap and towel and a place to hang one's clothes!) on condition that employers kept a record of the periods spent by occasional workers on painting. This was agreed at the enquiry.

<u>Drafting Amendments</u>

i) The Lead Paint Regulations covered painting of buildings and fixtures of buildings, but was deemed not to cover machines.

ii) The P.+ D.J.I.C. requested that the requirements to use pigment in paste form be extended to include red lead. Bellhouse supported this and the Enquiry agreed that the Regulations should be so extended 'if convincing evidence is given' that red lead was available as a paste in a form that would not set. In the event, the Regulations allow the procurement of dry red lead solely for preparing filling and stopping material.

iii) The draft Regulations included statutory provision of 5 minutes washing up time. The Engineering Employers objected to this because this might be demanded by other workers. Bellhouse noted that washing up time was included in earlier Regulations for lead processes, but not in recent codes. It had been included in the Lead Paint Regulations because it was already agreed between Master Painters and the Painting Unions. MacKenzie recommended that this requirement be dropped from the Regulations since it was a matter that could be more appropriately dealt with by mutual agreement in the industry concerned.

As thus amended, the Lead Paint Regulations were introduced on 6 September 1927 and came into force on 10 October.[134]

A Post Script to the Struggle Against Prohibition

It will be recalled that one of the opening moves of the 'White Lead Lobby' in its opposition to Internal Prohibition was a delegation by the National Confederation of Employers Organisations in 1923 which called for Regulation rather than Prohibition of the use of white lead paint. Whilst the major force behind this delegation was the White Lead Corroders, nine other employers organisations that would be affected by Prohibition also took part.[135]

Two of these organisations subsequently sought exemption of their own industries from Regulations that were produced as a result (the E.A.E.F. and N.E.A.V.B.).

The Shipbuilders and Ship Repairers who also took part in this lobby were even more fortunate. The draft Regulations on Shipbuilding produced by the Factory Department in June 1925 were never followed up (because of the exemption of Iron and Steel structures from the requirement for wet rubbing under the Lead Paint Regulations, the central plank of any Regulation strategy for Ship painting was infeasible). The only Regulations regarding ship painting were included as a clause within more general health and safety Regulations for the industry, and merely prohibited spray painting with lead paints in the interior painting of ships.

This sudden shift in attitude indicates that the commitment to Regulation by paint using industries was a tactical and opportunist move. What was being expressed was a more fundamental opposition by employers to state regulation of hazards.

Observations on the Development of Regulations

The analysis of the process of development of codes of Regulations for Paint Using Industries (and the Paint and Colour Industry, in Chapter 4) have been included partly for the sake of completeness and partly because they afford an illustration of some of the contradictory forces that shape state regulation of hazard, which were outlined in Chapter 1. In particular :

1) the contradictory interests of employers in supporting and opposing regulation,
2) the role of technology and expertise in influencing the content and process of development of regulations
3) the uneven representation of certain (in this case workers') interests.

Employers Attitudes to Regulation

An examination of the objections submitted by the employers' organisations illustrates a set of responses to the complex impacts of regulation on industrial interests. Two contradictory trends are apparent, one resisting and the other supporting the introduction of regulation.

Opposition to Regulation. This took two forms - total opposition to regulation and desire for exemption of a particular industrial sector from impending regulation - depending on the political and economic circumstances; for example, industry's perception of the likelihood of regulation being introduced and the centrality of the regulated process to the industry's activities. Underlying these positions are obvious motivations - simple self interest (resistance to cost of regulation), disbelief in the need or value of regulation, laissez-faire resistance to state control per se. These do not require further discussion.

Support for Introduction and Extension of Regulation. Underlying support for extending regulation to other industrial sectors was the desire of regulated firms not be undercut by non-regulated companies (this was apparent in the vehicle trade's opposition to the exemption of small firms from the Vehicle Painting Regulations) as well as a belief that if one industry is going to bear regulations to eliminate hazards other industries should be willing to accept the same. Thus the National Federation of Building Trades Employers, Law and Parliamentary Committee, discussing the 1925 Lead Paint Bill called for the inclusion of all paints in the regulation and to point out specifically that the Bill made no reference to the coach, ship and yacht building trades.[137] These attitudes are both expressions of what Marx called the wish by capital for "equality in the conditions of competition, i.e. for equality of restraint on the exploitation of labour".[138]

Support for the introduction of regulation into a particular industrial sector seems to have been motivated by the calculation that it would benefit firms already in that sector by creating or strengthening their monopoly over a particular productive activity.[139] This strategy was adopted by both the Master Painters Federation and the Scottish National Vehicle Builders Association (who called for all coach painting to be restricted to licensed and inspected premises).

In the development of these Regulations, it can be seen that economic considerations have frequently shaped the policy responses of sections of employers - and in some cases their role has been expressed quite openly. Such a motivation can also be detected (albeit less frequently) amongst the trade unions (e.g. the Painting Operatives Union supported the Master Painters in opposing the exemption of occasional painters in factories, who would probably be unskilled and non-union, from the provisions of the

Lead Paint Regulations).

It is not suggested that such economic interests were a simple determinant of employers' attitudes - some employers exhibited totally contradictory attitudes (e.g. the S.N.V.B.A.) and objections were evident which appear to have a purely 'ideological' basis (e.g. the E.A.E.F. opposition to restriction of Use of Lead paint on the inside of roofed vehicles). It is of interest to note that these factors seem to have been expressed more clearly in the closed regulatory discussions than the public discussions of regulation (in which ideological aspects played a bigger role.)

<u>The Process of Negotiation of Regulations</u>.

The process of negotiating regulatory provisions offered considerable opportunities for regulated industries to seek exemption from, amendment to, and dilution of particular provisions. In the pattern of success and failure of these attempts, a range of factors can be detected including the material impacts of the provision (costs and benefits), the technological underpinning of objections (and the technical feasibility of compliance), limits to the degree of state intervention and the need to maintain consensus.

i) <u>The Trade Off between Costs and Benefits</u> was notable in the considerable success of employers only indirectly or intermittently involved in painting in certain provisions. In particular they sought exemption from requirements to provide washing facilities and clothing accommodation (with a vigour that seems out of proportion with the costs of such a provision). In this case the Factory Inspectorate were willing to concede because the risk to health of such dilution would be small, since the work was of an occasional nature and because these ancillary precautions were by then believed to be less significant in reducing lead absorption than controlling the generation of lead dust.

The trade-off between compliance costs and health benefits was not uniform, but was influenced by the availability of knowledge about the nature and extent of the 'benefits and costs', the ability of firms to comply, and the desire for consent. This was particularly apparent in the negotiations over the Vehicle Painting Regulations which involved a series of compromises between stringency of regulation and exemption of small firms from the provisions.

ii) The State of Scientific/Technological Knowledge and Expertise was a major determinant of the success of attempts to dilute regulation, affecting both the ability of the Factory Inspectorate to demonstrate the necessity for and 'technical feasibility' of a control measure in the face of employers' objections. (It must be noted that the appeal to technical obstacles to compliance involved assumptions about the economic and administrative costs that would be borne as well as simple technical factors.)

The biggest problem that emerged in the discussion of the Lead Paint Regulations concerned their applicability to the painting of metal structures. In particular the central requirement of Regulation of housepainting and vehicle painting (the use of wet sandpaper/pumice stone) was not applicable to the wire brushing process in preparing metal for repainting. Although the Factory Inspectorate were able to conduct an examination of this process they were unable to suggest an alternative control method.

As a result, Regulation was not fully implemented in these areas (though they were kept under review, they have not been subsequently regulated).

Fundamental objections were also made about the Vehicle Painting Regulations, with variable success :

a) On the subjects where the Factory Inspectorate had sufficient knowledge about the industrial processes and hazards to counter the objections, Regulations subsequently introduced (e.g. the S.N.V.B.A. claim that wet rubbing could not be used on wooden surfaces, the N.P.M.A. claim for the perambulator industry to be totally excluded from Regulation).

b) In two areas, objections resulted in a significant dilution of Regulations. Here the Factory Inspectorate had agreed that certain processes should not take place on health considerations but were unable to demonstrate the necessity of preventing these processes (i.e. prohibiting spraying of lead paint and prohibiting the use of lead paint inside roofed vehicles) as opposed to conducting the processes only with certain precautions.

[In the latter case there was additional political pressure on the Inspectorate to revoke the Regulation.]

iii) Limits to the Degree of State Regulation were apparent in the resistance of employers to, and reluctance of the Administration to insist on, pre-emptive measures to constrain technological developments that would be potentially hazardous. Thus, even though the vehicle painting employers and the Factory Inspectorate agreed that application of lead paint by spray had not been adopted, primarily because of the hazards this would involve,[140] the employers insisted that they be allowed to use this process subject to ventilation. The employers prevailed, even though the Factory Inspectorate considered that the safe use of this process was only potentially possible.[141] It must be noted here that white lead was not suitable for use in the stoving enamels that were being adopted by the vehicle painters (because it promotes discolouration of the vehicle), and for this, and health reasons, it was not subsequently used in vehicle spray painting.[142]

iv) The Trade Unions were consulted, indeed their involvement was considered necessary where Regulations had a substantial impact on working practices. However the form of representation of workers interests differed from that of the employers, and their success in influencing the nature of the Regulations adopted was less even.

Unlike the employers, the unions were not necessarily involved at the earliest stages of development of Regulations. For the initial conference to discuss objections to the Paint and Colour Manufacture Regulations only employers were represented, and workers' representatives were not invited to contribute till a late stage in the process.[143] A similar situation prevailed with the Vehicle Painting Regulations. These arrangements were however open to political influence, as is demonstrated by the very different arrangements (with the involvement of the unions from the earliest stages) that existed in the development of Regulations for house-painting.

The unions did succeed in influencing the nature of the Regulations adopted, but only in relatively minor ways (e.g. the N.U.V.B. were unsuccessful in getting spray painting of vehicles with lead paint banned, but were able to strengthen the provisions for ventilation of this process).

This brief examination of the development of Regulations has focused in the differences that emerged during the development/negotiation of these processes. Equally notable is the fact that in most cases, the objections and amendments achieved were relatively minor and were resolved in negotiations. Thus, at the end of this process the consent of the regulated industry had been achieved.

CHAPTER SIX

LEAD POISONING FROM THE MANUFACTURE AND USE OF LEAD PAINTS

LEAD POISONING FROM THE MANUFACTURE AND USE OF LEAD PAINTS

Introduction

Previous chapters have examined the role of concern about lead poisoning in the process of regulatory development, and the economic and technological context and consequences of regulation of lead paint hazards. This chapter attempts to document the control of lead hazards in the painting and other industries, focusing on the role of state regulation and technological and other changes in painting activities.

In the absence of figures for workplace exposure to lead over time, the only means available to document the control of hazards is the reduction of harm, reflected in the available statistics of occupational lead poisoning. However, as will be shown below, the relationship between workplace exposure to lead and harm, and between harm and recorded poisoning is highly complex and varies between industries and over time. In order to examine this relationship, a detailed examination is made of the available statistics relating to poisoning. On this basis, an attempt is made to evaluate changes in the extent of harm to workers employed in the manufacture and use of lead pigments.

Finally, the long-term consequences of the Regulation strategy implemented for lead paints will be briefly discussed, focusing on the subsequent emergence of concern about the hazards of lead paint, particularly regarding 'sub-clinical' lead poisoning and the risk to the consumer.

The deliberations in this chapter require detailed treatment of statistical sources. Where necessary, these have been removed from the text and placed as a set of technical appendices to Chapter 6. (Appendix B). These technical appendices are to be read as part of Chapter 6, and the references they contain are included in Chapter 6.

Lead Poisoning Statistics Available

There are no statistics on the changing extent of hazards to the consumer from the use of lead paint for the period under examination. Information on lead poisoning amongst workers exists from four sources:

1. Notification of poisoning cases to the factory inspectorate (available since 1900).
2. Death Certificates attributed to lead poisoning, recorded by the Registrar General (available since 1900).
3. Returns for claims and awards for compensation for lead poisoning under the Workmen's Compensation Act 1906 (1906-1939).
4. Figures for claims of Industrial Disease Benefits under the National Insurance scheme. (available from 1952 to date) for spells of lead poisoning.

Because the former two statistics are available throughout the period under examination, they will be used as indicators of harm amongst workers exposed to lead hazards. However, as will be seen below, there is considerable variation in the significance of these statistics both over time and between industries. The relationship between these different statistics will be examined to document their significance.

Figures for cases of lead poisoning notified to the Factory Inspectorate and for deaths certified as due to lead poisoning recorded by the Registrar General are published in the Annual Report of the Chief Inspector of Factories.[1] These are presented in Table 6.1 which distinguishes pigment/paint production, paint use and other (non-paint) industries. The same data was plotted in Figures 4-1 and 4-2. Table 6.2 presents the lead poisoning statistics amongst house and industrial painters (comprising vehicle painters, ship painters and other industrial painters).

TABLE 6.1. Statistics for Occupational Lead Poisoning 1900 - 1959, distinguishing Pigment/Paint Production, Paint Use, and Other Industries

Cases of poisoning notified to the Factory Inspectorate, deaths certified to lead poisoning recorded by the Registrar General.

TABLE 6.2. Statistics for Occupational Lead Poisoning Amongst House and Industrial Painters 1900 - 1959

Cases of poisoning notified to the Factory Inspectorate, deaths certificate to lead poisoning recorded by the Registrar General.

Changes in the basis of reporting Lead Poisoning amongst Housepainters.

There has been a legal requirement for medical practitioners and factory occupiers to notify the Factory Inspectorate of cases of lead poisoning contracted in factories since 1895, reported on a consistent basis since 1899. (See section 73 of the Factories and Workshops Act 1901). However, poisoning arising from activities in premises not covered by the Factory Acts were not notifiable. The major trades at risk of such poisoning were housepainters and plumbers. Prior to 1926, a limited number of returns were made voluntarily by medical practitioners for housepainters and plumbers, either because they believed that they were obliged to do so by law (and that they would receive the certification fee) or to draw the attention of the authorities to the incidence of lead poisoning in these trades.[2]

The voluntary returns do not distinguish between housepainting and plumbers between 1900 and 1909. The number of returns attributable to housepainters alone have been estimated for this period (See Appendix B-1).[3]

Section 3 of the 1926 Lead Paint Act made cases of lead poisoning in housepainters compulsorily notifiable on the same basis as factory occupations. These voluntary returns were believed to represent a substantial underestimate of the true rate of lead poisoning amongst housepainters.[4] Fatalities amongst housepainters have been reported on a comparable basis to that of other industries throughout this period. The lack of comparable statistics for cases of lead poisoning amongst housepainters in this period poses a particular problem of determining:

i) the relationship between voluntarily notified (1900-1926) and compulsorily notified (1927-) lead poisoning amongst housepainters, and

ii) the relationship between notification of poisoning in housepainters and other occupations.

An attempt has been made to assess the validity of voluntarily notified cases of lead poisoning amongst housepainters in the period 1900-1926. This is presented in Appendix B-2.[4,5,6,7,8.] Estimates were produced of the number of cases of lead poisoning that would have been expected amongst housepainters if these had been subject to compulsory notification on the same basis as other industries. Two methods of estimating produced useful results:-

i) by extrapolating from the number of fatal cases of lead poisoning in housepainters, on the basis of the relationship between deaths and all cases of lead poisoning, amongst industrial painters, and

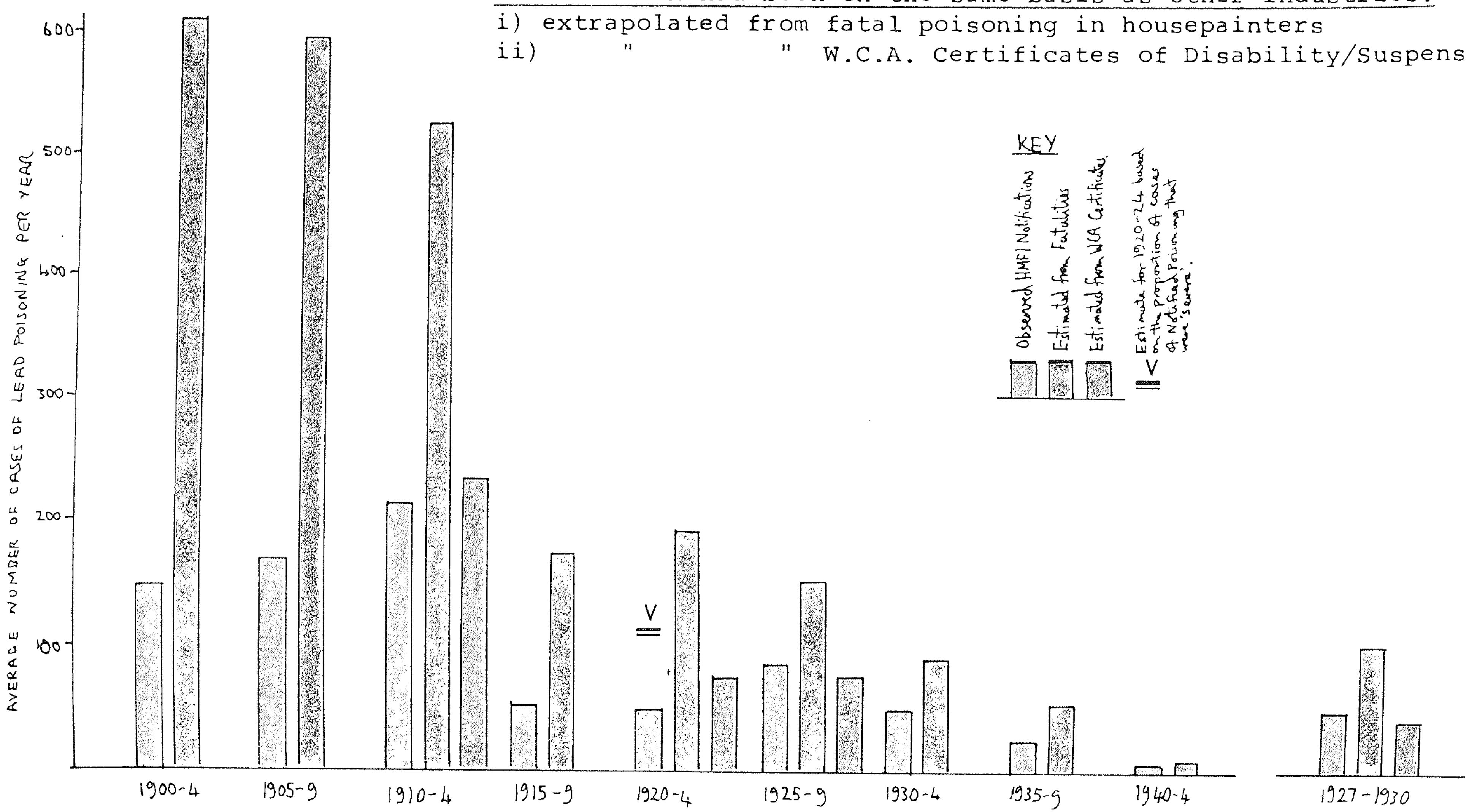
ii) by extrapolating from the number of certificates of disability and suspension due to lead poisoning in housepainters under the Workmen's Compensation Act, on the basis of the relationship between the numbers of WCA certificates and notifications to the Factory Inspectorate (HMFI) for lead poisoning in all factory occupations.

These estimates differ in some aspects. Of the two, the former is probably more reliable (both in terms of consistency with other information and the basis of estimation). The predicted levels of notification of lead poisoning that would have been expected amongst housepainters are shown in Figure 6-1.

It was concluded that there was significant under-reporting of cases of lead poisoning amongst housepainters during voluntary notification; that the extent of under-reporting varied during this period (in particular that voluntary notification was more complete during 1910-1914 than in 1920-1924, immediately prior to the introduction of compulsory notification).

Figure 6 - 1.

Cases of Lead Poisoning in Housepainters:
Observed Numbers of Cases Notified (voluntarily) to HMFI, compared
Estimated Numbers of Cases that would have been expected if
Notification had been on the same basis as other industries.
i) extrapolated from fatal poisoning in housepainters
ii) " " W.C.A. Certificates of Disability/Suspension.



Though not corroborated by the 'WCA estimate', the 'Deaths estimate' indicated

i) that only about 25% of expected cases of lead poisoning were voluntarily notified, and

ii) that even when compulsory notification was introduced for housepainters, notification levels were about 50% that which would be expected if notification had been on the basis as other industries.

Additional corroboration for the 'Deaths estimate' of expected level of notification of cases of lead poisoning amongst housepainters was obtained from consideration of the 'proportion of cases of poisoning classed as severe' and the incidence of lead poisoning (cases per 10,000 workers) in housepainters (see below). Though not entirely satisfactory, these estimates were used in the subsequent analysis of the control of lead paint hazards, supplemented where necessary by consideration of the observed levels of poisoning cases notified amongst housepainters.

The overall validity and significance of the statistics for occupational lead poisoning will now be assessed.

The Validity and Significance of Statistics for Deaths from Occupational Lead Poisoning

In 1914, the Medical Inspector of Factories commented that the 1906 Workmen's Compensation Act had encouraged medical practitioners to certify lead poisoning as cause of death in cases where death was a result of diseases strongly associated with lead absorption (as well as deaths following acute lead poisoning, which were by then a very small portion of deaths certified as due to lead). He suggested that this was responsible for the increase in the numbers of fatalities from occupational lead poisoning.[9]

This is confirmed by the Report of the Registrar General for 1911 which presents a breakdown of the number of deaths certified as due to lead.[10] The figures are reproduced in Table 6.3. This shows a decrease in the number of deaths attributable to lead at the beginning of the century which is reversed after 1906. A comparison of the number of deaths certified to lead in the five year periods before and after the 1906 Workmen's Compensation Act came into force, shows a marked increase in deaths certified due to occupational lead exposure (amongst factory workers, plumbers and housepainters). In contrast, lead poisoning not attributable to occupational exposure fell.

This finding is a reminder of the importance of legal/political factors, as well as scientific/medical considerations, in knowledge about occupational hazards. Although there may be some change in propensity to attribute deaths to lead, the mortality statistics remain the most consistent indicator of levels of harm from lead poisoning since certification of death is more complete than notification of disease. Variability in morbidity statistics is greater than mortality and, as will be shown below, is substantially affected by changes in the threshold for diagnosis of poisoning.

The Validity and Significance of Statistics for Cases of Lead Poisoning Notified to the Factory Inspectorate

The notification of cases of occupational poisoning is a highly complex social process and is affected by a wide range of factors including industry structure, industrial relations, costs and benefits to the worker involved, 'social pressures', administrative arrangements for reporting,

TABLE 6.3. Deaths Certified as Due to Lead Poisoning from all sources, 1900-1911

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Source: G.B.Registrar General, 74th Annual Report of the Registrar General for England and Wales for 1911 [Cd 7578], HMSO, London, 1914. p.88.

the relationship between notification and regulatory enforcement and arrangements for compensation, techniques and principles of industrial hygiene/medicine, social definitions of ill health as well as the 'level of harm' amongst the workforce. A variety of actors and agencies are involved, including the worker, employer, sections of the medical profession and the state. It is not therefore surprising that the extent (and therefore significance) of notification of occupational disease has varied substantially between industries and over time.

A comprehensive assessment of the significance of occupational lead poisoning statistics would involve a substantial research programme. For the purposes of this study, the factor of paramount importance is the reduction in the threshold of notification of lead poisoning during this century. This will be assessed, drawing on other sources of statistics for occupational lead poisoning. However, not all 'notifiable' cases of lead poisoning would be notified. The extent of under-reporting overall and differences between industries will be briefly examined below.

An Estimate of the Number of Poisoning Cases not Notified

An estimate of the extent of under-reporting of industrial diseases can be obtained from the overlap between notifications to the Factory Inspectorate by medical practitioners and factory occupiers. This is presented in Appendix B-3, which indicates that, during 1900-1914, some 17½% of cases of notifiable industrial diseases were not notified (these were predominantly lead poisoning). This must be considered a lower estimate of the extent of under-reporting.

Differences in Notification Rate between Industries

The effects of industrial structure on the notification rate were discussed in the case of lead poisoning in housepainters - where a low reporting rate was noted even with compulsory notification,[11] that was associated with the fragmented, decentralised structure of this industry. In other lead processes/industries, the application of Regulations not only had a long-term effect on industrial technology, and thus lead exposure and lead poisoning, but also, by instituting medical monitoring and selection/suspension of lead workers:

i) increased the rate of reporting of lead poisoning, and

ii) altered the relationship between lead exposure in the workplace and the level and type of harm to workers (i.e. the number and severity of poisoning cases).

For example:

i) In 1911, Legge (Medical Inspector of Factories) noted the absence of a reduction in lead poisoning levels in lead processes which had recently become subject to Regulations. This was attributed to the establishment, through these Regulations of periodic medical examination of lead workers by Certifying and Appointed Surgeons, who had been encouraged to notify cases of plumbism amongst the workers they examined. Legge argued that comparison between regulated and unregulated industries (without periodic medical examination) was unsatisfactory since the former would have a higher rate of reporting (especially of mild poisoning). A more accurate indicator would be the number of cases classed as severe.[12] A similar explanation was invoked in the case of the lead smelting industry, where an increase in the number of cases of poisoning was attributed to special scrutiny and periodic medical examination, rather than deterioration of conditions in the industry.[13]

ii) Medical selection and suspension of workers with excessive lead absorption or incipient frank lead poisoning could interrupt the progress of the disease, and result in reduction either in the number of lead poisoning cases, or in the severity of those cases. Such 'medical monitoring' was claimed to have brought about the virtual elimination of plumbism (i.e. frank lead poisoning) in one white lead factory[14] and in an electric accumulator (i.e. car battery) works.[15]

These differences in notification practice between industries (particularly between regulated/unregulated and centralised/dispersed industries) require extreme caution to be exercised in interpreting inter-industry differences in notified lead poisoning levels.

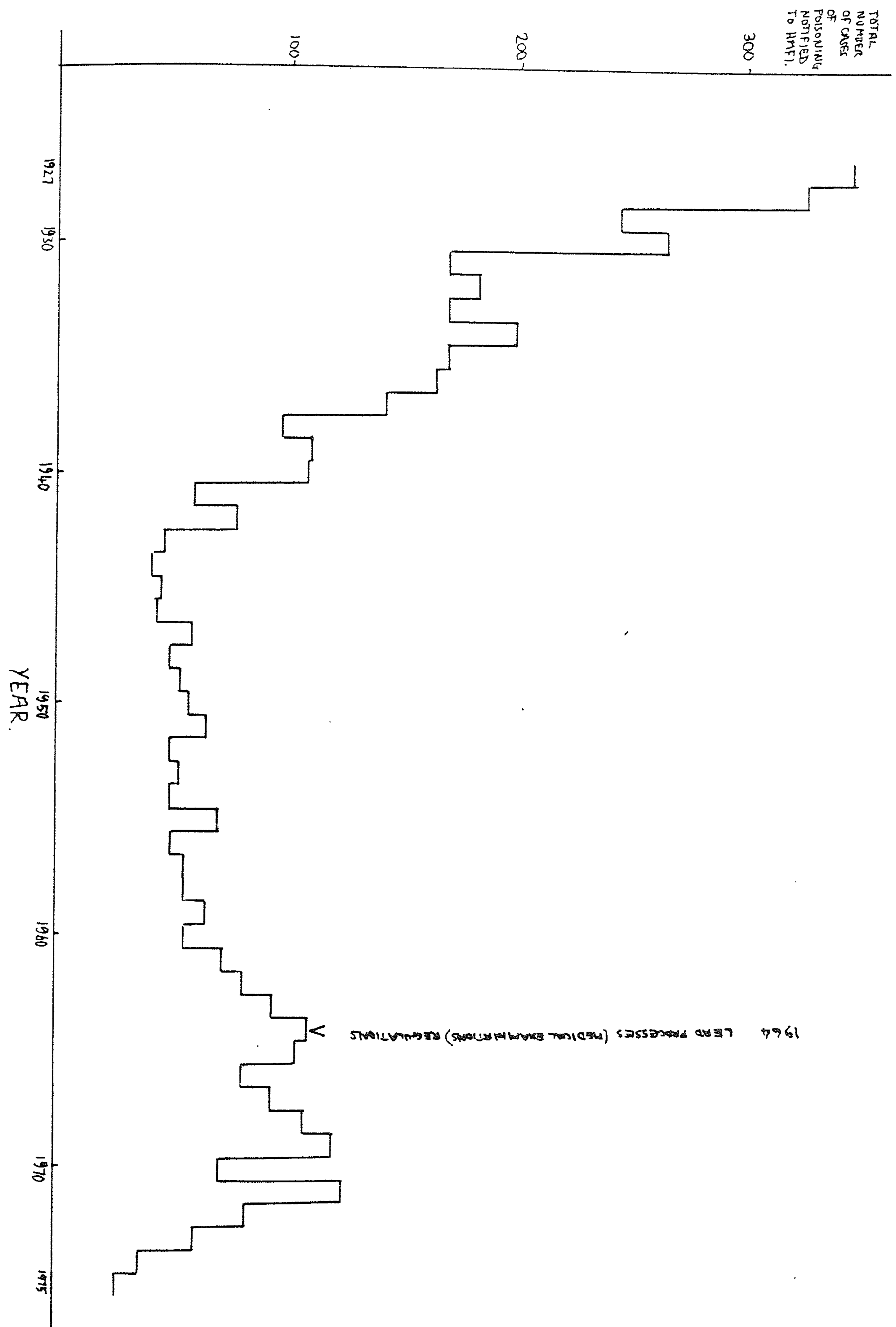
Changes over time in the Threshold for Diagnosis and Notification of Lead Poisoning

Figure 6-2 shows the total number of cases of lead poisoning notified to the Factory Inspectorate between 1927 and 1975.[16] In this period, the scope of industries covered by the requirement for notification has not altered.

The rapid fall in the numbers of cases at the beginning of this period continues the reduction that had been noted, particularly in industries subject to Regulations, since the beginning of the century (See Figures 4-1, and 4-2 and Chapter 4). Whilst this reduction in lead poisoning levels was partially offset by increased activity in certain hazardous industries (e.g. electric accumulator production in the first quarter of

Figure 6 - 2. Total Number of Cases of Lead Poisoning Notified to the Factory Inspectorate 1927 - 1975. (including all factory workers and housepainters.)

Source: Annual Report of the Chief Inspector of Factories. GB H.S.E., Health and Safety Statistics 1975.



the century, shipbreaking in the 1930s and 1950s) poisoning levels settle at a low level in the early 1940s and remain more or less at the same level until 1960, despite a doubling in lead consumption in the U.K. Indeed, the virtual disappearance of cases of fatal lead poisoning in this period suggests that, if anything, working conditions in lead processes were improving.

The increase in the levels of notified lead poisoning between 1960 and 1971 cannot be attributed to a worsening working condition, but seems instead to have been a result of a reduction in the threshold for diagnosis and notification of lead poisoning. The major factor underlying this change appears to have been the widespread adoption of biological monitoring of lead workers (examination of haemoglobin and lead levels in blood, lead and altered metabolite levels in urine) and the recognition that workers with excessive lead absorption might experience impairment in health before the appearance of symptoms of frank lead poisoning. It was suggested that such 'sub-clinical' poisoning would in the long term be associated with an excess of chronic diseases associated with lead (e.g. chronic nephritis and cerebral haemorrhage).[17]

The increasing use (and increasing sensitivity) of biological monitoring facilitated the earlier detection of potentially harmful lead absorption.[18] This in turn undermined the customary conception of 'poisoning' based on pathological symptoms (i.e frank poisoning) and its replacement by a broader definition of "identifiable departure from health" as the criteria for both medical intervention and notification of lead (and other industrial) poisoning.[19]

The use of such tests (in particular, haemoglobin levels in blood) became compulsory as part of the medical examinations required in Regulations for lead processes in 1964.[20] This approach was further developed in subsequent advisory standards and legislation, as a result of which, most notification of 'lead poisoning' reflects the withdrawal of workers from lead processes because of excessive lead absorption or altered levels of certain metabolites associated with such absorption, rather than frank pathological symptoms.[21]

Although this shift in diagnostic criteria becomes virtually complete, and is clearly shown in the statistics for lead poisoning in the period 1961-1971, this was but the final stage of a process which can be traced back to 40 years earlier. Thus the Medical Inspector of Factories noted in 1921 that blood testing and other modern methods of diagnosis enabled medical practitioners "to recognise lead absorption and intoxification at an earlier stage than heretofore".[22]

Indeed as noted in Chapter 2 (and illustrated in Figure 6-26) concern about the 'medical monitoring' of lead workers, reflected in the paint industry's literature abstracting service, reached a peak in the 1920-1958 period. There is no question about the scale of this transformation. However, for the purposes of this study, it is necessary to evaluate the extent of changes over time in the criteria for notifying cases of lead poisoning. An attempt has been made to assess this from other available statistics for lead poisoning.

In addition to the figures for Cases of Poisoning Notified to the Factory Inspectorate, and Deaths Certified as due to Lead Poisoning, the following sets of figures are available :

Notified Cases of Poisoning classed as 'severe'. 1900-1914, 1920-1924.

Workmen's Compensation Statistics. 1908-1914, 1920-1928.

Industrial Injuries Statistics for Prescribed Industrial Diseases, 1915-1979.

The relationship between these sets of statistics are examined in an attempt to determine changes in the criteria for diagnosing industrial lead poisoning.

Notified Cases and Severe Cases, and Deaths from Lead Poisoning

For ease of comparison, the statistics for lead poisoning recorded by the Factory Inspectorate have been summarised for five year periods for Pigment and Paint Producing Industries (distinguishing white lead manufacture, Red etc. Lead Manufacture, Paint and Colour Making) and Paint Using Industries (coach painting, ship painting, other industrial painting and housepainting) and All Factories (excluding housepainting). These are presented in Tables 6.4, 6.5 and 6.6, showing the number of cases of poisoning notified to the Factory Inspectorate, the number of notified cases classified by the Certifying Surgeon as 'severe' and the number of deaths certified as due to occupational lead exposure.

Tables 6.7 and 6.8 show respectively Fatal cases as a percentage of notified cases of lead poisoning, and severe cases as a percentage of notified cases of lead poisoning. These are plotted in Figures 6-3 and 6-4 (below).

Deaths and All Notified Poisoning Cases

It has been argued above that statistics for deaths are more reliable than for notified cases of poisoning and that the latter in particular are affected by a change in diagnostic practice which would make them become more frequent in later years, for a given level of lead exposure. Deaths would therefore be expected to fall as a percentage of cases of notified poisoning. However, as is shown in Figure 6-3, the reverse is the case. Fatal cases as a percentage of all notified cases of lead poisoning in fact rise between 1900 and 1930 in all industries (taken individually or together), and do not fall significantly until after the Second World War, by which time fatalities from occupational lead poisoning virtually disappear. A slightly different pattern can be noted amongst

TABLE 6.4. Cases of Lead Poisoning Notified to the Factory Inspectorate from Pigment and Paint Manufacture and Use 1900-1974 (5 year periods)

6.5. Deaths Certified as due to Lead Poisoning from Pigment and Paint Manufacture and Use 1900-1954 (5 year periods)

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TABLE 6.6. Cases of Notified Lead Poisoning Classed as Severe, from Pigment and Paint Manufacture and Use 5 year periods 1900-1914 (1920-1924)

6.7. Deaths as a Percentage of Total Notified Cases of Lead Poisoning from Pigment and Paint Manufacture and Use

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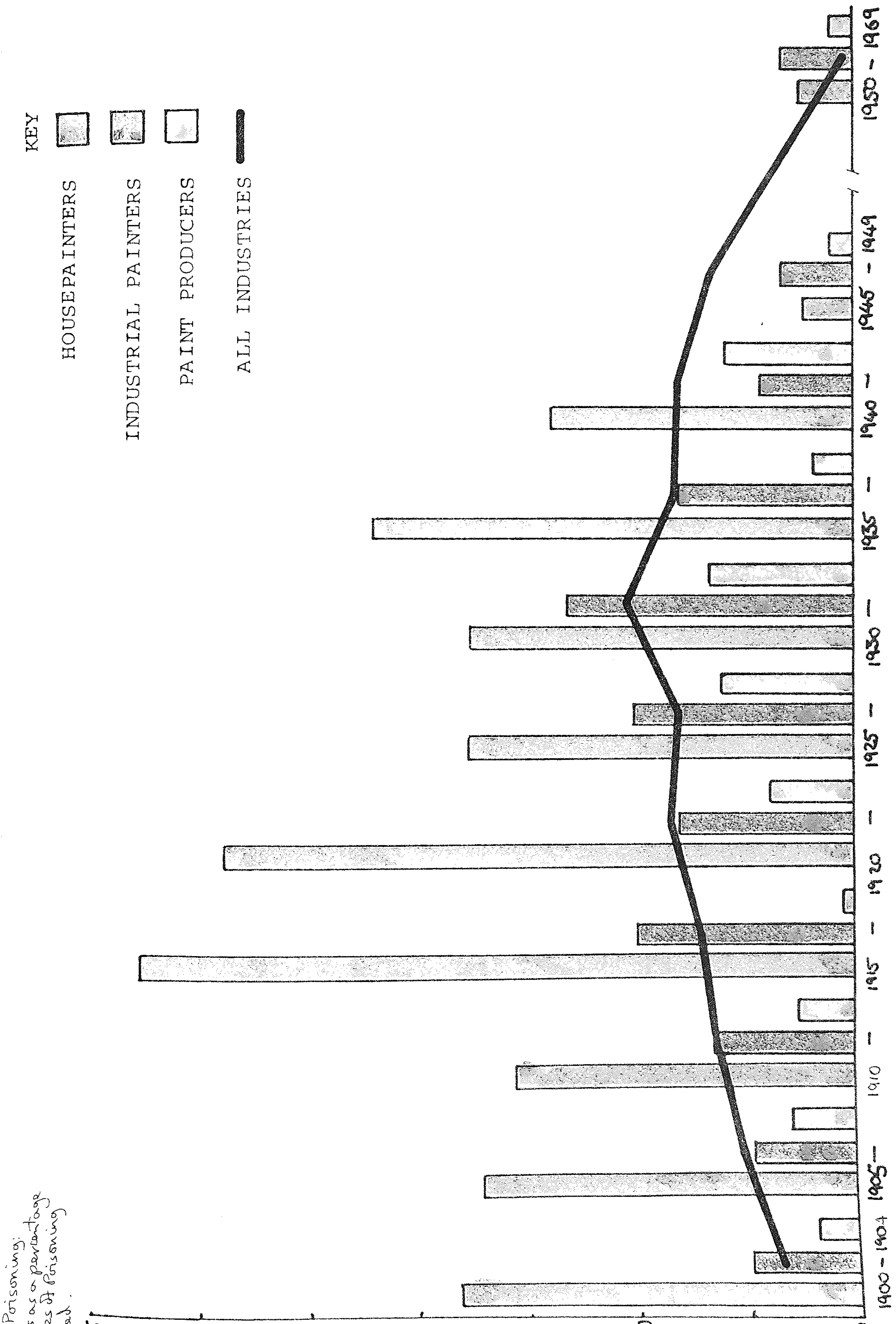
6.8. Severe cases as a Percentage of Total Notified Cases of Lead Poisoning from Pigment and Paint Manufacture and Use

Fig. 6-3 LEAD POISONING-DEATHS AS PERCENTAGE OF CASES NOTIFIED TO HMFI AMONGST ALL INDUSTRIES: PAINT PRODUCERS: AND HOUSE AND INDUSTRIAL PAINTERS 1900 - 1969



Poisoning:

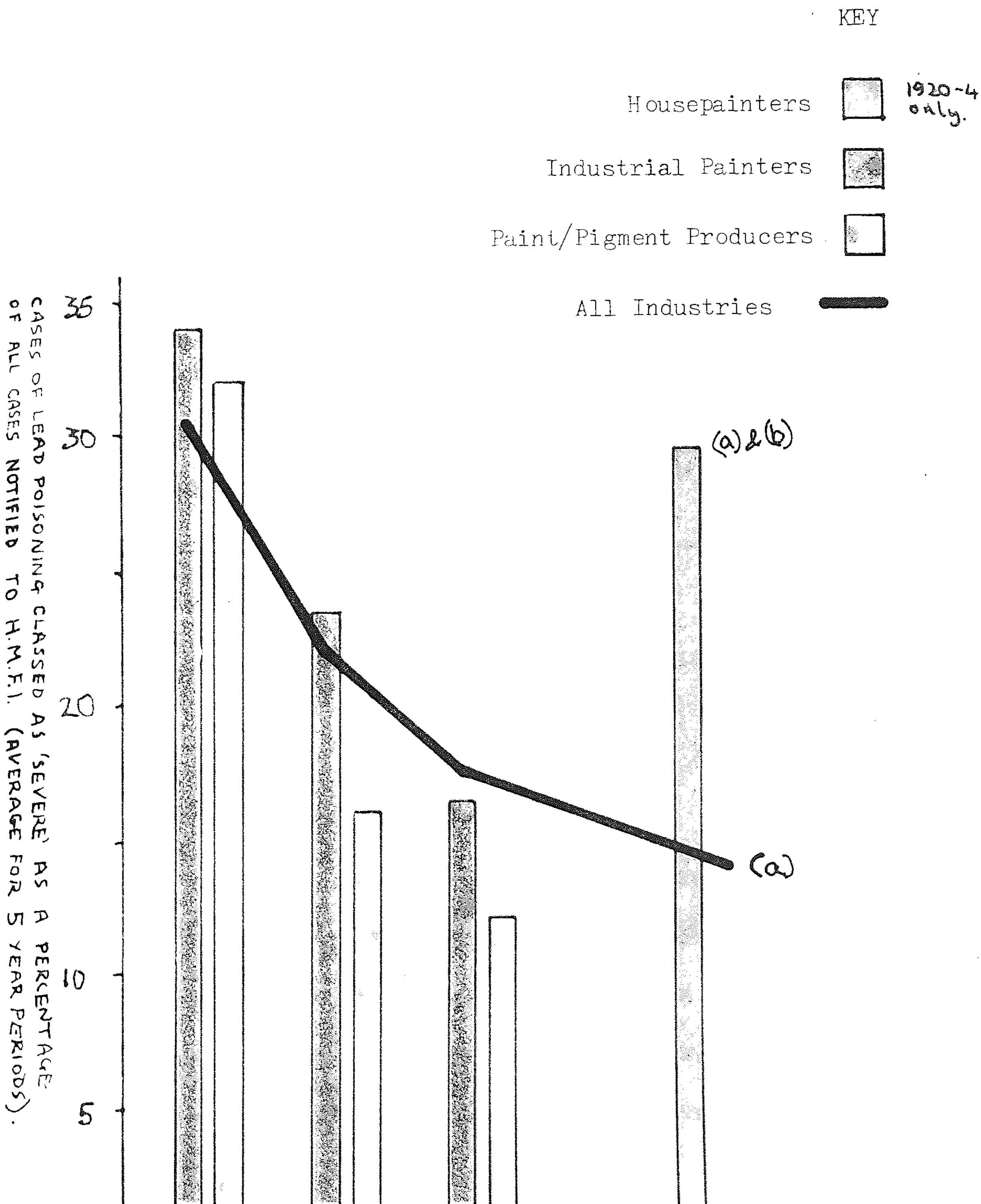
Figure 6-4: Cases of Lead Poisoning Classed as Severe, as a Percentage of All Cases of Lead Poisoning Notified to H.M.F.I. amongst All Industries; Paint/Pigment Producers and Industrial Painters 1900 - 1924. (5 year averages)

Sources:

Annual Report of the Chief Inspector of Factories

a) TM Legge, Industrial Maladies, 1934, op.cit.

b) G.B. Home Department, Report of a Committee (on Industrial Paints), 1923, op.cit.



housepainters, where as noted previously, deaths as a proportion of notified cases dramatically increases during and immediately following the first World War. These increases reflect the fact that the number of notified cases of lead poisoning are falling more rapidly over the years than fatal cases. This is a result of the application of industrial hygiene controls and medical monitoring in factory industries (and in the case of housepainters between 1915-1924 is mainly a result of the restriction in consumption of lead paints during the war years).

Cases of notified poisoning primarily reflect current exposure of workers to lead, whilst fatal lead poisoning reflects in addition the cumulative exposure of previous years, and is therefore slower to respond to reductions in exposure. Lagged correlation between fatal cases and all notified cases of poisoning was carried out to determine whether a relationship could be established between fatal cases and the levels of notified poisoning in preceding years. However, the strongest correlation was found to exist between fatal cases and notified poisoning in the same year, (notwithstanding a high degree of autocorrelation between adjacent years) indicating that current exposure levels are a strong component in fatal cases. It is not therefore possible to use fatal cases as an indicator of changes in the threshold of notification of lead poisoning.

Notified Poisoning Cases and Cases Classed as Severe

The diagnosis of lead poisoning for notification to the Factory Inspectorate was carried out by the workers own doctor (or employer) which was open to considerable variation. However, notified cases of poisoning were re-examined by the Certifying Surgeon for the region, who not only confirmed the diagnosis, but also categorised the severity of poisoning according to uniform criteria. As a result the number of cases of poisoning classed as severe was judged to be a much more reliable indicator of the 'absolute level' of harm/control of hazard.[23] Severe poisoning included paralysis, encephalopathy (e.g. convulsions and 'mental affections') and chronic ill-health from kidney failure and arteriosclerosis. Unfortunately data for 'severe' poisoning are only available for a limited period (1900-1914 and, for housepainters and factory workers for 1920-1924).[24]

The proportion of notified cases of lead poisoning classed as severe, as shown in Figure 6-4, falls sharply in all industries between 1900-1904 and 1910-1914, (down to 58%, 49% and 38% of their earlier levels in respectively all factory industries, industrial painters and paint/pigment producers) a trend which continues (at least amongst factory workers) until 1920-1924. This reduction is most marked amongst paint producers - a fact which appears to be associated with the institution of medical examinations in this industry. However it would be misleading to attribute all of this reduction to changes in practices of diagnosing and notifying lead poisoning, since there were additional changes in the nature of industrial exposures to lead (which were coming under control) and the introduction of medical selection and suspension of workers, thereby preventing the appearance of severe poisoning.

It is not possible on the basis of this information alone to distinguish between changes in notification of poisoning, the effects of medical selection and changes in industrial hazard, as factors behind this reduction in the proportion of notified lead poisoning classed as severe. The severity data indicate that harm (and probably industrial lead exposure) is falling faster than indicated by levels of total notified poisoning. Other statistics on lead poisoning have therefore been examined.

An Estimate of Under-reporting of Poisoning in housepainters

This can be derived from the observation that in 1920-1924, 29% of voluntarily notified lead poisoning in housepainters was found to be 'severe' when investigated by the Factory Department. Severe cases amounted to 14.3% of poisoning notified amongst factory workers, yielding an estimate of 49% under-reporting of lead poisoning in housepainters, had they been subject to notification on the same basis.

Statistics for Compensation under the Workmen's Compensation Acts 1908-1930.

The 1906 Workmen's Compensation Act allowed employees in all industries who had been certified as disabled or suspended from work as a result of lead poisoning to claim compensation from their employer.

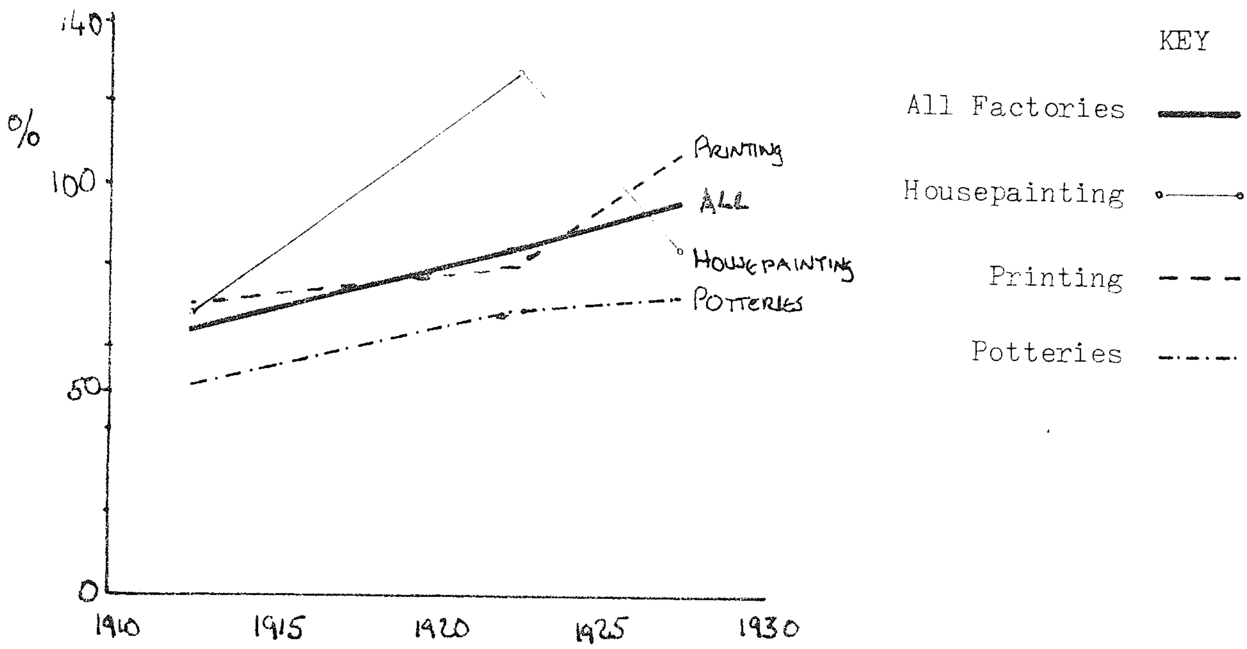
The basis of this system of compensation continued, with some administrative changes, until the Second World War. Statistics for 'cases of industrial disease (i.e. lead poisoning) for which compensation was paid' are available, broken down into industrial groupings, for 1908-1914 and 1919-1938. The industrial groupings used for these figures differ from those used by the Factory Inspectorate. However in the case of "All Factories", "Printing", and the "Pottery Industry", the categories appear to be broadly comparable.

In addition, statistics are available for the number of 'Certificates of Disability and Suspension from Employment given by Certifying and Appointed Surgeons' for lead poisoning. Up to 1930, these are available broken down into industrial groupings, distinguishing the same factory industries used in 'cases of compensation' and in addition housepainting. The latter figures were used to estimate 'under-reporting' of lead poisoning in housepainters (see Appendix B-2).

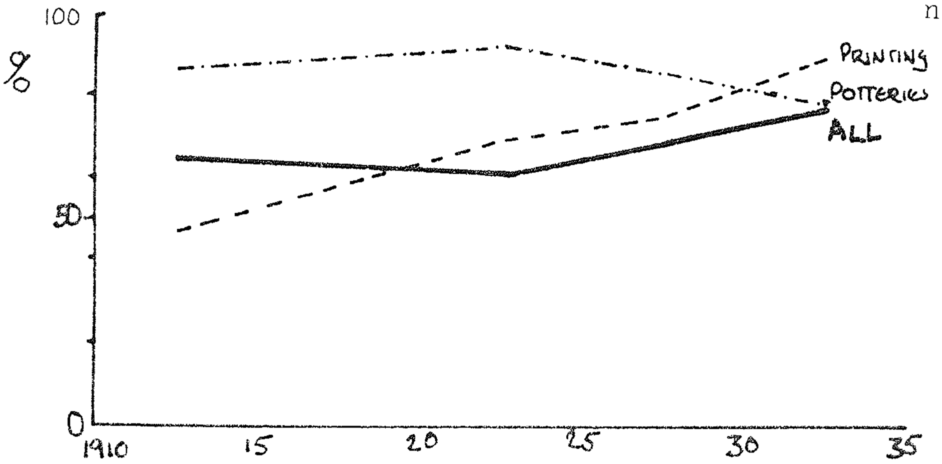
The legal and administrative basis of Workmen's Compensation, and the relationship between the statistics for Workmen's Compensation for lead poisoning and cases of lead poisoning notifed to H.M.F.I. are examined in Appendix B-4.[25,26,27,28,29,30,31.] It was found that the relationship between the W.C.A. statistics varies over time and between industries, reflecting changes in the arrangements for paying compensation. The results are summarised in Figure 6-5. This indicates that, at different periods, both sets of Workmen's Compensation Act statistics apparently exclude a significant number of cases of compensatable lead poisoning. Thus the number of WCA Certificates of Disability and Suspension issued in the 1910-1914 period for lead poisoning in 'All Factories' and particularly in Potteries is lower than the number of cases of compensation paid under the W.C.A. (and the number of cases of lead poisoning notified to H.M.F.I.) due to the willingness of employers to concede claims on the basis of the evidence of the factory doctor of the victim's doctor. Though the number of W.C.A. cases of Compensation for Lead Poisoning increases relative to the number of cases of poisoning notified to H.M.F.I. the excess of W.C.A. Certificates over W.C.A. Compensation claims indicates that a significant and apparently increasing number of certificated cases of lead poisoning were not leading to recorded compensation under the Workmen's Compensation Acts (possibly a result of claims not being paid, but more probably because the payment was made but not reported to the Home Office for inclusion in W.C.A. statistics). In this context, there is an apparent convergence in later years between the issue of a W.C.A. Certificate of Disability/Suspension and Notification of lead poisoning to the Factory Inspectorate.

Fig 6-5 THE RELATIONSHIP BETWEEN STATISTICS FOR LEAD POISONING UNDER THE WORKMEN'S COMPENSATION ACTS AND THE FACTORY ACTS 1910 - 1934: In All Factories, Printing, Potteries & Housepainting

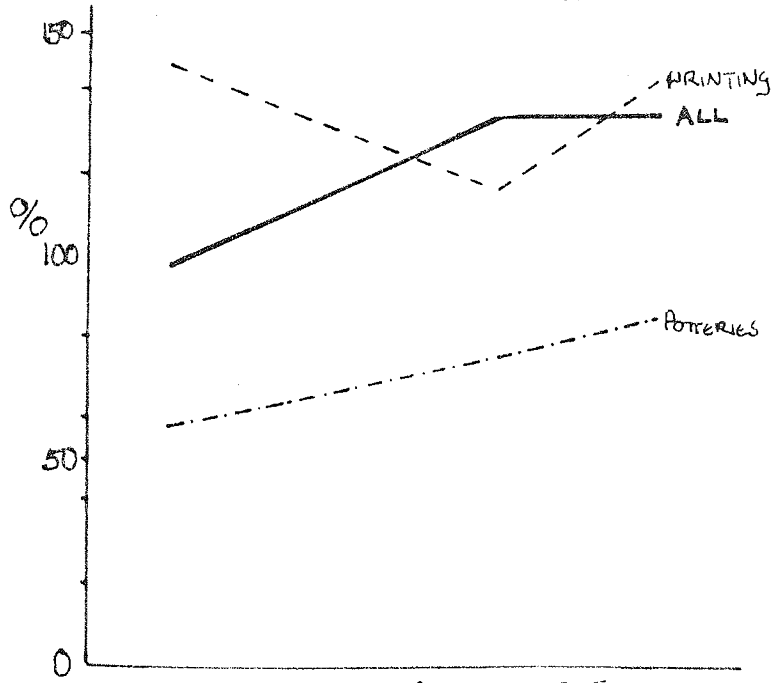
a) W.C.A.Certificates of Disability/Suspension as a Percentage of Cases of Poisoning Notified to HMFI.



b) New Cases of W.C.A. Compensation as a Percentage of Cases of Poisoning notified to HMFI.



c) W.C.A. Certificates of Disability/Suspension as a Percentage of W.C.A. New Cases of Compensation.



It is therefore not possible to use the Workmen's Compensation Act statistics to assess changes in the significance of (and in particular the diagnostic practice underlying) Notification of lead poisoning to the Factory Inspectorate. However it would appear that any increase in propensity to Notify lead poisoning is more than matched by an increase in the propensity to Certify/provide Compensation for lead poisoning under the Workmen's Compensation Acts.

Statistics for Spells of Prescribed Industrial Disease under the National Insurance Industrial Injuries Acts 1951-1979

Workers suffering from industrial lead poisoning (Prescribed Disease No.1 - P.D.1) have been eligible for industrial injury, disability and death benefits under the 1946 National Insurance (Industrial Injuries) Act, under a scheme administered by the Department of Health and Social Security (D.H.S.S.). Statistics for the number of spells of lead poisoning (P.D.1) arising in different Standard Industrial Classification (S.I.C.) industries are available for the period June 1951 - June 1979.

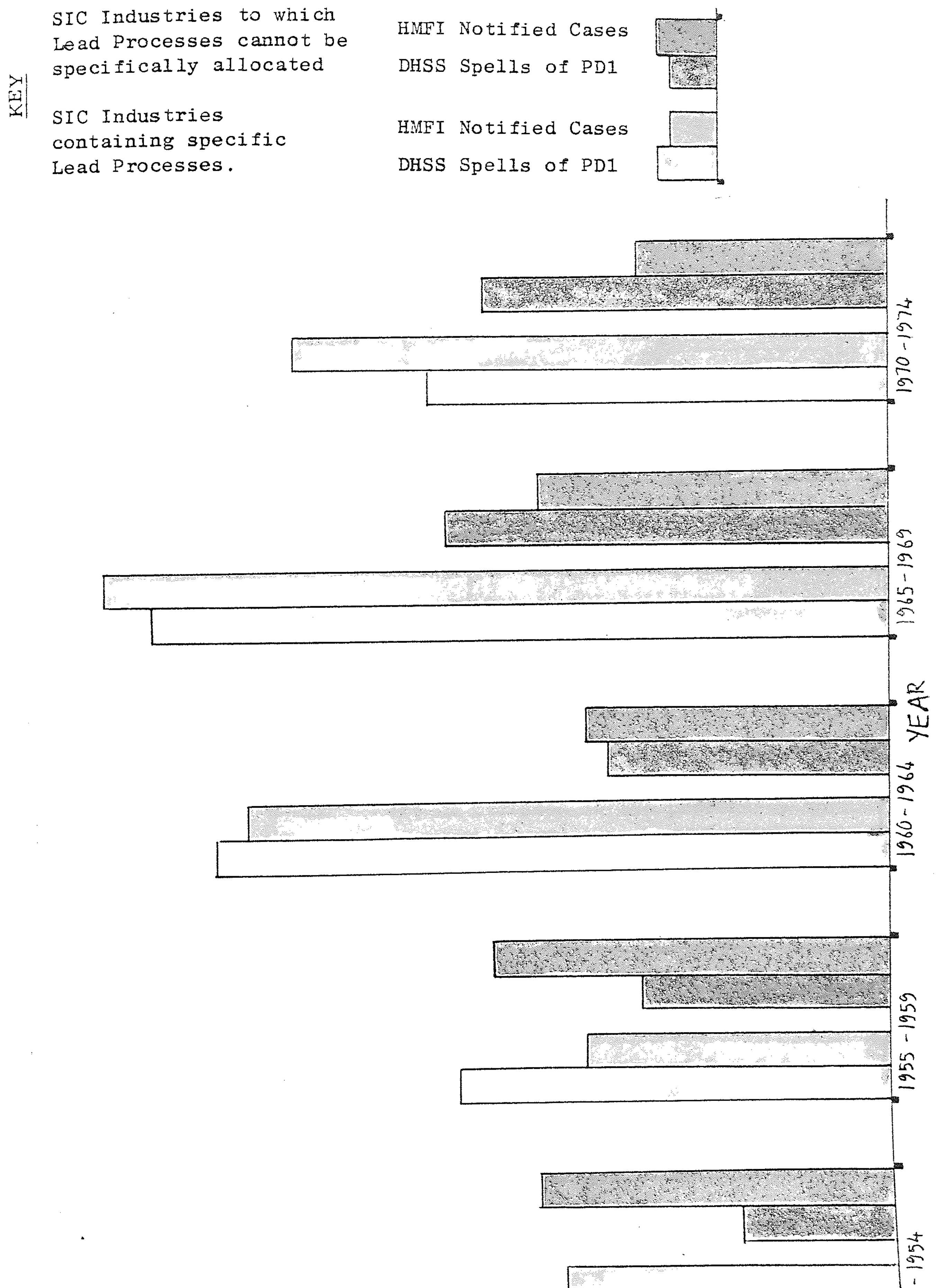
It has been possible to allocate some of the Lead Processes (subject to Regulations under the Factory Acts - F.A.L.Ps) to specific S.I.Cs. On this basis a comparison has been made between the number of Spells of P.D.1 and cases of lead poisoning Notified to H.M.F.I. in specific industries (F.A.L.Ps and S.I.Cs containing those F.A.L.Ps) and for factory industries as a whole (distinguishing those industries subject to Regulations for lead processes and those not containing Regulated lead processes), in five year periods between 1952 and 1974. The basis of the comparison, and results are given in Appendix B-5.[32,33,34,35,36]

The results of the comparison are shown in Figure 6-6. This shows that the relationship between H.M.F.I. Notified lead and poisoning and Spells of P.D.1 receiving benefit through the D.H.S.S. is reversed amongst

Figure 6-6: Lead Poisoning in Factory Industries 1952 - 1974, Comparing the average annual number of Cases of Lead Poisoning Notified to H.M.F.I., with Spells of P.D.1 receiving D.H.S.S. Benefit, amongst:

a) industry groups containing specific lead processes,

b) industries to which specific lead processes (under the Factory Acts) cannot be allocated.



industries including Factory Act Lead Processes (subject to Regulations) and industries not including Regulated lead processes). Amongst industries that were covered by Regulations of lead processes :

i) D.H.S.S. New Spells of P.D.1 are initially lower than H.M.F.I. Notified lead poisoning

ii) Between 1960-1969 there is an increase in the number of H.M.F.I. Notifications consistent with changes in the method of diagnosing/assessing lead poisoning

iii) However, this is matched by an increase in the number of D.H.S.S. Spells of P.D.1. This increase appears to start later than in the case of H.M.F.I. notifications but subsequently overtakes them.

Thus there is evidence that Notification of lead poisoning has become more comprehensive (e.g. due to a lower threshold for Notification or more complete Notification) but this is matched by a similar increase in propensity to award benefits for P.D.1.

The opposite trend can be noted amongst industries not covered by Regulations for lead processes. Here an increase in the propensity to Notify cases of lead poisoning to H.M.F.I. (partly attributable to the activities of the Factory Inspectorate) was not matched by an increase in the number of Spells of P.D.1. receiving benefits. The precise reasons for this anomaly could not be determined.

Finally, the relationship between H.M.F.I. Notifications and D.H.S.S. Spells of lead poisoning in the construction industry (relative to Notification in factory based, Regulated lead processes), estimated at 20-33% of the expected levels in the 1952-1974 period - a figure remarkably consistent with other estimates.

A Note on The Use of Compensation statistics as an indicator of Notification practice

Compensation statistics might be expected to be a more consistent indicator of lead poisoning than H.M.F.I. Notification since there is an economic incentive to the worker to claim compensation, and the degree of 'lead poisoning' (e.g. disability from working) is defined. However, the statistics that have been examined for compensation under the Workmen's Compensation Acts (1908-1930) and for Spells of P.D.1. under the National Insurance (Industrial Injuries) Act (1952-1974) indicate that changes in diagnosis of lead poisoning for Notification purposes have been broadly comparable to changes in diagnosis for compensation purposes. This involves both technical questions of sensitivity of diagnosis and social definitions of 'poisoning'. In addition, the compensation figures reflect changes in the administrative arrangements for claiming.

Direct comparisons between statistics are impeded particularly by the lack of a comparable classification of industries in published returns.

In the analysis of control of hazards in the following section, the main source of information on reduction of harm will be the statistics for lead poisoning Notified to the Factory Inspectorate. Before addressing this, it is useful to examine the incidence, or risk to individual workers, of lead poisoning in the various industries.

Incidence of Poisoning

The preceding sections have considered only the absolute number of victims of lead poisoning in different industries. However, in assessing the control of hazards it is important also to consider the incidence of lead poisoning. This is expressed as the number of cases per year of notified lead poisoning per 10,000 workers and the number of deaths from lead poisoning per year per 100,000 workers.

The use of incidence figures gives a more realistic picture of the risk to individual workers. It offsets changes caused by the expansion of industries and gives a more accurate assessment of the hazard facing workers. Obviously a large number of cases of poisoning may reflect a small industry with a high risk to individual workers, or a larger industry with lower risk. Consideration of incidence is particularly important when it comes to assessing the control of hazard (reduction in hazardous working conditions reflected in the reduction in recorded harm to workers), where it will be seen that different groups of workers faced markedly different 'hazard profiles'.

The numbers of manual workers employed in pigment and paint production and paint use between 1901 and 1952 have been estimated in Appendix B-6. [37,38,39,40,41,42] These estimates relate to England and Wales, while the figures for H.M.F.I. Notified lead poisoning relate to the U.K. However this discrepancy has only a minor effect on incidence of lead poisoning since both notified poisoning and employment were heavily concentrated in England. For the purposes of this exercise (the comparison of relative risk across industries and over time) this discrepancy can be ignored and the calculated incidence figures can be taken as a realistic estimate of incidence in England and Wales.[43] In addition to the figures for total manual employment in pigment/paint production and use, an attempt has been made to estimate the numbers directly involved in contact with lead.

The employment estimates and the statistics of industrial lead poisoning produced by the Factory Inspectorate have been used to calculate the incidence of lead poisoning (annual average number of cases of poisoning notified to H.M.F.I. over a five year period per 10,000 manual workers employed in the industry) and of fatal lead poisoning (annual average number of deaths over five year period per 100,000 workers), in pigment/paint producing and using industries. The results are shown in Table 6.9. Table 6.10 shows the incidence of cases of lead poisoning classed as severe. (1900-1914 only).

Table 6.11 presents more detailed figures for lead poisoning in the paint production industry, distinguishing white and red etc. manufacture, and showing incidence of lead poisoning amongst workers in direct contact with lead.

Table 6.12 presents more detailed figures for incidence of lead poisoning amongst manual painting workers. It is assumed that spray painters (who comprise a significant proportion of painting workers by 1931 - about 10%) do not contribute significantly to the number of cases of lead poisoning, and the incidence of lead poisoning has been calculated for the remaining manual painters.

Finally, Table 6.13 presents the estimated incidence of lead poisoning amongst housepainters that would have been expected if notification of poisoning to H.M.F.I. had been on the same basis as other lead industries. (industrial painting). This estimate is derived by assuming that the ratio of fatal to non-fatal lead poisoning is the same amongst house-painters as industrial painters (see Appendix B-2). The fact that this gives figures for incidence that are highly comparable with incidence amongst industrial painters would appear to give some corroboration of the validity of this method of

TABLE 6.9. Incidence of Lead Poisoning (Fatal and Total Cases) in Paint Production and Use 1900-1954
Calculated from employment estimates in Appendix B-6

Incidence of H.M.F.I. Notified Lead Poisoning (Annual average number of cases of Notified Lead Poisoning per 10,000 workers employed)

	White, Red etc. Lead Manufacture	Paint and Colour Works	Paint and Pigment Production	House Painters	Ship Painting	Vehicle Painting	Other Industrial Painters
1900-4	970.2	81.1	315.1	11.9	67.4	47.9	
1910-4	145.8	23.3	58.1	13.5	61.2	46.0	
1920-4	115.2	7.9	20.9	4.1	14.1	11.6	4.7
1930-4	36.1	5.9	7.6	3.4	5.6	4.4	0.9
1950-4	-	2.4	-	0.1	-	0.1	0.2

Calculated from Table 6.3 and Appendix B-6.

Incidence of Fatal Lead Poisoning (Average annual number of deaths from lead poisoning in five year periods per 100,000 workers employed)

	White, Red etc. Lead Manufacture	Paint and Colour Works	Paint and Pigment Production	House Painters	Ship Painting	Vehicle Painting	Other Industrial Painters
1900-4	178.6	10.6	54.8	21.5	22.9	28.3	
1910-4	52.0	2.3	15.7	21.0	68.0	28.4	
1920-4	37.2	3.8	7.9	12.0	13.7	11.5	2.6
1930-4 *	36.1	3.2	5.1	6.1	14.0	3.8	1.3
1950-4	0	0	0	0	0	0	0

* In later years, the death rates become more erratic due to the low numbers involved.

Calculated from Table 6.4 and Table B-6.

TABLE 6.10. Incidence of Severe Cases of Lead Poisoning in Paint Production and Use 1900-1914

Incidence of Cases of Lead Poisoning Assessed as Severe (Annual average per 10,000 workers)

Period	White Lead Manufacture	Red etc. Lead Manufacture	White and Red etc. Lead Manufacture	Paint & Colour Works	Pigment/Paint Production	House Painting	Ship Painting	Vehicle Painting
1900-4	313.6	239.6	306.5	27.3	100.8	-	31.7	12.2
1910-4	19.3	30	20.1	2.1	6.9	-	12.0	6.4
1920-4						1.2 (Estimated)		

Source: Calculated from Table 6.5 and Appendix B-6.

TABLE 6.11. Estimated Incidence of Lead Poisoning in Manual Workers in Pigment/Paint Production

Incidence of Lead Poisoning (Annual average per 10,000 workers)

Period	All Manual Workers		Workers in Lead Processes (direct contact with Lead)	
	White Lead Manufacture	Red(& Yellow) Lead Manufacture	White Lead Manufacture	Paint and Colour Making (Intensity weighted
1900-4	1003.2	656.2		
1910-4	126.2	(380 *) Estimated employment figure	223.4	131.6
1920-4				77.4
1950-4				72.3

Incidence of Fatal Lead Poisoning (Annual average per 100,000 workers)

Period	All Manual Workers		Workers in Lead Processes	
	White Lead Manufacture	Red etc. Lead Manufacture	White Lead Manufacture	Paint and Colour Making
1900-4	197.4	0		
1910-4	56.2	0	99.6	12.9
1920-4				37.5
1950-4				0

Source: Tables 6.4., 6.5. and Appendix B-6.

TABLE 6.12. Incidence of Lead Poisoning amongst Manual Painting Workers (excluding numbers employed in spray painting)

Incidence of H.M.F.I. Notified Cases of Lead Poisoning (Annual average number of cases per 10,000 workers)

Period	Ship Painters	Vehicle Painters	Other Industrial Painters
1930-4	6.3	4.7	1.0
1950-4		0.1	0.3

Incidence of Fatal Lead Poisoning (Annual average number of deaths per 100,000 workers)

Period	Ship Painters	Vehicle Painters	Other Industrial Painters
1930-4	15.7	4.0	1.4
1950-4		0	0

Source: Tables 6.4., 6.5. and Appendix B-6

TABLE 6.13. Estimated Incidence of Lead Poisoning Amongst Housepainters had Notification been conducted on a comparable basis to Factory Industries. 1900-1954

1900-4	44.0
1910-4	32.9
1920-4	15.6
1930-4	6.1
1950-4	0.2

Number of cases of poisoning amongst housepainters estimated by assuming that the ratio of fatal to non-fatal cases is the same amongst housepainters as industrial painters.

See Appendix B-2.

Source: Appendix B-2 and B-6.

Observations on the Incidence of Lead Poisoning

Painting Workers. The increase in numbers of cases of lead poisoning amongst industrial painters in the 1900-1914 period is revealed to be a probable result not of deterioration of working conditions, but of the expansion of employment in these industries, since incidence of poisoning remains broadly static.[44] (Indeed the rapid reduction in the numbers and incidence of severe cases of poisoning in this period would indicate that, if anything, conditions were improving).

The relative magnitude of incidence of lead poisoning amongst painting industries is markedly different from that of absolute numbers (both of cases of poisoning and fatal poisoning). The incidence of poisoning in any period is broadly comparable between different painting industries (using the estimated rather than observed incidence of cases of poisoning for housepainters), with ship painting tending towards a slightly higher incidence in most periods, except that the incidence of lead poisoning from 'the use of paint in other industries' is much (3-6 fold) lower in the periods for which this measure is available.

Pigment and Paint Production. The incidence of cases of lead poisoning in white and red etc. pigment production is an order of magnitude greater than other sectors of the paint industry up to 1924. Even though the total number of cases of poisoning in lead pigment manufacture is comparable with lead using industries, the number employed is much smaller, and the risk to individual workers is much greater.

In contrast, amongst paint using industries, though the total burden of harm was high, the risk to individual workers was low.

These differences in incidence of lead poisoning between industries are a product of the numbers involved in handling lead (in particular in lead processes generating airborne lead dust) and the intensity of workers exposure to lead (in addition it is also affected as noted earlier by the arrangements for medical examination/screening of workers). Some information is available on these matters, and it is possible to produce figures for incidence of lead poisoning corrected for changes in numbers and intensity of exposure to lead.

Numbers Exposed to Lead Processes/Intensity of Exposure to Lead

In white and red lead manufacture, a high proportion of the workforce is involved in lead processes/exposed to lead dust, and this exposure is continuous (insofar as other, lead free materials are not used/produced). As a result the incidence of lead poisoning in lead pigment manufacturing is very high for all manual workers, and slightly higher amongst workers in lead processes (see Table 6.11).

In paint and colour manufacture, a smaller proportion of manual workers are engaged in dusty lead processes (14½% in 1911 - see Appendix B-6). This proportion is not known for subsequent years. However, it is known that the intensity of exposure to lead falls in subsequent years with the increasing consumption of non-lead pigments. This was the basis of the estimates for 1920-1954 of 'workers in lead processes' of paint making (Table 6.11). N.B. This estimate would be a correct estimate of numbers in lead processes only if paint making plant were dedicated to lead and non-lead paint. In practice it will be an index not only of numbers exposed, but also intensity of exposure.

The incidence of lead poisoning amongst lead process workers (adjusted for intensity of use of lead pigments) in paint making is much higher than that calculated for all manual workers in paint making. Incidence of cases of lead poisoning in lead process workers borders on the incidence found in lead pigment production, although there is a greater differential on incidence of fatal lead poisoning.

This estimate of changes in intensity of exposure does not take into account changes in the technology of paint making (which would both affect the numbers involved in lead processes and the levels created), but only changes in materials used. The effects of changes in production technology will be examined later.

In contrast to pigment and paint manufacture, in the paint using industries exposure to lead dust is intermittent (only some of the painting processes yielding lead dust). Moreover with the increasing consumption of non-lead paints, this exposure becomes increasingly 'diluted'. As a result, the incidence of poisoning in painting workers is substantially lower than amongst workers at factory lead processes.

There are no figures that would allow a distinction between painting workers engaged in lead processes and non-lead processes. In all likelihood many painting workers were exposed to both lead and lead free paints (particularly those engaged in painting houses, ships and civil engineering works). The probable exceptions here are spray painters(already noted) and certain industrial painters (where works were dedicated to painting a particular industrial product e.g. vehicle painting).where the type of paint used would be more constant, and where non-lead paints would probably be used more frequently.

There are no figures available for white lead consumption in different sectors of painting though it has been possible to estimate the probable allocation of white lead into industrial painting as a whole and to interior and exterior paints in housepainting. (See Chapter 3. The results are summarised in Table 6.15 below).

These figures have been used to estimate the incidence of lead poisoning that would be expected amongst painters using solely white lead paints, (i.e. correcting for the dilution of lead by non-lead pigments). These estimates also represent the incidence of lead poisoning that would be expected if all paints had been made from white lead.

Incidence of lead poisoning has been assumed to be proportional to the tonnage of pigments consumed. It has been assumed (see notes to Table 6.15) that the use of lead paints in interior (decorative) painting leads to ten times as much poisoning as the same weight in exterior (protective) painting. The consumption figures for 1907 have been used for the period 1910-4 (though lead consumption may have been slightly greater in this period). It has been necessary to apply the same correction factor across all sectors of industrial painting (even though it is likely that white lead consumption was unevenly distributed across these sectors). The results are shown in Table 6.14.

This correction results in a much higher incidence of lead poisoning being recorded, particularly in later years. This suggests that reduction in lead consumption may have played a significant role in the fall in lead poisoning over the years. These findings will be discussed in the next section which deals with the role of different factors in the control of lead poisoning in painters.

The application of this correction leads to estimates of the incidence of lead poisoning that would be expected amongst painters working solely with white lead that are broadly comparable to the incidences calculated amongst lead process workers in lead pigment and paint manufacture (incidence of cases in the former are a quarter to a half of the latter, but incidence of fatal poisoning appear to be broadly similar in both - the difference may be attributable to differences in notification practice and medical

TABLE 6.14. Estimated Incidence of Lead Poisoning in Painters if all paints had been made from white lead a)

Incidence of H.M.F.I. Notified Lead Poisoning (annual average number of cases per 10,000 workers)

Period	Housepainting b),c)	Ship Painting	Vehicle Painting	Paint used in other industries
1910-4 d)	61.9	88.9	66.9	
1920-4	50.7	29.4	24.2	9.8
1950-4	3.1	-	1.45	2.9

Incidence of Fatal Lead Poisoning (annual average number of cases per 100,000 workers).

Period	Housepainting b),c)	Ship Painting	Vehicle Painting	Paint used in other industries
1910-4 d)	39.6	98.8	41.3	-
1920-4	41.1	28.5	23.9	5.3
1950-4	0	0	0	0

a) Assuming incidence of poisoning in painters is proportional to weight of white lead consumed in paints.
Based on estimated consumption of white lead and other pigments in industrial, protective (exterior) and decorative (interior) house-paints from Chapter 3, and Table 6.15

b) Using the estimated levels of cases of lead poisoning in house-painters from Table 6.13.

c) Consumption of white lead in interior (decorative) paints assumed to cause ten times as much poisoning as same weight consumed in exterior (protective) paints. (See notes to Table 6.16).

d) 1907 figures for white lead etc. consumption used.

TABLE 6.15. Estimated Consumption of White Lead in Different Sectors of the Painting Industry 1907-1963 (Thousand tons)

Year	Sector of Painting Industry	Estimate based on pigment weight: Combined Consumption of Major White Pigments by UK Paint Industries.	Estimate based on pigment weight: White Lead Consumption	Estimate based on pigment weight: Relative Consumption of White lead as percentage of combined consumption of White Pigments in UK Paint Industry.	Estimate based on pigment hiding power: Combined Consumption of Major White Pigments by UK Paint Industries.	Estimate based on pigment hiding power: White Lead Consumption	Estimate based on pigment hiding power: Relative Consumption of White lead as percentage of combined consumption of White Pigments in UK Paint Industry.	"Best Estimate" Average Relative Consumpt[ion] of White [lead] from two methods [of] estimati[on]
1907	Industrial	11½	8	70	13	9½	73	71½
	Decorative	17½	9½	54	14½	6½	45	50
	Protective	17½	14½	83	19½	16½	85	84
1926	Industrial	19½	5	32	14½	3½	24	28
	Decorative	19	5½	28	15.3/4	3½	22	25
	Protective	19	13½	71	22.1/4	15	67	69
1948	Industrial	30	1½	5	24½	2	8	6½
	Decorative	26½	1½	5½	27½	2	7	6.1/4
	Protective	26½	12	45	31	11	35	40
1954	Industrial	29½	1	3½	25.1/4	1	4	3.3/4
	Decorative	24	1	4	27	1	3½	3.3/4
	Protective	24	8	33	26.3/4	8	30	26½
1963	Industrial	32½	½	1½	30	½	1½	1½
	Decorative	23½	½	2	25½	½	2	2
	Protective	23½	3	13	24	3	12½	12.3/4

monitoring and the profile of hazard between the industries).

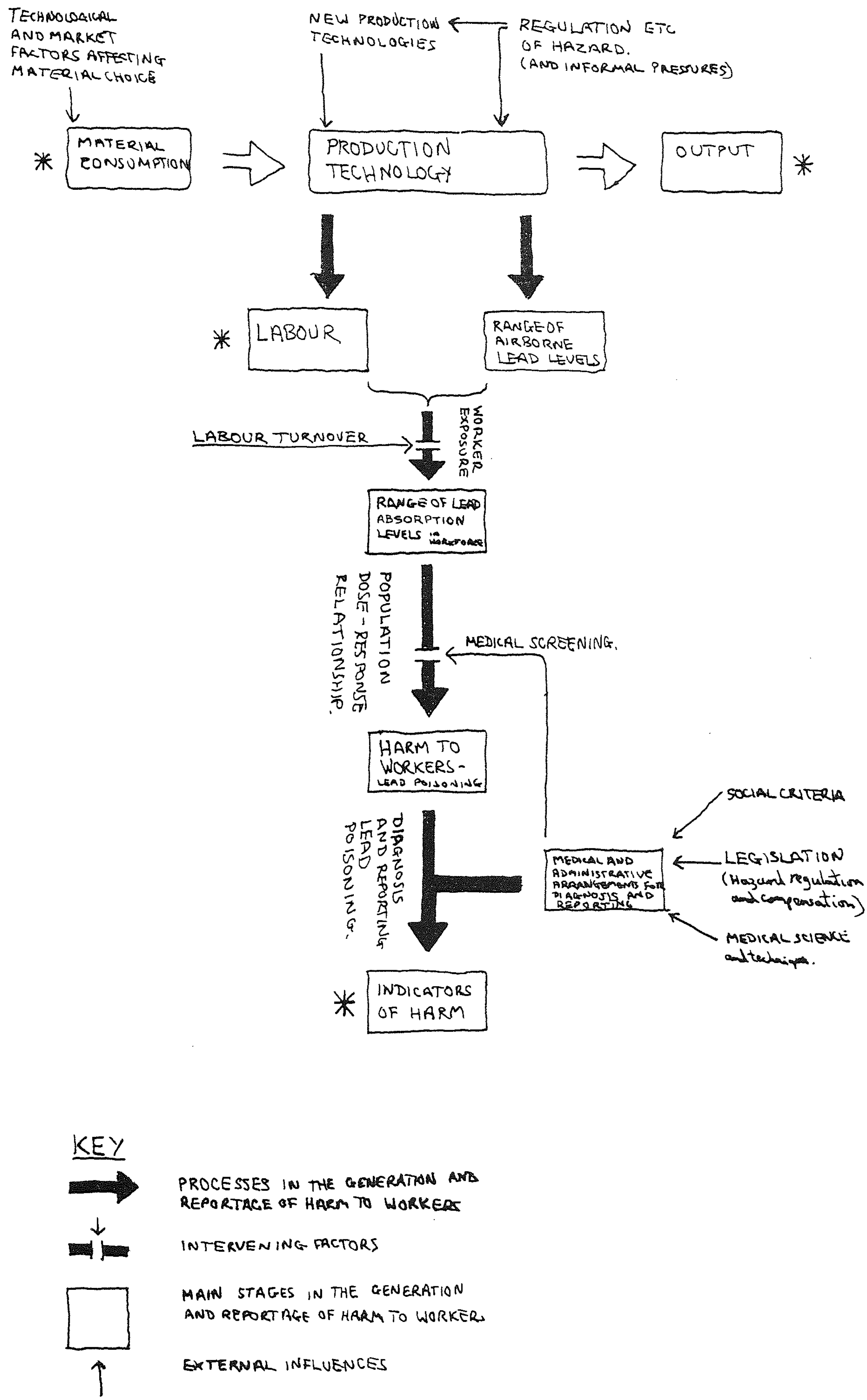
The Relationship between Exposure to Lead and Lead Poisoning

The preceding calculations of incidence of lead poisoning adjusted for numbers involved in lead processes and intensity of exposure have implicitly assumed a linear relationship between exposure to lead dust and lead poisoning. Whilst this assumption does allow estimates to be made of the effects of changes in employment structure and lead consumption on poisoning levels, it may be misleading.

The relationship between lead consumption, exposure to lead dust and lead poisoning is highly complex. The main stages, processes and influential factors in the process by which production gives rise to recorded lead poisoning are summarised in flow diagram form in Figure 6-7.

The range of airborne lead levels and consequently of levels of lead absorption by workers, generated by production processes is not known - particularly the way these change over time with changes in production technology and materials consumption. These must therefore be inferred from information about the production process/materials consumption and about lead poisoning levels. Changes in the production process will affect not only the average levels but also the range of exposure to lead. Measurement of levels of airborne contaminants in the workplace indicate that these may vary geometrically rather than arithmetically for a given production process.[45] By implication, a change in workplace emissions might not produce a linear change in the average and particularly the distribution of levels of workplace exposure and worker absorption. The relationship between lead exposure/absorption and harm/recorded poisoning is also problematic. The effects of differential diagnosis and reporting rates and medical intervention on recorded lead poisoning, for different

Figure 6 - 7: Flow Diagram of the Main Stages and Influencing Factors in the Relationship between Industrial Use of Lead and Recorded Lead Poisoning.



industries and periods, have already been discussed. The relationship between lead absorption and the proportion of the workforce suffering a given degree of harm (for which the term population dose-response relationship has been used) is characterised by :

i) the existence of thresholds of exposure, below which a given level of harm will not be observed

ii) the proportion of the population suffering a given degree of harm will increase linearly with geometric increases in worker exposure.[46] Thus a given reduction in exposure in likely to reduce a disproportionately larger reduction in levels of harm.

iii) since lead is a cumulative poison, levels of harm will be affected by both current and previous absorption/exposure.[47]

Caution must therefore be exercised in the interpretation of lead poisoning statistics, and particularly in the inference from these of the levels of worker exposure to lead. Whilst the assumption of a proportional relationship between exposure and poisoning is a necessary 'first approximation' due to the lack of alternative information, there are good reasons to believe that this may be incorrect, and this is particularly important when it comes to assessing the control of lead paint hazards.

In addition to the factors mentioned above, labour turnover, job rotation, duration of involvement in processes generating lead dust can affect levels of lead poisoning without any change in levels of workplace lead exposure. As well as average exposure levels, peak exposures may be particularly significant, especially in the contraction of severe and acute (i.e. based on short term exposure) poisoning.

These characteristics of worker exposure are likely to vary between industries and over time. Some indication of these differences can be obtained from the relationship between the different indicators of harm (in particular cases, severe cases and fatal cases of lead poisoning recorded by the Factory Inspectorate). As noted earlier, from the turn of the century, fatal lead poisoning reflected primarily long term exposure to lead. Although the number of cses and severe cases of lead poisoning were affected by long-term exposures, immediate exposures would play a much larger role.

One of the consequences of this, as noted earlier, is that the control of lead hazards has a more immediate effect on cases of poisoning than deaths and results in a temporary increase in the number of fatal cases as a percentage of total notified poisoning. In addition, it can be noted that some lead industries had a much lower ratio of deaths to total cases of lead poisoning (e.g. red lead production, printing) indicating that in these industries most poisoning was as a result of sporadic, short-term exposure.

It is now possible to consider the control of lead paint hazards.

The Control of Lead Paint Hazards

The control of lead paint hazards will now be assessed. Control is defined as a reduction in harm, reflected, albeit imperfectly, in the statistics for lead poisoning. Thus defined, it can be seen that control of a hazard can be a consequence of many factors as well as the adoption of specific precautions as a result of state regulation. Informal pressures, whether from the state, labour or wider society may be important. In addition labour, technological and market factors may play a significant role. An attempt will be made to assess these factors underlying the pattern of control of the hazards of using (lead) paints. The control of lead hazards for painting workers will then be compared with the control of lead hazards in pigment/paint production and other industries in order to assess the relative affectiveness of the different regulatory strategies implemented.

The information on levels of lead poisoning amongst painting workers is summarised in a set of figures.

Figures 6-8 and 9 show the number of cases of notified lead poisoning and the number of deaths from the use of lead paint in housepainting, ship building, vehicle painting and paint in other industries (averages for five year periods, 1900-1969).

Figure 6-10 presents the incidence of cases of lead poisoning amongst manual painters in the same sectors of the painting industry (the figure for housepainting includes both the observed incidence of lead poisoning and the estimated incidence of lead poisoning had notification in this industry been complete - from Tables 6-12 and 6-13 respectively.

In the following sections, unless otherwise specified, figures for numbers and incidence of cases of poisoning in housepainters will refer to the

Figure 6-8: Cases of Lead Poisoning Notified to HMFI due to the Use of Lead Paint in Vehicle Building, Shipbuilding and 'Other Industries'. 5 Year averages 1900 - 69.

Lead poisoning in Housepainters shown for comparison on ¼ scale.

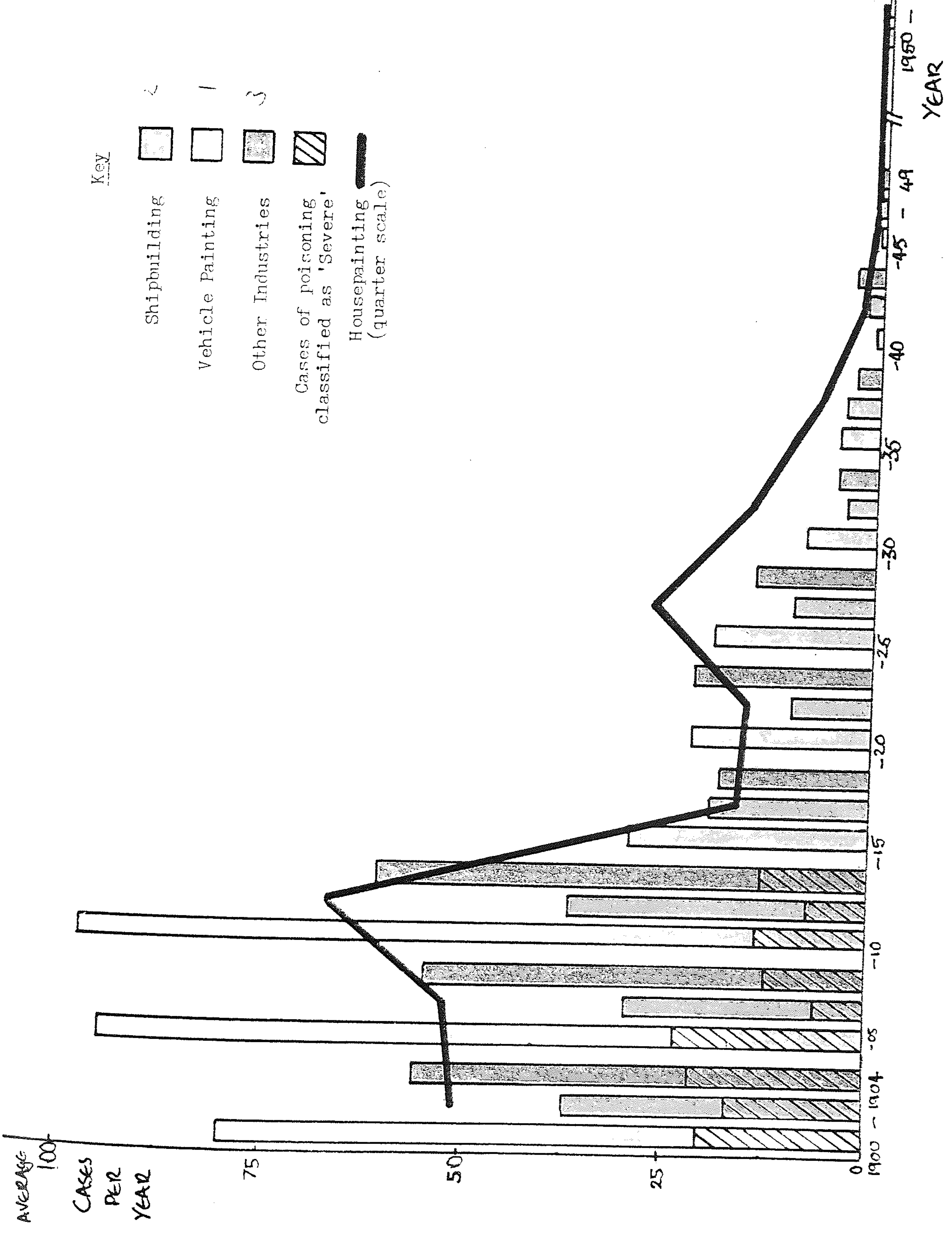


Figure 6-9: Deaths Certified due to Lead Poisoning from the Use of Lead Paint in Vehicle Building, Ship Building and 'Other Industries'. 5 Year averages 1900 - 49.

Fatal lead poisoning in Housepainters shown for comparison on ¼ scale.

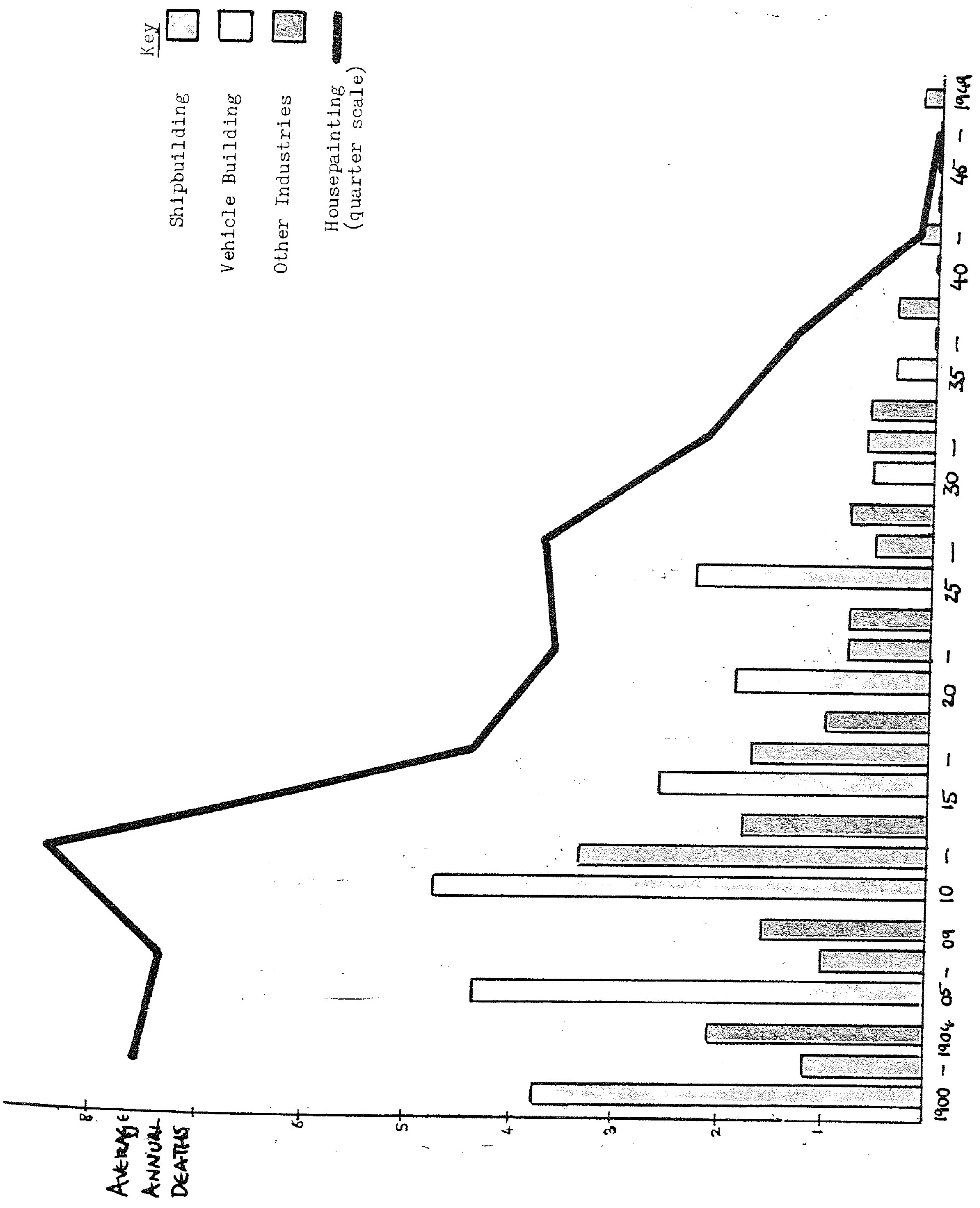
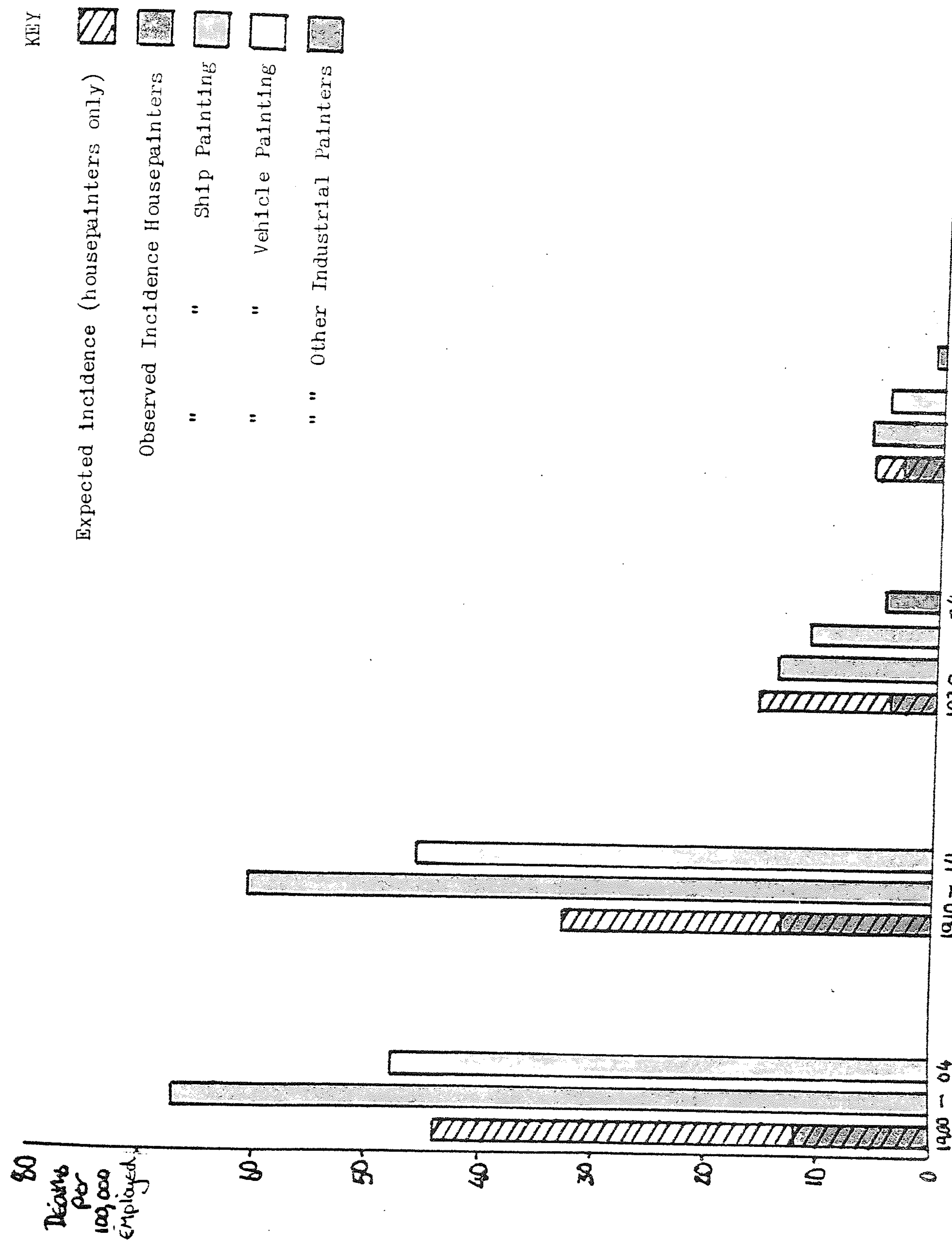


Fig 6-10 INCIDENCE OF LEAD POISONING AMONG MANUAL PAINTERS IN DIFFERENT INDUSTRIES

1900-54

Average annual number of deaths from lead poisoning in five-year periods per 100,000 workers employed.



Source: Tables 6-9, 6-12, 6-13

estimated number of cases that would be expected if notification had been complete rather than the observed number of voluntary notifications to H.M.F.I.

A brief description will be made of the major features of the pattern of control of hazards, pinpointing differences between successive periods and between paint using industries. This review of detailed tendencies suggests some of the factors underlying the process of control. These will be discussed further in the next section.

Stages in the Control of Lead Paint Hazards

1900-1914 - the increase in the number of cases of poisoning amongst painting workers over this period appear to be a consequence of the growth in the painting trade (with increasing employment and total consumption of white lead) and is not associated with an increase in incidence of cases. (The increase in fatal poisoning in most sectors of painting and the increase in voluntarily notified cases of lead poisoning amongst house-painters are the result of changes in reporting and diagnostic practice noted earlier). The number of deaths from lead poisoning in ship painting is somewhat erratic and the high incidence of deaths immediately prior to the war appears to be an anomaly, possibly related to re-armament.

While incidence of cases of lead poisoning has remained constant, the numbers and incidence of cases classed as severe fell during this period, though it is not possible to determine whether this is a consequence of changes in the working environment or the prevention of the emergence of severe poisoning resulting from improved health care and the provision of compensation for workers with lead poisoning under the Workmen's Compensation Act.

1915-1919 The First World War - During the First World War, the government restricted the output of white lead to about 50% of pre-war levels and production ceased altogether in 1917.[48] This shortfall was not made up by imports, and lead substitutes were widely used in whatever painting was carried out. The effect of this move, on lead poisoning in the painting industry was dramatic, and is shown most clearly in Figures 4-3 and 4. The number of cases of lead poisoning fell rapidly, by over 50% per year initially, to almost one tenth of prewar levels.

Other factors, including enforced labour mobility due to conscription, reduced levels of painting, disruption of reporting arrangements, may have also been at work. However this period gives an indication of the likely impacts of Prohibition had this been introduced. It is notable that the reduction in number of cases of lead poisoning was disproportionate to the reduction in consumption of white lead. In addition the reduction in fatal lead poisoning was less marked that in all cases of poisoning. As a consequence the proportion of cases of notified poisoning that were fatal rises sharply.

The reduction in lead poisoning amongst pigment and paint makers is less marked (and more temporary).

1920-1924 After the War, Prior to Regulations - The number of notified cases of lead poisoning amongst house and industrial painters begins to rise again, but does not revert to pre-war levels (in no year reaching 50% of pre-war levesl). Incidence of lead poisoning is even further depressed (between 25-40% of pre-war levels) reflecting the growth in the painting trade. Fatal lead poisoning amongst painters remains at wartime levels. Fatal cases as a percentage of total lead poisoning remains high (only slightly lower than wartime levels).

Observations

The implication of these observations is that lead poisoning is coming under control in this period, prior to the introduction of Regulations for the use of lead paint in house and vehicle painting. Table 6.14 indicates that a much smaller reduction in incidence of lead poisoning in painters might have been observed if lead paints had not been significantly substituted by lead free paints (with predicted incidence of lead poisoning if lead paint had not been substituted only down to 33-80% of pre-war levels).

1925-1944 Regulations were introduced for the use of lead paint in vehicle painting in 1926 and in housepainting 1927 and spraying lead paint in the interior of ships was prohibited in 1931. (See Chapter 5). Following these Regulations, there is a gradual decline in the number and incidence of cases of lead poisoning in all painting industries (including those not, or not yet subject to specific Regulations). Fatal cases of lead poisoning also fall, though fatal cases as a percentage of all notified poisoning remains elevated over pre-war levels.

Thus the hazards of using lead paint do come under control in this period. The rate of control is much less rapid than during the First World War. (It is difficult to obtain a precise measure of the relative rates of reduction because of the amount of interyear variation, however the reduction in number of notified cases in a single year in the 1910-1914 period is comparable to the reduction over five years in the 1925-1944 period).

1945-1969 - The last cases of fatal lead poisoning amongst painters were observed during the 1945-1949 period. Cases of lead poisoning amongst painters become sporadic, and disappear altogether amongst coach painters after 1954 and ship painters after 1959. Amongst other industrial painters and housepainters the reduction in poisoning levels, noted in the previous twenty years, appears to 'bottom out', though the small numbers involved make trends difficult to assess. This may be a consequence of changes in the threshold of notification (as evinced by the increasing number of cases of lead poisoning notified from all factory occupations during successive five year periods between 1945 and 1969).

The elimination of fatal lead poisoning and relegation of cases of poisoning to very low levels coincides with a significant drop in the total consumption of white lead and its share of the paint market.

Differences between Sectors of the Painting Industry

Although the overall trends in levels and incidence of lead poisoning between the various sectors of the painting industry were broadly similar, some differences can be noted which can be related to the differential effects of formal and informal regulatory pressures and changes on technology and materials.

i) Ship painting has the highest incidence of lead poisoning in virtually all periods, which can be related to the potentially very hazardous nature of painting the interior of ships.

ii) The pre-Regulatory reduction in incidence of poisoning (in the period 1920-4 compared to 1910-4) is more marked in shipbuilding and vehicle painting than housepainting. In the case of vehicles, this would appear to be related to the curtailment of use of lead paints as a result of technological changes (the installation of spray painting and stoving enamels) with which it was not desirable to use lead paint (due respectively to hazards and technical problems). In the case of shipbuilding, this trend may be anomalous.

iii) The reduction in lead poisoning immediately following the introduction of Regulations for house and vehicle painting is broadly comparable in all sectors of painting in indicating that non-regulated sectors were introducing changes in technology, materials or working practices, either as a result of informal regulatory pressures or economical technological reasons.

iv) Between 1930-4 and 1950-4 the reduction in incidence of lead poisoning is greater amongst vehicle painters than house painters. This could be a result of two factors in particular;

- that Regulation was more effective and better enforced in vehicle than house painting
- that technological and materials changes (in particular reduced consumption of white lead) were reducing the lead poisoning hazard.

Though information is not available to indicate which trend was responsible, the subsequent total elimination of lead poisoning from vehicle painting (in contrast to housepainting) suggests that reduction in lead paint consumption may have been a significant factor, since, it could be argued that use of lead paint subject to Regulations would lead to some cases of poisoning.

v) 'Painting in other industries' has a substantially lower incidence of lead poisoning in the 1920-1930 period for which figures are available (though the estimate of numbers of painters employed in this residual sector is least certain), particularly fatal poisoning. This group comprises mainly painters of industrial products (i.e. consumer goods) and factory based decorators (many of whom were covered by the Lead Paint Regulations

1926). Lead poisoning in the former would be relatively simple to control (by engineering controls or the use of lead free paints).

The elimination of lead poisoning occurs earlier amongst ship painting than 'other industrial painting' - although in both sectors use of lead paints was only partially subject to specific Regulations. The former is highly centralised while the latter is very dispersed. If the reduction in lead poisoning in these sectors is due to informal regulation it would appear that this factor is more effective in centralised industries than decentralised ones, in which outposts of inadequately controlled (painting) processes may persist.

Factors in the Control of Lead Paint Hazards

Precise attribution of causality in the control of lead paint hazards is hampered by the lack of detailed quantitative information on paint consumption, workplace exposure to lead, working methods and paint technology across industries and over time. The preceding examination of detailed trends has given some indication of the factors which may be operating in this process. An attempt will be made to draw these different factors together.

The pattern of control of hazards is far removed from the naive model of regulation conceived as a force which has an impact on an otherwise static industrial system. It is clear that voluntary control and informal regulation had a substantial impact on levels of lead poisoning. For example, the biggest single reduction in the number of cases of lead poisoning in painters took place before the introduction of Regulations for the use of lead paint (i.e. the reduction in incidence of lead poisoning in painters between 1910-1914 and 1920-1924 was greater than that between 1920-1924 and 1930-1934). Underlying this 'voluntary' control were changes in technology, working practices and materials consumption which can be attributed to informal regulation by the state as well as 'social pressures' and technological and market changes not connected with concern about hazards. The significance of informal regulation is demonstrated by the reduction in lead poisoning amongst paint using industries not subject to the specific Regulations for use of lead paints.

The Role of Changes in the Consumption of Lead Paints

The level of consumption of white lead would from apriori consideration be likely to be a major factor in the magnitude of lead poisoning hazards from painting. In addition it is the matter on which systematic qualitative data are most available. The role of this factor in the control of lead hazards will be examined first. The contribution of other factors can then be inferred from the remaining, unexplained changes of lead poisoning levels in painters.

Figures for the changes in the consumption of major white pigments overall and in the painting industry and the determinants of this process have been derived in Chapter 3.

The first issues to be addressed is the relationship to be assumed between changes in pigment consumption and lead poisoning in painting. If it is assumed that a reduction in the relative consumption would produce a proportional reduction in lead poisoning in painting, then it would appear that the reduction in consumption of lead paint was a significant contributor to control of poisoning particularly in the 1920-1924 period as well as the final elimination of lead poisoning amongst painting workers in the 1960s. In addition it can be inferred that the substitution of lead paint occurred more rapidly in some sectors, e.g. vehicle painting, and thereby contributed to the earlier elimination of lead poisoning from this sector.

However there is evidence that a given reduction in white lead consumption may produce a disproportionately greater reduction in lead poisoning in painting. In particular the halving of white lead consumption between 1914 and 1917 because of the First World War was accompanied by a reduction in poisoning amongst painters from 340 to 103. Although part of this may be due to increased mobility of labour it does suggest that reduced lead consumption produced a larger reduction in lead poisoning implying that an even greater proportion of the reduction in lead poisoning in painters since 1900 was attributable to reduced white lead consumption. Two explanations for such a phenomenon are possible:

i) The incidence of poisoning amongst painters was low compared to other lead workers. In other words, though many painters were exposed to lead, only a small proportion absorbed sufficient lead to overcome the threshold at which lead poisoning developed. Reduction of the lead content of paints (or, for that matter, the elimination of the dustiest jobs in painting) might bring the lead absorption levels of a disproportionately large group of painters below the threshold of poisoning. It is difficult to evoke this factor as the sole explanation of both the rapid reduction in lead poisoning in the First World War and the slower reduction over the subsequent 30 years. Another factor must therefore be in operation possibly in conjunction with this.

ii) Lead paints were substituted differentially for certain applications. In particular, it would be very probable that lead would be retained for protective paints, applied to the exterior of buildings, whilst zinc paints and distempers would be used in the interior of buildings. It had been noted that a given weight of white lead in paint caused ten times as many cases of poisoning when used in internal painting as external painting.[49]

Though figures for detailed consumption of lead paints in different sectors of painting are lacking, a set of estimates of the allocation of white lead into decorative (internal) and protective (external) house-paints and industrial paints was made in Chapter 3. The results are shown in Table 6.15. Assuming that the number of cases of poisoning in painters is proportional to the consumption of white lead paint, a set of estimates can be made about the level of lead poisoning cases that would be expected amongst housepainters. These are presented in Table 6.16, and are based on the relationship between white lead consumption and poisoning observed in the 1910-1914 period. The estimates are for levels of lead poisoning expected in housepainters solely due to reduction in white lead consumption in house paints:

I on the basis of the reduced weight of white lead consumed in paints overall since 1907.

II on the basis of the reduced proportion of white lead consumed in paints overall since 1907.

III on the basis of the reduced proportion of white lead consumed in housepaints since 1907.

IV on the basis of the reduced weight of white lead in external and in internal paints since 1907.

V on the basis of the reduced proportion of white lead in external and in internal paints since 1907.

Between 1910-1914 and 1950-1954 there was a 175-fold reduction in the number of cases of lead poisoning in housepainters. Consumption of white lead in house paints fell by only 2.5 times in absolute terms and 3.1 times as a proportion of combined white pigment consumption. This would appear to indicate that reduced consumption of white lead made only a minor contribution (1½ to 2%) to the reduction in poisoning, if a proportional relationship between consumption and poisoning is assumed.

However if white lead was displaced preferentially from internal painting (which carried a tenfold greater risk of lead poisoning)[50] a much higher proportion of the reduction of lead poisoning can be attributed to changes in consumption of white lead in house paints - between 3-5% of the total. N.B. rather different results are obtained from the different methods of estimating depending on whether absolute or relative white lead consumption is used. The former would be more appropriate for estimation if use of white lead were concentrated amongst a small group of workers; the latter is a better indicator of intensity of exposure if this is spread across all painters. The real situation will lie somewhere between these two and average figures for these two methods of estimation have therefore been used in subsequent calculations.

Examination of individual periods shows that changes in white lead consumption played a varying role in reduction in lead poisoning at different periods which was at times substantial.. It would appear from Table 6.16 that 55% of the threefold reduction in lead poisoning in housepainters between 1910-1914 and 1925-1929 can be attributed to reduced consumption of white lead. In the subsequent 20 year period, only 8% of the 31-fold reduction in lead poisoning could be attributed to reduced

TABLE 6.16. **Predicted Number of Cases of Lead Poisoning that would be expected amongst Housepainters, solely due to changes in Consumption of White Lead in Paints.**
(assuming number of cases of poisoning is directly proportion to lead consumption, based on levels of lead consumption and lead poisoning observed in 1907) a)

Period	Number of Cases of Poisoning in Housepainters b)	I Number of Cases of poisoning in housepainters predicted on basis of reduction since 1907 in total consumption of white lead in paint c)	II Number of Cases of poisoning predicted on the basis of the reduction since 1907 of white lead as a proportion of total white pigments in paint. d)	III Number of Cases of poisoning in housepainters predicted on basis of reduction since 1907 in white lead consumption in housepaints f)	IV Number of Cases of poisoning in housepainters predicted on basis of estimated changes in total consumption of white lead in internal and external painting. c) e)	V Number of Cases of poisoning in housepainters predicted on the basis of estimated changes in the proportion of white lead consumed in internal and external painti[ng] d) e)
1905-9	2971	(2971)	(2971)	(2971)	(2971)	(2971)
1925-9	966	1857	1475	2486	1876	1622
1945-9	31	782	1393	1711	907	534
1950-4	17	561	928	1162	563	322
1960-4	2	194	371	452	250	167

a) Figures for consumption of white lead and other white pigments from Chapter 3. Estimated consumption of white lead in internal, external and industrial paints from Table 6.15 based on the average levels of pigment consumption obtained by the two methods of estimating (on a weight and hiding power basis).

b) Number of cases predicted for five year period if lead poisoning had been notified on the same basis in housepainters as industrial painters. Source : Appendix B-2.

c) Assuming level of poisoning in painters falls proportionately to reduction in tonnage of white lead consumption in paint.

d) Assuming level of poisoning in painters falls proportionately to reduction in white lead as a proportion of white pigments consumed in paint.

e) Poisoning levels calculated separately for internal and external painting on basis that a given level of white lead consumption will produce ten times the level of lead poisoning in internal as external painting. 49

f) i.e. assuming that relationship between white lead consumption in interior and exterior paints is consumption of white lead. All of the threefold reduction in lead poisoning in housepainters between 1945-1949 and 1950-1954 could be explained on the basis of the reduction in white lead consumption. Figures for allocation of lead consumption in 1960-1964 are rather uncertain and poisoning statistics are uncertain because of the small numbers involved and changes in notification practice in this period. However it would appear that only 20% of the 8.5-fold reductions in lead poisoning could be attributed to reduced lead consumption. This assessment of the reduction in lead poisoning in housepainters due to the reduction in consumption in white lead is based on a conservative estimate of a linear relationship between these variables. If hypothesis I) above is correct, a significantly higher proportion of the reduction in lead poisoning could be attributed to the reduced consumption of white lead. Lacking the means to estimate the nature or extent of this relationship, the assumption of a linear relationship will be used.

Although it has not been possible to estimate the allocation of lead and non-lead pigments into different sectors of the industrial paint market, a similar exercise can be conducted for industrial painting as a whole. The results are summarised in Table 6.17. On the basis of the estimated consumption of white lead in industrial paints it can be inferred that some 70% of the threefold reduction in lead poisoning in industrial painters between 1910-1914 and 1920-1929 could be attributed to reduced consumption of white lead in industrial paints. Only 6% of the 20-fold reduction in lead poisoning in the subsequent 20 years could be attributed to this factor along with 87% of the reduction between 1945-1949 and 1950-1954 (and 34% of the reduction between 1950-1954 and 1960-1964).

A broadly similar pattern could be noted in the control of lead poisoning in house and industrial painters, though reduced consumption of white lead

TABLE 6.17. Predicted Number of Cases of Poisoning that would be expected amongst Industrial Painters, due solely to changes in Consumption of White Lead in Paints. a)

Period	Number of Cases of lead poisoning observed in Industrial Painters (total for five year period)	I Number of Cases of poisoning predicted in Industrial Painters on the basis of the reduction since 1907 of total white lead consumption in paints. a) c)	II Number of Cases of poisoning predicted in Industrial Painters on the basis of the reduction since 1907 of white lead as a proportion of total white pigments in paint. a) d)	III Number of Cases of poisoning predicted in Industrial Painters on the basis of the reduction since 1907 of the (simulated) consumption of white lead in industrial paints. b) c)	IV Number of Cases of poisoning predicted in Industrial Painters on the basis of the reduction since 1907 in the simulated proportion of white lead consumed in industrial paints. b) d)
1905-9	722	(722)	(722)	(722)	(722)
1920-4	222	519	451	351	286
1945-9	11	338	190	144	47
1950-4	6	225	136	83	36
1960-4	1	64	47	41	16

a) Based on figures for consumption of white lead and other white pigments in paint from Chapter 3.

b) Based on simulated consumption of white lead in industrial paints from Table 3.

c) Assuming level of poisoning in painters falls proportionately to reduced tonnage of white lead consumption in paints.

d) Assuming level of poisoning in painters falls proportionately to reduction in white lead as a proportion of white pigments consumed in paint.

appears to have played a larger role in the latter.

It can be concluded that, while changing consumption of white lead can only account for a relatively small proportion of the overall reduction in numbers of cases of lead poisoning during the Twentieth Century it would appear to be a major factor in this reduction over certain periods - in particular the massive fall in the number of cases between 1910-1914 and 1920-1924. In the period following introduction of Regulations for the use of lead paint the contribution of reduced lead consumption is markedly smaller in both house and industrial painting (1925-1949). In the post-war period, reductions in lead consumption appear to play a larger role. However caution must be exercised in interpreting the later figures (for the 1960-1964 period) because the small number of cases of poisoning involved. In addition in this period changes in diagnostic and notification practice were most marked and poisoning from the use of other lead pigments (red lead oxide, lead chromate, calcium plumbate) may have become a significant distorting factor. These pigments were less likely to give rise to lead poisoning than white lead (principally due to their lower solubility), as is demonstrated by the figures for poisoning in white lead and red and yellow lead manufacture. However their consumption, initially much lower than white lead, was falling at a slower rate than white lead. Thus while the influence of these pigments on lead poisoning amongst painters does not significantly affect poisoning levels at the beginning of the study, in this latter period their influence may become more significant. The figures for sales of other lead pigments by U.K. manufacturers are summarised in Figure 6-18.[50] Both of these distorting factors would have the effect of inflating recorded cases of lead poisoning relative to previous years and hence overestimating the contribution of reduced lead consumption to the control

TABLE 6.18. U.K.Sales of Red Lead, Lead Chromate and related materials (Thousands of tons).

a) Sales by U.K. Chemical Industry

Year	Lead	Red and Orange Lead	Total Lead Oxides Red & Orange Lead and Litharge	Total Lead Compounds excluding White Lead	Chrome Pigments Lead Chromate + Zinc and Barium Chromate and Mixtures thereof and other chrome pigments
1910			11.8 a)		
1935				28.1	
1937				27.1	
1948		20.6	27.2	38.0	8.2
1951			32.5	47.5	10.3
1954				40.5	9.7
1958					9.7
1963			25.9		10.2
1968					10

b) Purchases by U.K. Paint Manufacturers

	Total Lead Oxides (Red, Orange and Litharge)	Chrome Pigments (Lead, Zinc, Barium etc. Chromate and others including mixtures).
1948	6.7	4.1
1951	6.0	4.05

a) G.B.Home Department [Cd.7882], 1915, op.cit., p.64

Source : G.B.Census of Production for the years 1935, 1948, 1951, 1954, 1958, 1963, 1968.

of poisoning in the period after 1949.

As was shown in Chapter 3, the substitution of white lead by 'lead free' pigments can be explained on the basis of the technological and economic advantages of 'lead free' pigments. The contribution of substitution of white lead to control of lead hazards can thus be seen as primarily a result of the economic/technological trajectory of the paint industry, with concern about health hazards and regulation playing only an indirect and probably minor role.

The Role of Changes in Paint Application Technology and Working Practices in the Control of Lead Paint Hazards

Least direct/systematic information is available on the subject of changes over time and differences between industries in paint application technology and working practices. However, it would appear that the reduction in poisoning from the use of white lead paint which cannot be attributed to changes in pigment consumption is attributable to changes in paint technology/working practices. Some idea of the magnitude of the contribution of the latter can thus be made. Particular changes can on occasion be related to specific causes.

The method of conceptualising the interaction of these different factors in the control of lead paint hazards, requires consideration. Factors operating earlier in the period have the biggest impact on numbers of cases of poisoning. However other control factors might have had an equally large impact on numbers of victims had they operated earlier. What is of interest is the rate of reduction rather than the absolute reduction of levels of poisoning that were stimulated by a particular factor. To offset these problems (and to facilitate data display) the number of cases of poisoning have been plotted on a logarithmic scale.

(showing reductions in observed levels of poisoning from the levels observed in 1910-1914). The levels of poisoning that would have been expected solely on the basis of reductions in the consumption of white lead are shown.(Tables 6.16 and 17). The difference between these represents the control of lead paint hazards due to changes in paint application technology and working methods. The results are plotted in Figures 6-11 for housepainters and 6-12 for industrial painters.

In Figure 6-11, a distinction is made between the reduction in lead poisoning attributable to the reduced consumption of white lead in house paints (Table 6.16 estimate III) and that attributable also to the preferential elimination of white lead from interior paints (Table 6.16 average of estimates IV and V).

In Figure 6.12 two lines are plotted in addition to the observed number of cases of poisoning amongst industrial painters. Poisoning amongst vehicle painters after the introduction of the Vehicle Painting Regulations 1926, which dealt with the use of lead paints shows a different trend to poisoning amongst ship painters (in which only spray painting with lead paints was covered by specific Regulations after 1931) and industrial painters (not subject to specific Regulations). The trends of lead poisoning levels in these two groups have been plotted separately after 1920-1924. The difference is assumed to be primarily a result of the application of specific Regulations to the former, while the latter were only partially or indirectly subject to specific Regulations (N.B. other factors e.g. technology, differential consumption of white lead may also have played a role).

A further distinction is made between the reduction in lead poisoning that takes place prior to the introduction of Regulations on the use of lead

Figure 6-11: Factors Underlying the Control of Lead Paint Hazards in Housepainters 1905 - 1964

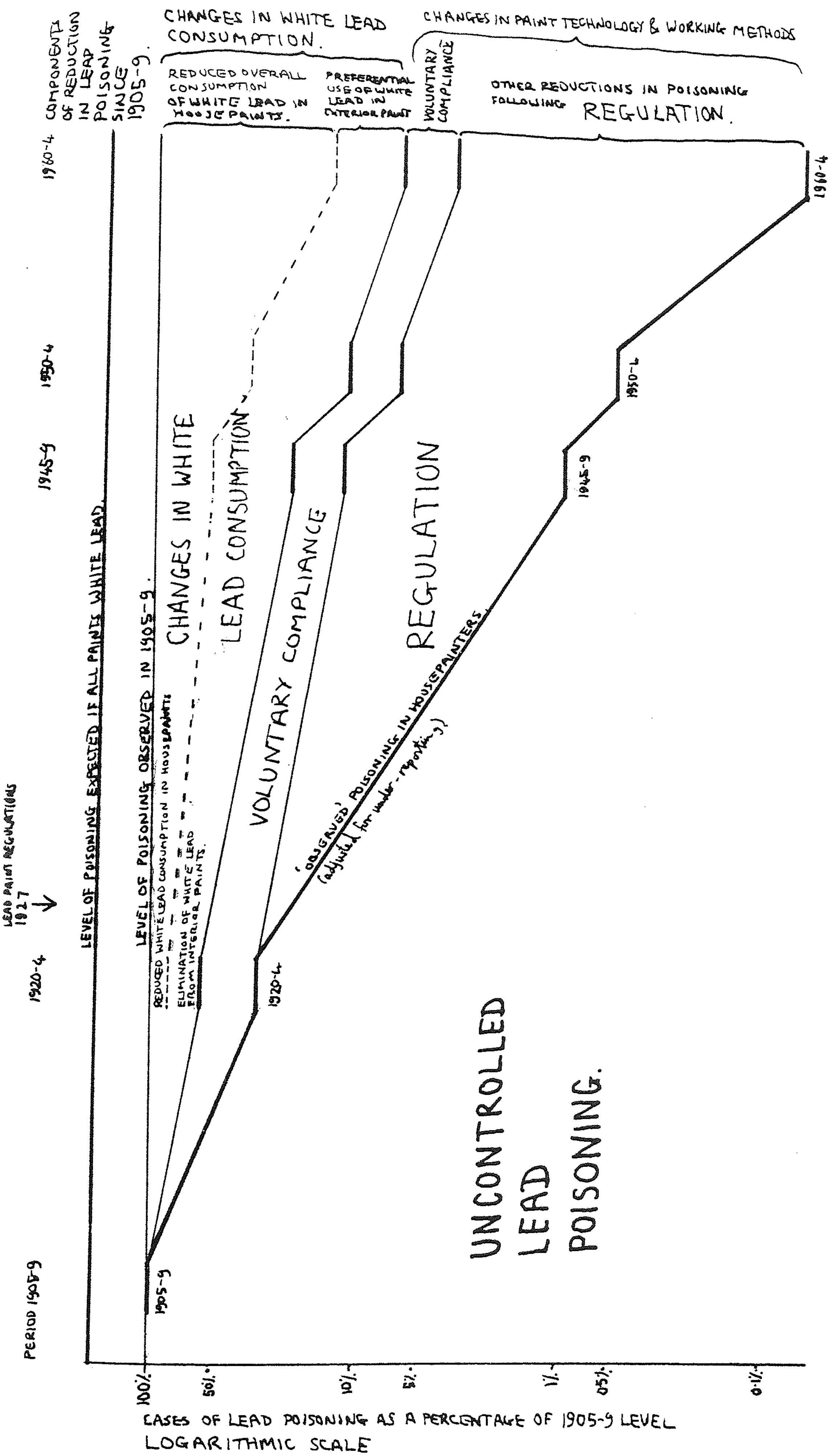
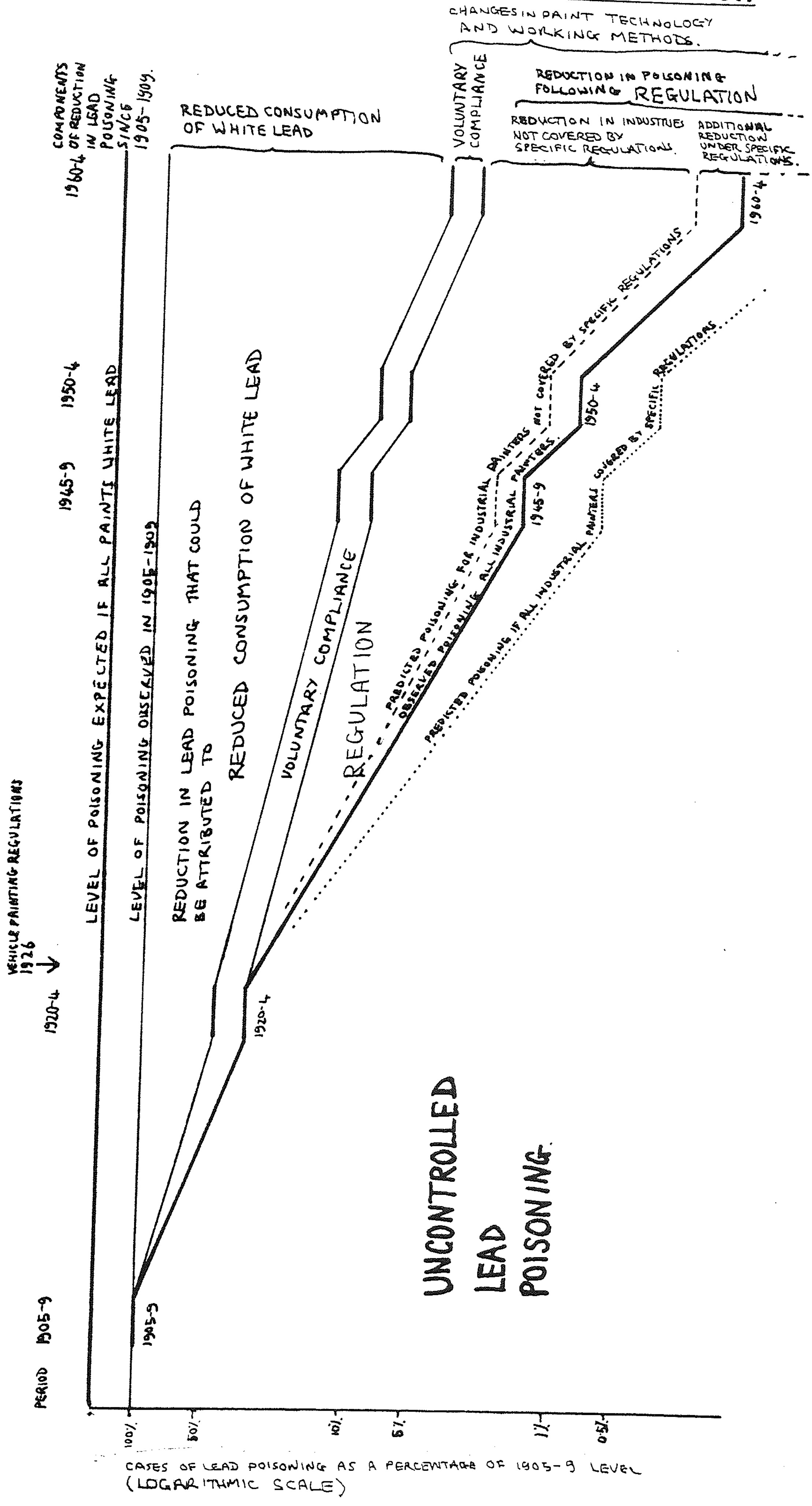


Figure 6-12: Factors Underlying the Control of Lead Paint Hazards in Industrial Painters 1905 - 64.



paint - termed voluntary compliance, and that which takes place afterwards. Thus 45% of the reduction in lead poisoning in housepainters between 1910-1914 and 1920-1924 and 30% of the reduction amongst industrial painters cannot be attributed to the reduced consumption of white lead, but must be a result of changes in painting technology/methods. The relative impact of this voluntary compliance has been charted for subsequent years in Figures 6-11 and 6-12.

It is important to note that in Figures 6-11 and 12 the categories of voluntary compliance and regulation (specific Regulations or otherwise) refer to the regime under which control of hazards due to changes in paint technology/methods took place, not to the stimulus for the change which may have involved commercial concerns or health/regulatory concerns in both cases.. The possible mechanisms and stimuli for these periods of control will be reviewed.

<u>Voluntary Compliance - changes prior to the Regulations on use of lead paint</u>

The hypothesis was examined that this control was a result of voluntary compliance by painting firms with the precautions subsequently required under the Regulations on the use of lead paints.

The major changes in paint technology/methods noted in this period were the use of ready mixed or paste paints (rather than dry pigments for mixing on site) and the introduction of some spray painting and stoving enamels in industrial painting (particularly vehicle painting). The latter reduced lead poisoning primarily by stimulating the use of 'lead free' paints. Commercial/technological reasons appear to have predominated though concern about the hazards of spraying lead paint have played a role.[51]

The two main precautions subsequently required under the Regulations for house and vehicle painting were the elimination of the practice of mixing paints on site from dry pigments and the use of 'wet rubbing' of painted surfaces. As noted in Chapter 5, wet rubbing had not been significantly adopted prior to the implementation of the Regulations.

Wet rubbing did not confer economic benefits to employers but only costs. In contrast the adoption of ready mixed and paste paints not only eliminated the most hazardous process of mixing paints from dry pigments, but also conferred substantial cost savings to employers by reducing the requirements for labour-especially craft labour. The use of ready mixed paints was stimulated not only by the economic advantages to painting employers but also by the evolution of the paint making industry and indirectly by the earlier Regulations for pigment and paint manufacture (see Chapter 4).

Thus the voluntary adoption of controls in advance of the compulsory requirement under Regulations was greater where they conferred economic benefits and conformed to the technological trajectory of an industry, and least where they simply imposed costs.

The rate of control of hazards (i.e. the rate of reduction in the number of cases of lead poisoning) due to changed painting methods and technology during voluntary compliance, (4% p.a. in housepainters and 2½% p.a. in industrial painters between 1905-1909 and 1920-1924) is much slower than in the period after the introduction of Regulations on the use of lead paint (10% p.a. and 7% per year respectively between 1920-1924 and 1945-1949)

Changes following the introduction of Regulations on the use of lead paint

The factors underlying the control of hazards from technology/methods changes can be characterised as follows:

i) health precautions adopted to comply with Regulations, either

   a) because of specific Regulations in that industry (formal regulation), or

   b) in painting sectors not subject to specific Regulations because of informal regulatory pressures.

ii) additional health precautions adopted because of informal regulatory pressures.

iii) changes in paint technology and methods adopted as part of the commercial/technological development of an industry.

A definitive distinction between these factors is not possible, however their probable contribution can be discussed.

It would be misleading to attribute the differences in the control of poisoning between industrial painting subject to specific Regulations and that indirectly or partially covered solely to the greater affectivity of formal over informal regulation. The sector of industrial painting subject to specific Regulations was vehicle painting, in which the car industry was very advanced in its adoption of new painting technology and vehicles. This in turn would have promoted the displacement of white lead. The differences between sectors of industrial painting in the extent of control due to paint technology and methods demonstrated in Figure 6-12 may partly be an artefact due to the more rapid displacement of white lead from certain sectors, in particular the vehicle industry (which it has not been possible to estimate). In addition there were differences in the technological potential and development between vehicle painting and other sectors of industrial painting as well as in the application of specific Regulations.

Notwithstanding these reservations, it would appear that formal regulation (i.e. Regulations) did have a greater impact on lead poisoning than informal regulation. However the effect on lead poisoning of changes adopted because of informal regulation and as part of commercial/technological development were substantial and would account for about half of the control of lead hazards due to changing paint technology and methods since 1920-1924.

It would seem likely that the impact on lead poisoning of compliance with the requirements of specific Regulations on overall levels of lead poisoning [(i) a) above)] would take place in the first twenty years after the introduction of the Regulations. In the subsequent period, after 1949, the reduction is presumably a result solely of changes in paint technology for commercial reasons and the adoption of additional health precautions due to informal regulatory pressures. The rate of control of hazards due to changed painting methods and technology during the period 1945-1949 to 1960-1964 (11% p.a. in housepainters and 8% p.a. in industrial painters) was only slightly lower than that in the preceding 25 years 1920-1924 to 1945-1949 (10% p.a. in housepainters and 7% p.a. in industrial painters).[52]

It can be concluded that the direct impact on lead poisoning of compliance with Regulations on the use of lead paint made only a relatively minor contribution to the overall reduction in levels of lead poisoning amongst painters. However such Regulations also appear to have had important indirect impacts on industries not covered by specific Regulations as well as possible longer term effects on the adoption of further changes in the materials/technology/methods of painting.

It would appear that all four of the possible factors controlling lead poisoning by changing painting technology and working methods were in operation over the period examined. Although it is not possible to determine the exact contribution of each of these different factors, the direct impact of Regulations does not appear to be substantially greater than the other factors.

However it is important to note the difficulties of allocating specific affectivity to the different factors in hazard control, which derive not only from the lack of data, but are a necessary consequence of the model of the regulatory process outlined in Chapter 1. This focused on the interactions between the process of industrial development and the promulgation of Regulations, mediated by the existence of voluntary compliance. A simple attempt to disaggregate the impacts of Regulations from the trends preceding and following their implementation might therefore be misleading.

The Control of the Hazards of Lead Pigment and Paint Production

It will be recalled from Chapters 4 and 5 that the regulatory strategy embodied in the Regulations for the use of lead paint did not conform to the regulatory strategy successfully applied by the Factory Inspectorate to other lead processes and particularly pigment and paint manufacture. An examination will therefore be made of the factors underlying the control of lead poisoning in these industries which will be compared with the situation in paint using industries.

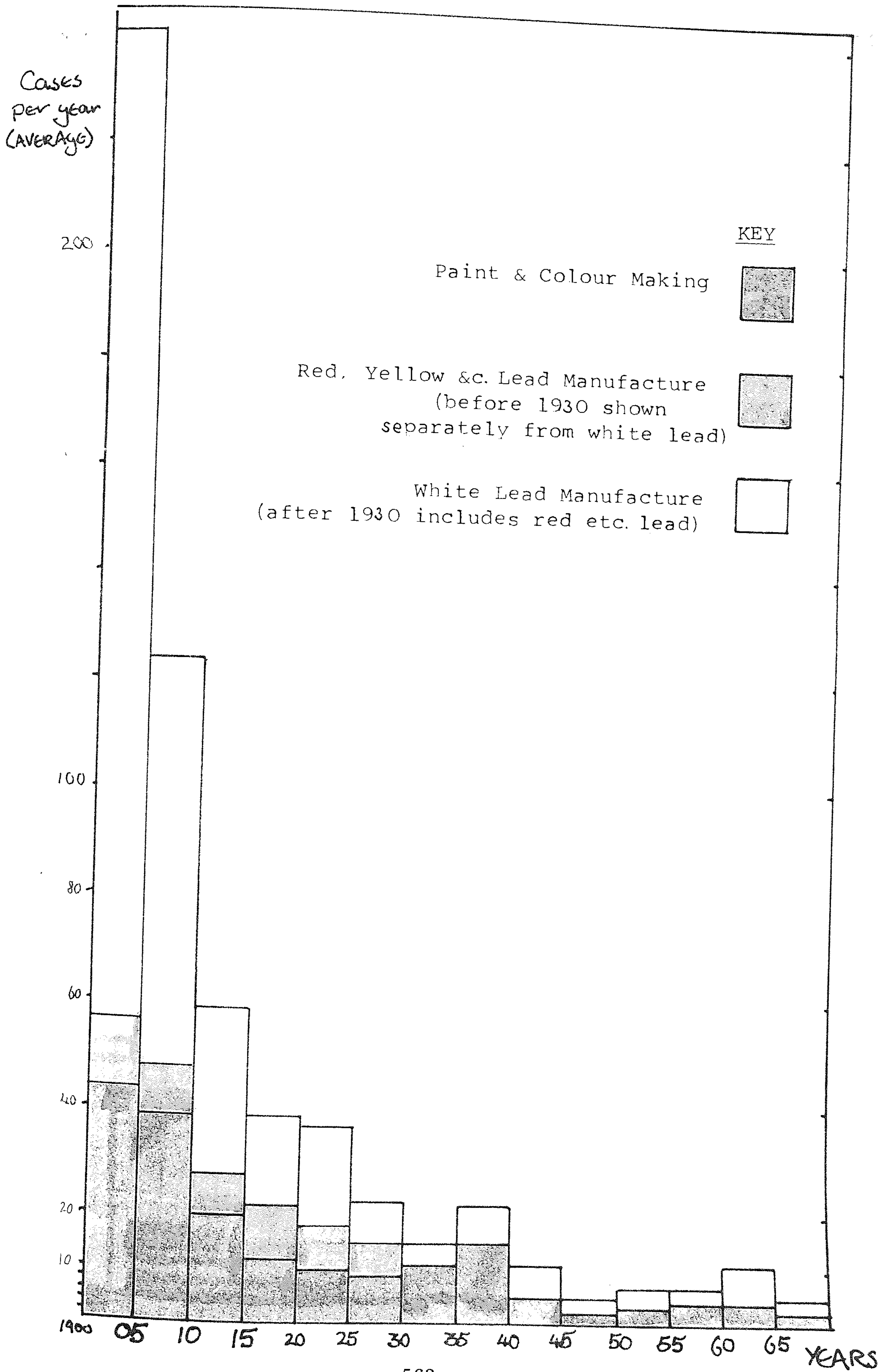
The number of cases of lead poisoning notified to H.M.F.I. from pigment and paint manufacture is shown in Figure 6-13 (5 year averages, 1900-1969, distinguishing paint making and white lead manufacture and red, yellow etc. manufacture - after 1930 white and red lead were not recorded separately). Figure 6-14 presents the same data for fatal lead poisoning (there were no deaths from red etc. lead manufacture between 1900 and 1930).

As noted above, the profile of lead poisoning in paint and pigment manufacture differs markedly from that in paint using industries. The incidence of poisoning is higher (reflecting the continuous exposure of a high proportion of manual workers to lead dust), but the proportion of lead poisoning cases that were fatal remains substantially lower for most of the period (reflecting the different arrangements for medical examination and notification in these industries).

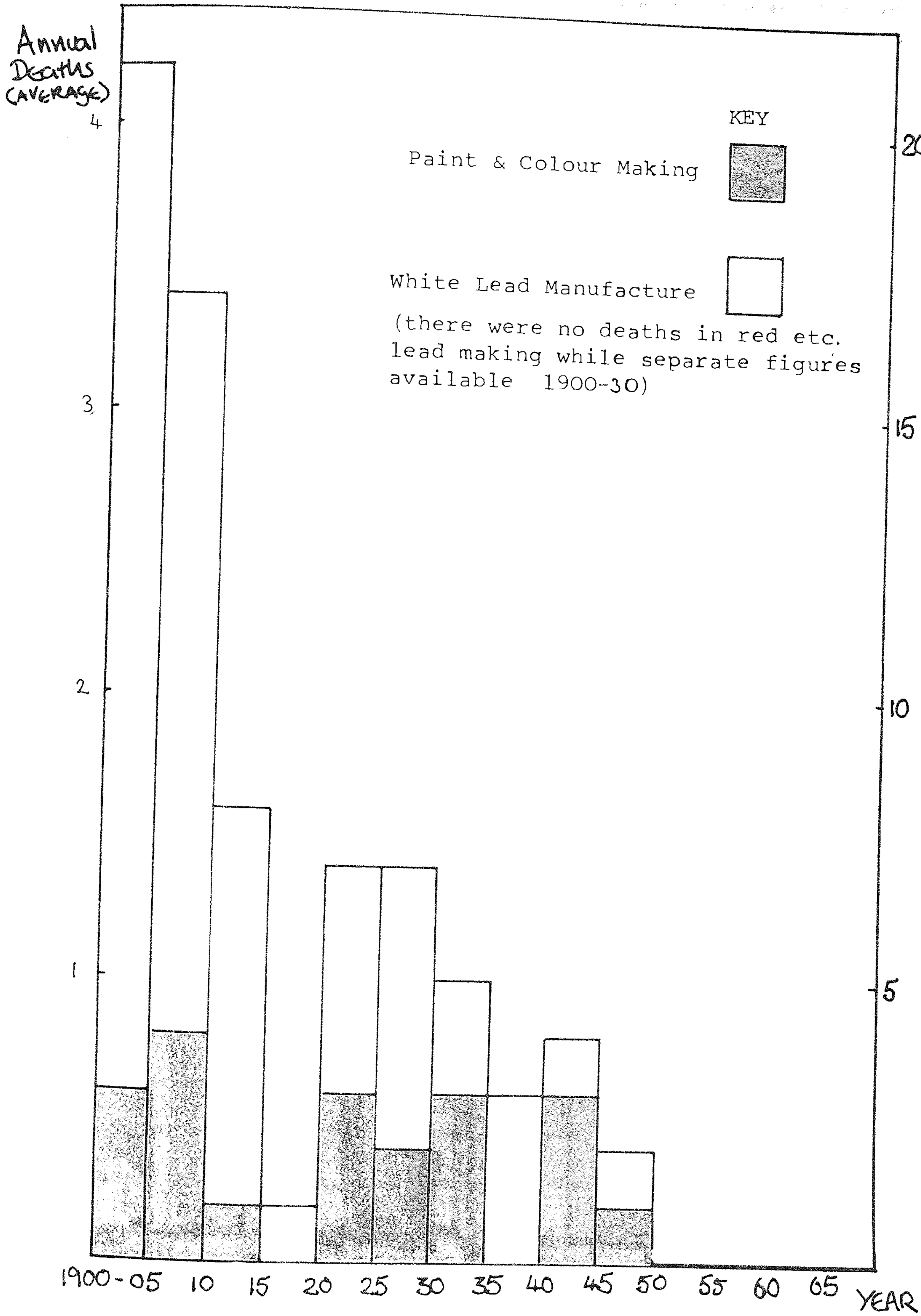
Paint and Pigment production had been subject to detailed state regulation under Special Rules since the 1890s, subsequently updated by Regulations. These were described in Chapter 4.

The level of lead poisoning amongst pigment and paint producers is falling very rapidly from the turn of the century, with a distribution that corresponds to an exponential decay over time. Paint, red etc. lead and white

Fig 8-15. CASES OF LEAD POISONING IN PIGMENT AND PAINT PRODUCTION - 5 YEAR AVERAGES 1900-1969
(Cases notified to H.M.F.I.)



PRODUCTION - 5 YEAR AVERAGES 1900-1969



lead manufacture show slightly different trends. There are also perturbations due to the First World War which are not relevant for this account. The two main industries, white lead and paint making, will therefore be examined separately.

White Lead Manufacture

This industry was exhibiting the most rapid reduction in lead poisoning, with the number of cases of notified poisoning falling 5.8-fold between 1900-1904 and 1910-1914. In the same period incidence of cases fell 6.7-fold, fatal poisoning fell 2.6-fold and cases classed as severe fell 11.9-fold.

Figure 6-15 shows the level of lead poisoning that occurred amongst white lead workers between 1900 and 1939 corrected for constant lead output, and for constant employment. This shows the reduction in lead poisoning that could be attributed to changes in the production technology and working methods of white lead manufacture. The difference between these two lines indicates the increasing productivity of white lead manufacture which rose from 22.4 tons per operative per year in 1907 to 23.3 in 1910 and 19.5 in 1930.

There is evidence of a change in the rate of reduction. Lead poisoning at constant white lead output falls by 23% p.a. between 1905-1909 and 1910-1914, by 3% p.a. between 1910-1914 and 1920-1924 and 9% p.a. between 1920-1924 and 1930-1934. However it is notable that the rate of reduction in the number of cases of lead poisoning observed in white lead making is more constant over this period : see Table 6-19. There is uncertainty about the extent of the changes in rate of control because the poisoning figures relate to five year periods whereas the output and employment figures relate to single years which may be exceptional. In addition it has been necessary to estimate the portion of cases of

Figure 6-15: Factors Underlying the Control of Lead Poisoning in White Lead Manufacture 1900-39.

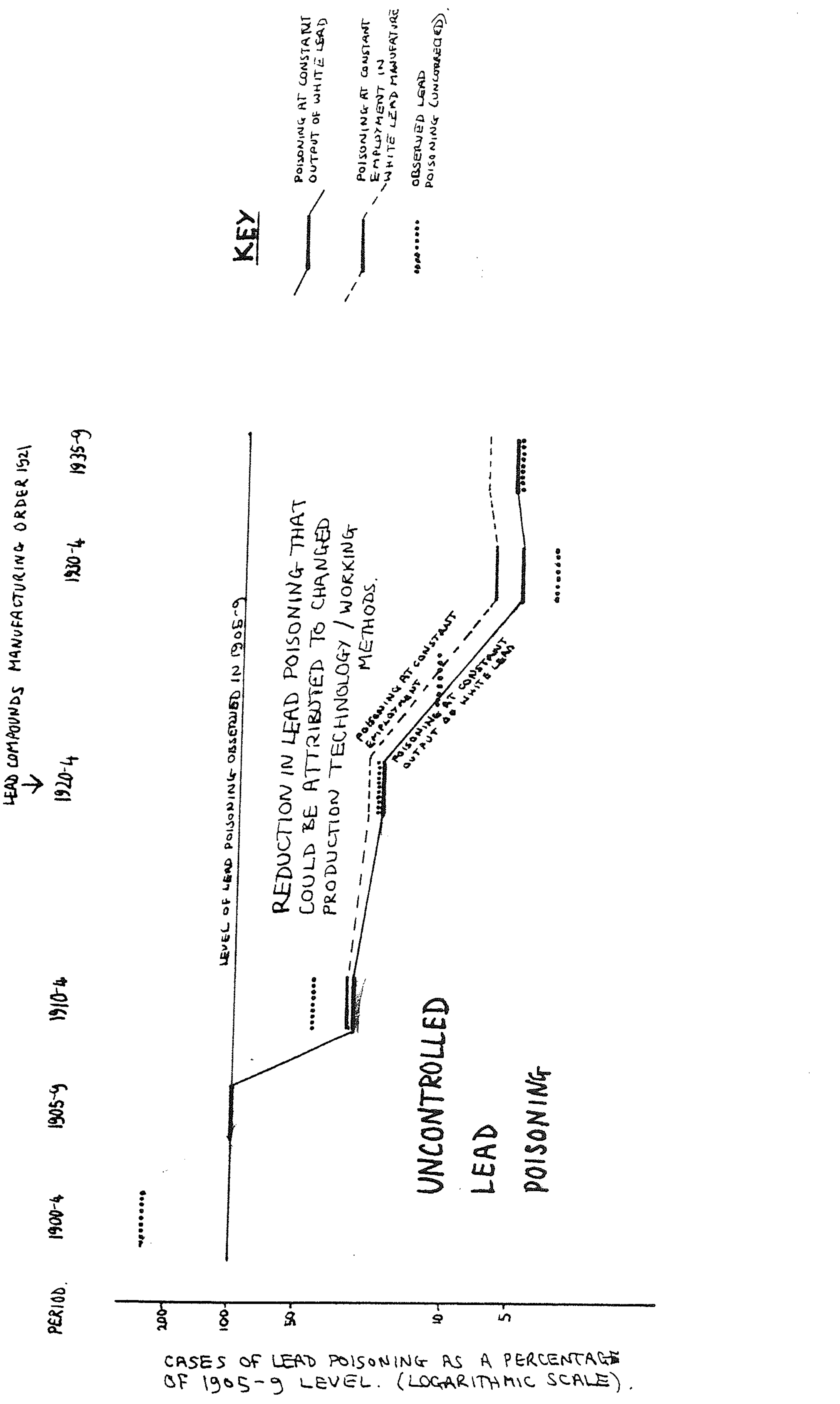


TABLE 6.19. <u>Rate of Reduction of Cases of Lead Poisoning in White Lead Manufacture 1900-1939</u>

Percentage Reduction in Cases of Lead Poisoning Per Year

Period	Observed Lead Poisoning	Lead Poisoning at Constant Output
1900-1904 to 1905-1909	16%	
1905-1909 to 1910-1914	16%	23%
1910-1914 to 1920-1924	6%	3%
{1910-1914 to 1915-1919	14%}	
{1915-1919 to 1920-1924	0%}	
1920-1924 to 1930-1934	17%	9%
{1920-1924 to 1925-1929	12%}	
{1925-1929 to 1930-1934	22%}	
1930-1934 to 1935-1939	9%	

Source : Table 6.4.

Prior to 1930, statistics for lead poisoning notified to H.M.F.I. distinguish poisoning in white lead manufacture from Red etc. lead manufacture. After 1930, these groups are aggregated. It has therefore been necessary to estimate the probable number of cases of poisoning arising in white lead manufacture for the periods 1930-1934 and 1935-1939. These are estimated graphically as 13 and 20 . respectively.

poisoning from white lead manufacturing for 1930-1934-1939 from the total for white and red etc. lead making for this period (estimated as 13 out of 20 for 1920-1924 and 20 out of 35 for 1935-1939).

The period with the greatest rate of reduction in lead poisoning, prior to 1914, coincided with the widespread adoption of damping in handling lead materials, the provision of ventilation of dusty processes and the mechanisation (in particular of the stoves used to dry the white lead) which, as was seen in Chapter 4, were stimulated by the Special Rules for white lead manufacture, but also coincided with the increased mechanisation and capitalisation of the industry. In addition the process of preparing white lead as a paste in oil directly from a water slurry (pulping - described in Chapter 4) was stimulated by Regulations for paint making in 1907. This method also conferred commercial advantages. Thus the most rapid control of the hazards of white lead manufacture was affected by the convergence of direct and indirect regulatory pressures, with the trends of commercial and technological development. The Factory Inspectorate had powers to exempt manufacturers from some of the regulatory requirements (e.g. for ventilation) where alternative methods (e.g. automating dusty processes) were adopted that were less hazardous. Pressures from the enforcement agencies were particularly effective in this highly centralised industry.[53] Though there is no direct data on these changes in equipment and methods, Factory Inspectorate returns show a reduction in the number of workers in lead processes (i.e. directly handling dry white lead) in white lead manufacture from 1,405 in 1911 down to 1,119 in 1914 : see Appendix B-6. Whilst this reduction in numbers might reflect a general contraction in white lead output, there are no figures or statements that would indicate that this had occurred.

Another important factor in controlling poisoning was the institution of periodic medical examinations.[54] These factors coincided to bring about the most rapid reduction in lead poisoning of all the industries involved in the manufacture and use of lead pigments (with a rate of control of lead hazards attributable to changes in technology/working methods in white lead manufacture more than twice that found in any period in the paint using industries).

This period of very rapid control of lead hazards is followed by a long period with a much slower rate of control - although some acceleration in rate of control is evident in the decade after the introduction of the 1921 Lead Compounds Manufacturing Order which brought the regulatory requirements for white lead manufacture 'up to date' but involved few specific additional requirements.

While deaths from manufacture of white lead cease by 1950, cases of poisoning from white and red etc. lead manufacture continue. Much of these may be due to lead chromate and red lead production which continued at higher levels than white lead. Indeed between 1950 and 1964 an upward trend in lead poisoning is apparent in lead pigment manufacture. In contrast to painting, in which lead poisoning disappears in the face of the reduced proportion of pigments used that were lead based, lead pigment production continued to pose a risk of lead poisoning which becomes more marked as the threshold of notification of poisoning falls.

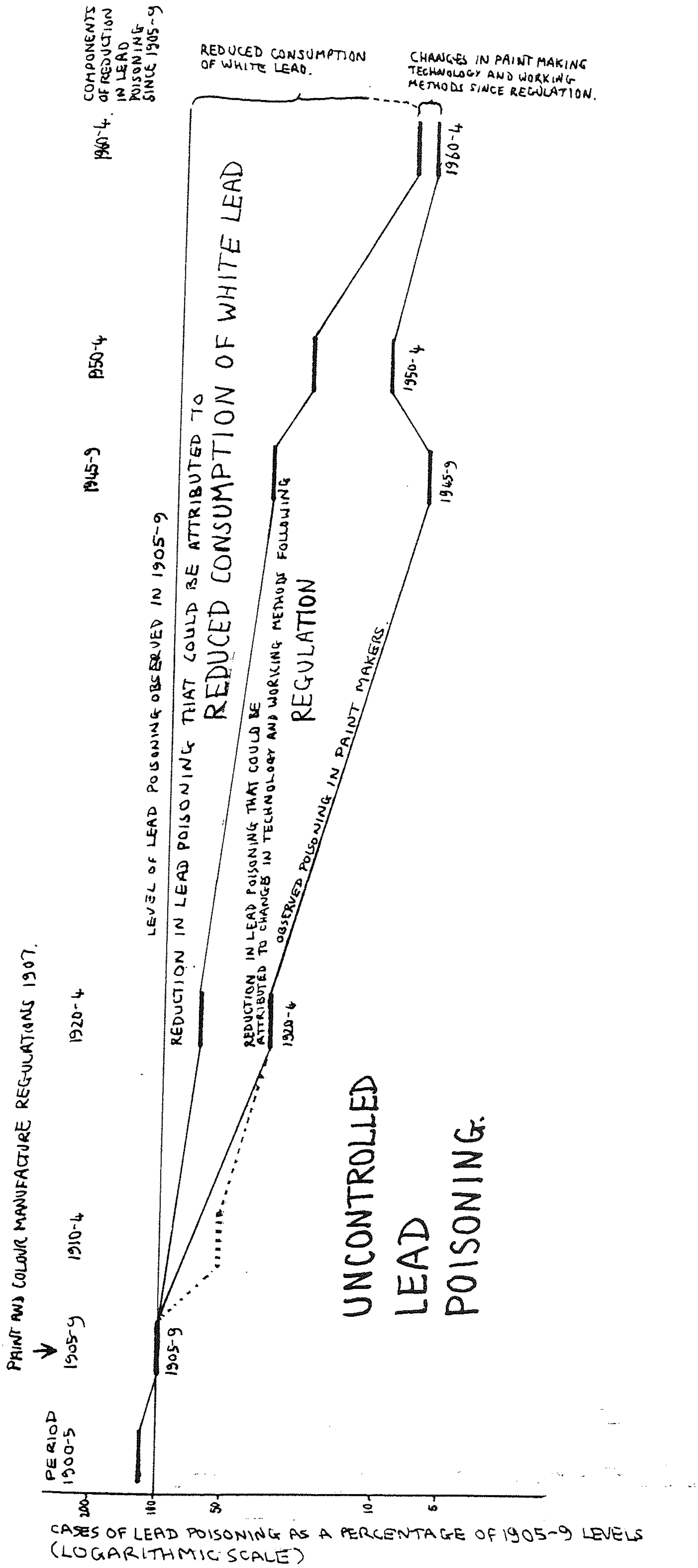
Paint Making

The level of lead poisoning that would be expected solely on the basis of reduced consumption of white lead in paint making since 1905-1909 has been calculated (using the same method adopted in the case of house and industrial painting). The results are shown in Table 6.20 and Figures 6-16 which also show the observed level of lead poisoning in paint making - the difference being attributable to changes in the technology and working practices since the introduction of the 1907 Paint and Colours Manufacture

TABLE 6.20. Predicted number of Cases of Lead Poisoning that would be expected amongst Paint Makers due solely to changes in the Consumption of White Lead in Paint

Period	Observed cases of Poisoning in Paint Makers	White Lead Consumption in Paints Thousand Tons	White Lead as a Percentage of combined white pigment consumption in paints	Number of cases of lead poisoning that wou[ld be] expected solely due to the reduction in wh[ite] lead consumption in paints since 1907: On the basis of the Reduction in tonnage of white lead consumed	On the basis of t[he] Reduction in whit[e] lead as proportio[n] paint pigments
1904-9	229				
1905-9	193	32	69%	(193)	(193)
1910-4	102				
1915-9	58				
1920-4	62	23	43%	138	119
1925-9	44				
1930-4	55				
1935-9	74				
1940-4	20				
1945-9	12	15	18%	91	51
1950-4	20	10	13%	60	36
1955-9	24				
1960-4	16	4	04%	24	9
1965-9	12				
1970-4	4				

Figure 6-16: Factors Underlying the Control of Lead Poisoning in Paint Making 1900-64.



Regulations. There is a rapid reduction in lead poisoning observed following these Regulations (12% reduction p.a. between 1905-1909 and 1910-1914). The slower rate of reduction in lead poisoning in the subsequent 50 years (averaging 4% per year) is marked by frequent increases in the number of cases of poisoning between successive five year periods (between 1925-1929, 1930-1934, 1935-1939 and between 1945-1949, 1950-1954, 1955-1959 - see Figure 6-18). The reduction in lead poisoning attributable to changes in paint making technology and working methods is slow - 5% per year over the period 1905-1909 and 1920-1924 and 7% per year between 1920-1924 and 1945-1949. The apparent contraction in the reduction of lead poisoning attributable to changes in paint making methods/technology after 1945-1949 is presumed to be an artefact caused by the continued consumption of lead pigments other than white lead (i.e. red lead, lead chromate, calcium plumbate etc.) in paints. These contributed towards lead poisoning although excluded from the estimate of the level of poisoning expected on the basis of (white) lead pigment consumption, which must be seen as inflated especially in later years. Thus 15 out of 31 cases of lead poisoning in paint works between 1945 and 1954 were attributed to use of lead chromate pigment rather than white lead. (Fourteen of these arose between 1951 and 1954).[55]

In addition, the upward trends observed in lead poisoning in this period are probably a reflection of changes in the threshold of diagnosis/notification of lead poisoning. The high rate of reduction of lead poisoning observed in paint making between 1905-1909 and 1910-1914 would appear to be a result of the 1907 Paint and Colour Regulations. The slower rate of reduction of lead poisoning attributable to changes in paint making technology and methods after 1914 contrasts sharply with the situation in white lead manufacture. It would appear that the impact of regulation and commercial-technological development on lead poisoning was less marked in paint making than white lead manufacture. The reasons for this difference will be reviewed below.

The output of the paint making industry was growing rapidly in this period, initially by extensive growth (employment trebled between 1901 and 1921 while output per head remained largely static) and subsequently by intensive growth (employment approximately constant, increase in output achieved by increasing labour productivity). See Figure 2-1(a). The process of industrial concentration was offset by the creation of new paint firms with the result that the number of paint works remained high (351 works recorded in 1904, 397 in 1968). The bulk of technological change in the paint making industry comprised the utilisation of new materials (see Chapter 2). The physical activities of the industry remained relatively straightforward - the mixing and packaging of these materials. Since the original mechanisation of paint mixing, when the pigment was dispersed in the vehicle by passing it through steel rollers (roller mills), several generations of dispersal equipment have been introduced into paint making - namely ball (or pebble) mills, sand (or glass bead) mills developed in the 1950s and subsequently 'high speed mixers' (dispersal achieved by a rapidly rotating serrated disc). These have increased the rate of paint mixing by higher energy input, more efficient dispersal techniques, economies of scale and latterly, moves towards continuous production. Further increases in productivity have been achieved by bulk transfer/storage of liquid ingredients and the computerisation of control of paint composition (colour, viscosity etc.) [56]

The focusing of technological change in paint making equipment on a particular phase of production is a corollary of the narrow range of activities in paint making. This change was concentrated on only one aspect of paint making that posed a risk of exposure to lead dust. The other process liable to generate lead dust (potentially in greater quantities than paint mixing), of handling the loose pigment (especially in dry form), was not cited in the literature as being the site of substantial technological change as part of the commercial development of the paint industry. Any improvement of ventilation and enclosure of this aspect of paint mixing would appear to be related primarily to concern about hazard and regulation.

Comparison between factors in the Control of Hazards in White Lead Manufacture and Paint Making

The greater rate of reduction of lead poisoning due to changes in technology and working methods in white lead manufacture than paint making can be related to differences in the nature of regulatory pressures given the structure of the industry and the nature of the hazardous processes involved and the ways they were affected by the commercial/technological development of the industry.

i) The Paint and Colour Regulations 1907 were the shortest and least detailed of the Regulations and Special Rules applied to pigment and paint manufacture (the main Regulations applying to the handling of dry lead pigments and to roller mills). In contrast the white lead industry was subject to very detailed, specific requirements developed over an extended period of regulation and had further discretionary powers for Factory Inspectors to approve additional changes (See Chapter 4.), thereby giving greater scope for pressure from the Factory Inspectorate.

ii) The paint making industry was in a state of flux, and was highly dispersed, with 351 works in 1904 recorded employing an average of 16 workers each. In contrast the white lead industry was static and heavily and increasingly concentrated, with 27 works employing an average of 68 workers. The structure of the white lead industry thereby made it easier to inspect thereby encouraging both effective enforcement of existing Regulations and the application of informal regulatory pressures to adopt additional controls.

iii) Only two of the processes in paint making posed particular risk of exposure to lead dust. In contrast, most of the processes in white lead manufacture involved potential exposure to lead dust. (As a consequence of this, 56½% of white lead workers were classed as involved in lead processes in 1911 compared to 14½% of paint and colour workers - see Appendix B-6). The incidence of lead poisoning in white lead works was therefore substantially greater than paint making at the turn of the century, as was the scope for control of lead poisoning.

iv) The technological change in paint making directed towards increasing productivity was concentrated on one aspect of its activities - paint mixing. This affected only one of the lead processes in paint making (and arguably the least hazardous one). Technological change in the other lead process (application of ventilation/enclosure to handling the dry pigment) was primarily due to concern about hazards. In contrast technological change in white lead manufacture involved the full range of its activities and affected most of its lead processes, including the introduction of new methods of preparation of white lead, mechanisation of materials handling and in particular the extraction of the white lead from its water slurry. These changes had a direct effect on the numbers exposed to white lead by reducing the number of workers needed and by eliminating their need for contact with dusty processes. In addition the mechanisation and structural changes facilitated the enclosure and ventilation of lead processes. The centrality of lead processes to white lead manufacture resulted in the convergence of commercial factors and concern about health in the technological development of the industry.

v) Finally, it is notable that white lead manufacture achieved a higher rate of growth of labour productivity between 1907 and 1930 than paint making, 32% compared to 21% (see Figure 6-17). While figures for capital investment in white lead manufacture are not available, the rate of investment (relative to sales) in paint making was significantly lower than in the chemical industry (see Figure 2-1(b)).

Comparison between Pigment/Paint Making and Paint Use

Precise comparison between the pattern of control between these two groupings is hindered by the differing relationship between the indicators of harm - the statistics for lead poisoning notified to H.M.F.I. As Figure 6-4 showed, the proportion of cases of lead poisoning classed as severe was falling more rapidly in pigment/paint manufacture than in industrial painters. The relationship between the figures for deaths and cases of lead poisoning as shown in Figure 6-3, differs between pigment/paint production and industrial painting, with fatal poisoning accounting for a much higher proportion of the latter. However this relationship also changes over time. This complex pattern is a consequence of the characteristics of exposure to lead and its control, medical monitoring of workers in paint/pigment making and the varying degree of notification of lead poisoning.

The trends in lead poisoning in pigment/paint manufacture and house and industrial painting have been illustrated in Figure 6-18 (cases of lead

White Lead and Paint Making Industries since 1907.

Output of White Lead (tons per employee)

Value of Net Output per employee of the Paint and Varnish Industry (£ per employee adjusted to 1963 values).

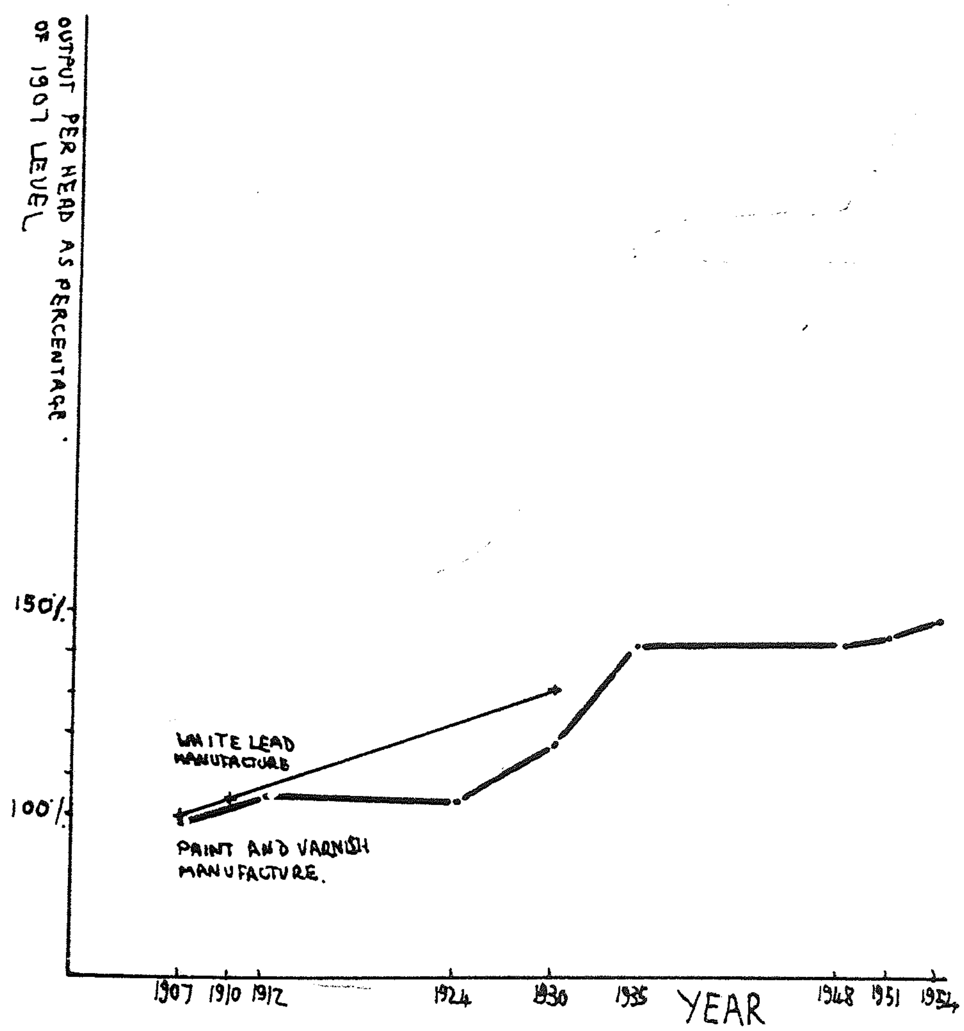


Figure 6-18: Cases of Lead Poisoning in Pigment and Paint Making and Paint Use (Relative to levels in 1905-9, logarithmic scale) 1900-64.

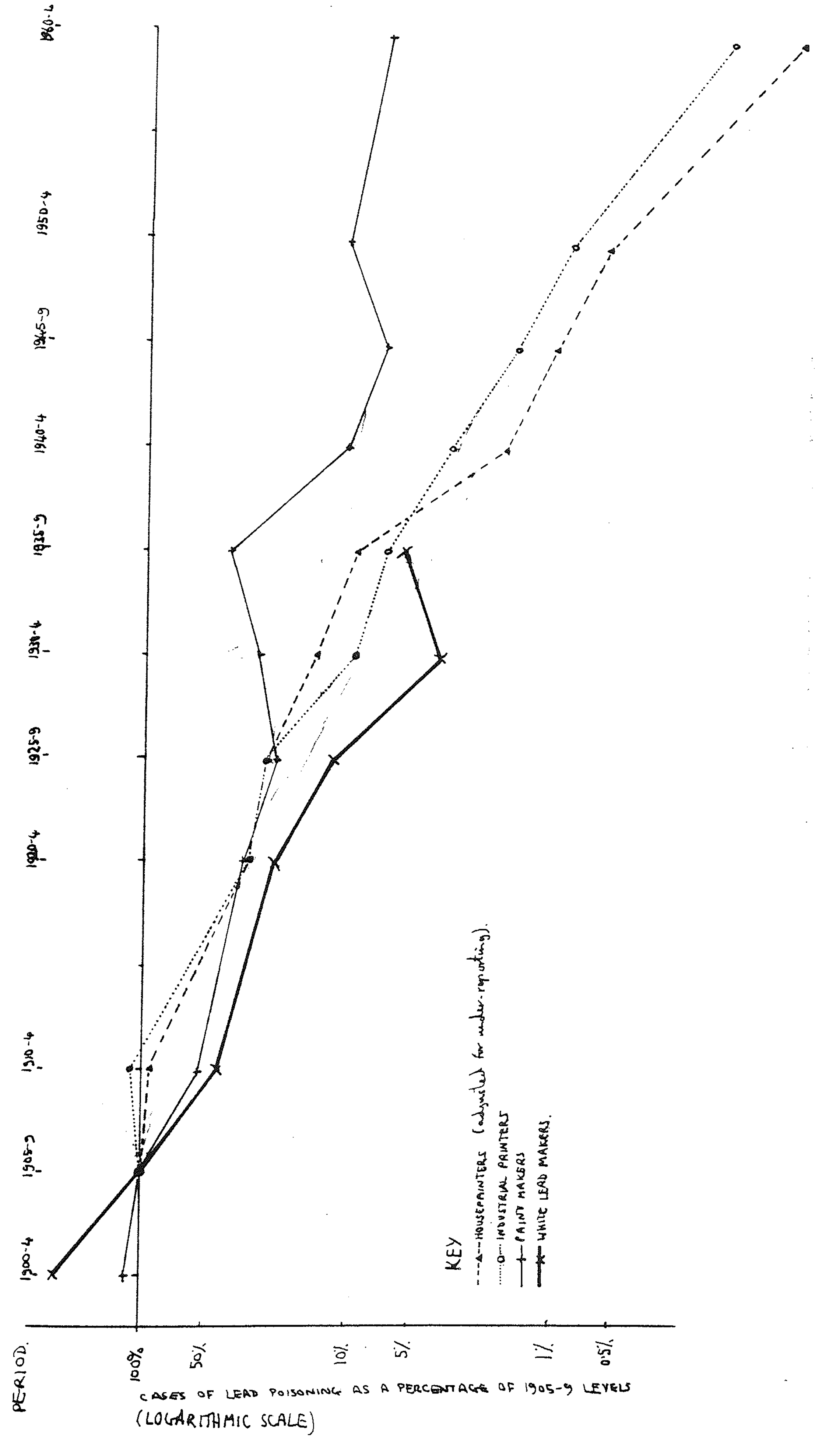
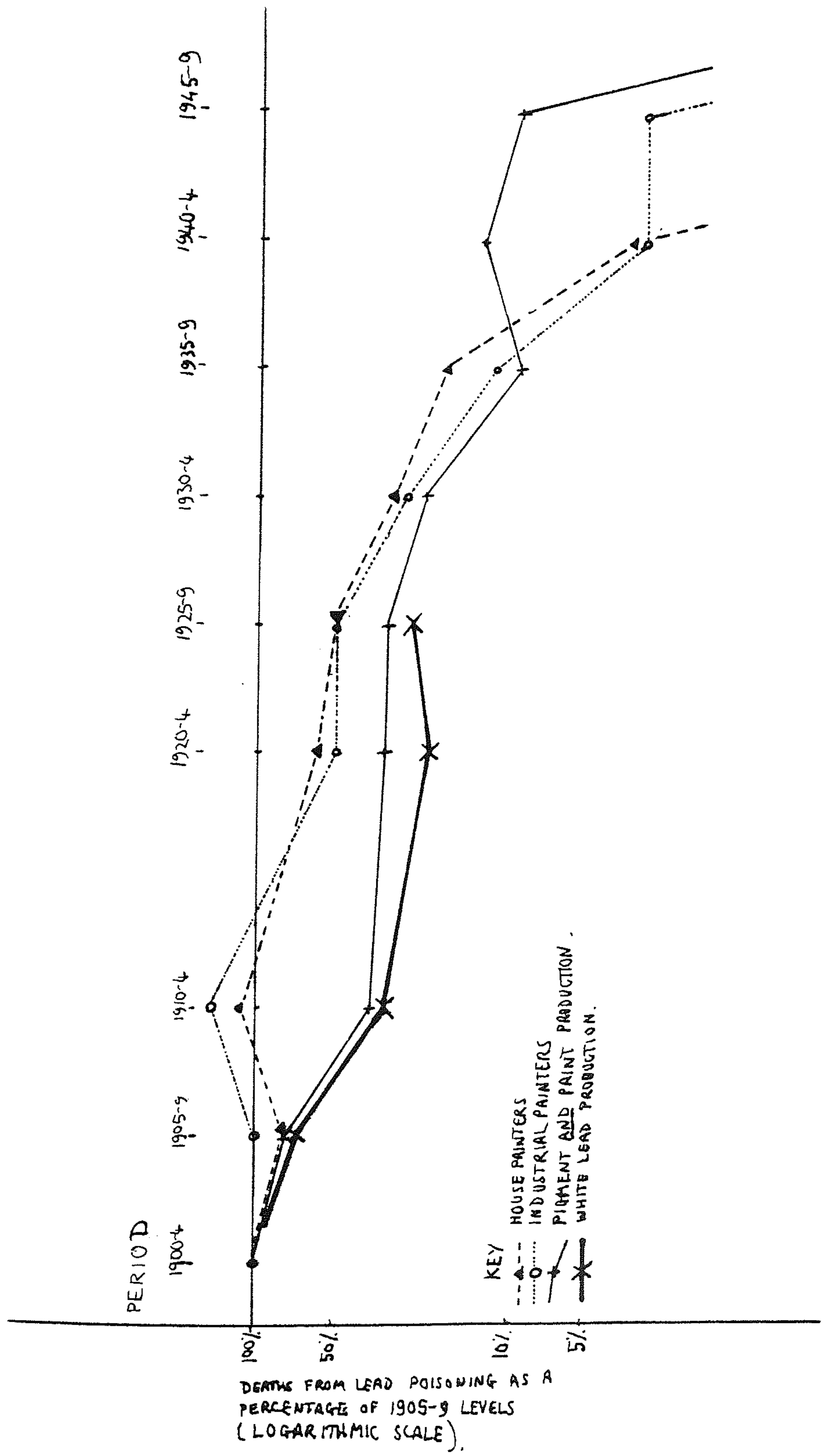


Figure 6-19: Deaths from Lead Poisoning in Pigment and Paint Making and Paint Use (relative to 1900-4 levels, logarithmic scale) 1900-49.



poisoning) and 6-19 (deaths from lead poisoning) by plotting on a logarithmic scale the level of poisoning relative to 1905-1909 and 1900-1904 respectively. It has not been possible to plot deaths from paint making because of the small numbers involved. Deaths have been plotted for all paint/pigment production together and for white lead manufacture till 1929. The rate of reduction of deaths in paint making, notwithstanding the high degree of variation, appears to be low (relative to both deaths in other industries and to other indices of poisoning in paint making).

There is an apparent slowing down in the rate of reduction of lead poisoning in paint and pigment production in later years, while poisoning in painters continues to fall at an unabated or increasing rate. This cannot be explained in terms of consumption of lead in paints since the output of paint makers constituted the bulk of materials consumed in paint use. It would also be misleading to attribute this divergence in trends simply to different patterns of control of lead exposure. Changes in the practice of notifying lead poisoning may also have been at work. In particular :

i) A differential change in either the criteria or completeness of notification of lead poisoning between pigment/lead production and paint use - with notification at a given degree of harm increasing amongst paint and pigment makers relative to users. The mechanism of this change might be the adoption of broader criteria of notification of lead poisoning in pigment/paint production due to the requirements for periodic medical examination in these industries (not required in paint use) or alternatively a falling off of completeness of notification as cases of poisoning become more sporadic - this would be more marked in paint use than paint production due to its lower incidence of lead poisoning.

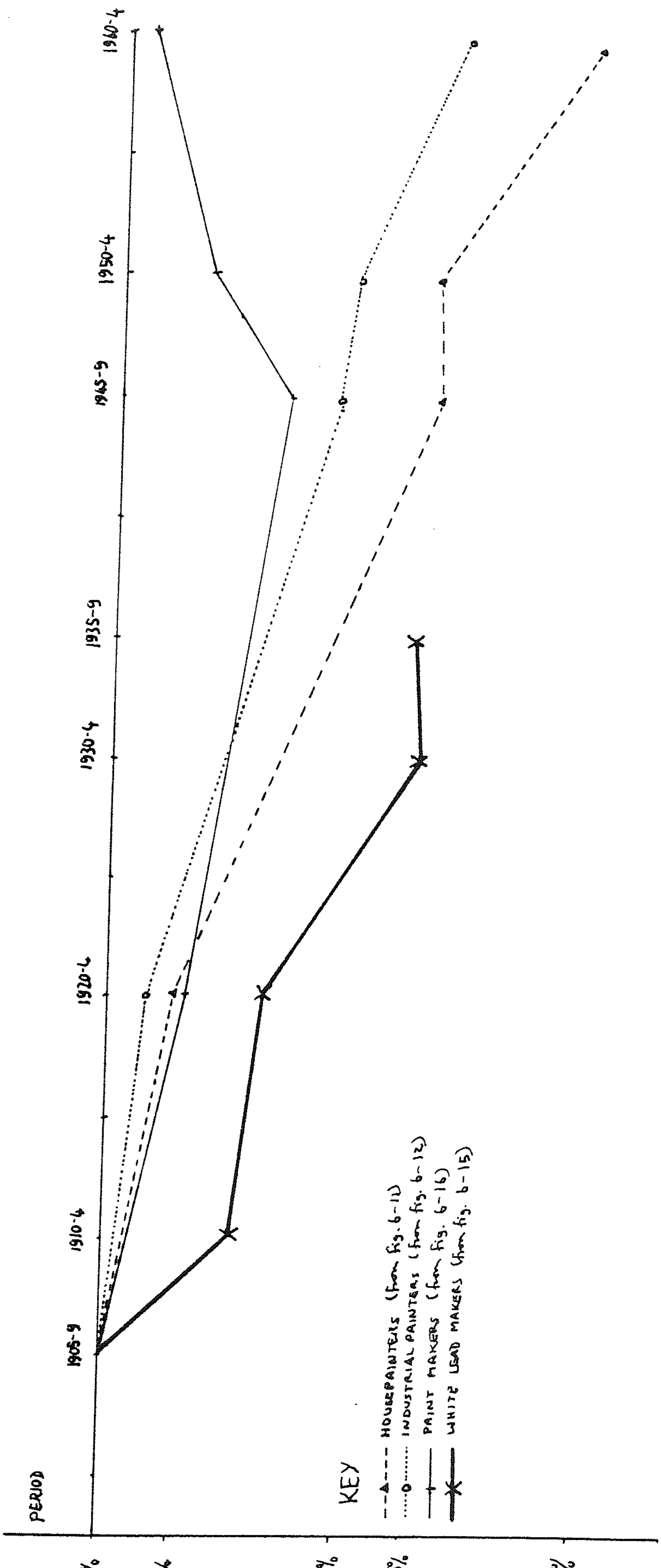
ii) The existence of thresholds of lead absorption required to cause a given degree of harm might result in a certain reduction in lead exposure giving rise to a greater reduction in harm/lead poisoning amongst paint users than amongst pigment/paint producers. In paint use, where the incidence of lead poisoning, and presumably level of lead absorption, was lower than in pigment/paint production, application of additional controls on lead exposure, whether due to changes in technology or materials used might produce a greater reduction in recorded poisoning by reducing lead absorption below the threshold needed to cause a given degree of harm.

Figure 6-20 summarises the estimates from Figures 6-11, 6-12, 6-15 and 6-16 of the reduction in cases of lead poisoning that could be attributed to 'technological control' - changes in technology and working methods - since 1905-1909 in house and industrial painting, white lead manufacture and paint making. It is suggested that the 'levelling off' and reduction of the estimates of control attributable to changes in technology/working methods in the case of pigment and paint manufacture is an artefact due to the differences in notification and 'threshold' effects described above.

Figure 6-20 shows that the rate of 'technological control' of lead poisoning in white lead manufacture is initially substantially faster than the other industries - a fact which can be attributed to the convergence of regulatory pressures and commercial technological development described above. Technological control of lead poisoning in paint making is only slightly greater than that in painting. Moreover, it would appear from the previous examination of this industry that the bulk of this initial control took place in the period immediately after the Paint and Colour Regulations and was followed by a period with a much slower rate of control.

Reduction in Lead Poisoning Attributable to Changes in technology and working methods in White Lead Manufacture, Paint Making, and House and Industrial Painting 1905-64.

(from figs. 6 - 11,12,15 and 16.)



REDUCTION SINCE 1905-9 IN CASES OF LEAD POISONING THAT COULD BE ATTRIBUTED TO CHANGES IN TECHNOLOGY AND WORKING METHODS (RELATIVE TO 1905-9 LEVELS OF POISONING — LOGARITHMIC SCALE).

The sustained rate of control of lead poisoning in painting due to changes in methods/technology of painting is remarkable. It will be recalled that the Factory Inspectorate had been highly sceptical about the effectiveness of a regulatory strategy for painting based on changes in working methods (Regulation) compared to their regulatory strategy based on the application of 'engineering controls' to factory processes. (See Chapter 4). Whilst not all of the 'technological control' of painting hazards was a consequence of changes in working methods due to regulation and concern about the hazard of lead poisoning, these must have played a major role.

Changes in painting technology and working practices attributable to commercial rather than health considerations that might have contributed to the reduction in lead poisoning in industrial painters are myriad and were extensively reviewed in Chapter 2. Such changes taking place amongst house painters in this period include the following :

i) the adoption of new paint vehicles, particularly after the Second World War, and the use of lead in combination with pigments with a higher hiding power. These changes in paint formulation led to paints which could be applied in greater thicknesses (requiring fewer coats), with less brush work (due to better consistency control) and, most importantly, that did not show brush marks as much as white lead/linseed oil based paints, thereby reducing the need for sanding the freshly painted surface between coats.

ii) increasing quantities of paints applied by the consumer.

iii) a factor which it has not been possible to adjust for is the falling lead concentration of lead in old paints which had to be removed prior to repainting.

The rate of 'technological control' in painting following the introduction of Regulations on paint use is approximately the same as that for paint making and about one third of that found in white lead manufacture.

Comparison of the Rate of Control of Lead Hazards in Paint and other Industries

In order to obtain a broader assessment of the observations about the rate of control of lead poisoning in pigment/paint production and paint use, a brief comparison was made with the control of lead poisoning in other industries/processes not connected with painting. Figure 6-21 shows the number of cases of poisoning notified to H.M.F.I. in the main factory lead processes other than paint/pigment production and use showing separately :

a) those industries subject to specific Regulations on lead hazards (Smelting of Metals, Pottery, Electric Accumulators), and

b) those industries not covered by specific Regulations (Printing and Other Industries).

These figures are for five year periods between 1900 and 1944. Though the Factory Inspectorate returns cover other lead processes/industries, they cannot be included in this comparison because of changes in categorisation during this period (the exception here is 'other industries' in which it is possible to reconcile earlier and later categories and thereby calculate a rate of reduction for the whole period in poisoning in this industry grouping).

The same data have been plotted on a logarithmic scale in Figure 6-22 a) and b) to show the number of cases of lead poisoning relative to 1905-1909 levels (on the same format as Figure 6-18). The increase in lead poisoning in the electric accumulator industry reflects the rapid increase in size of this industry in line with the growth of the motor industry. The main factor in the control of lead poisoning in these industries is

Figure 6-21(a): Cases of Lead Poisoning in Major Lead Industries other than Paint Production and Use 1900-44.

a) Industries Subject to specific Regulations.

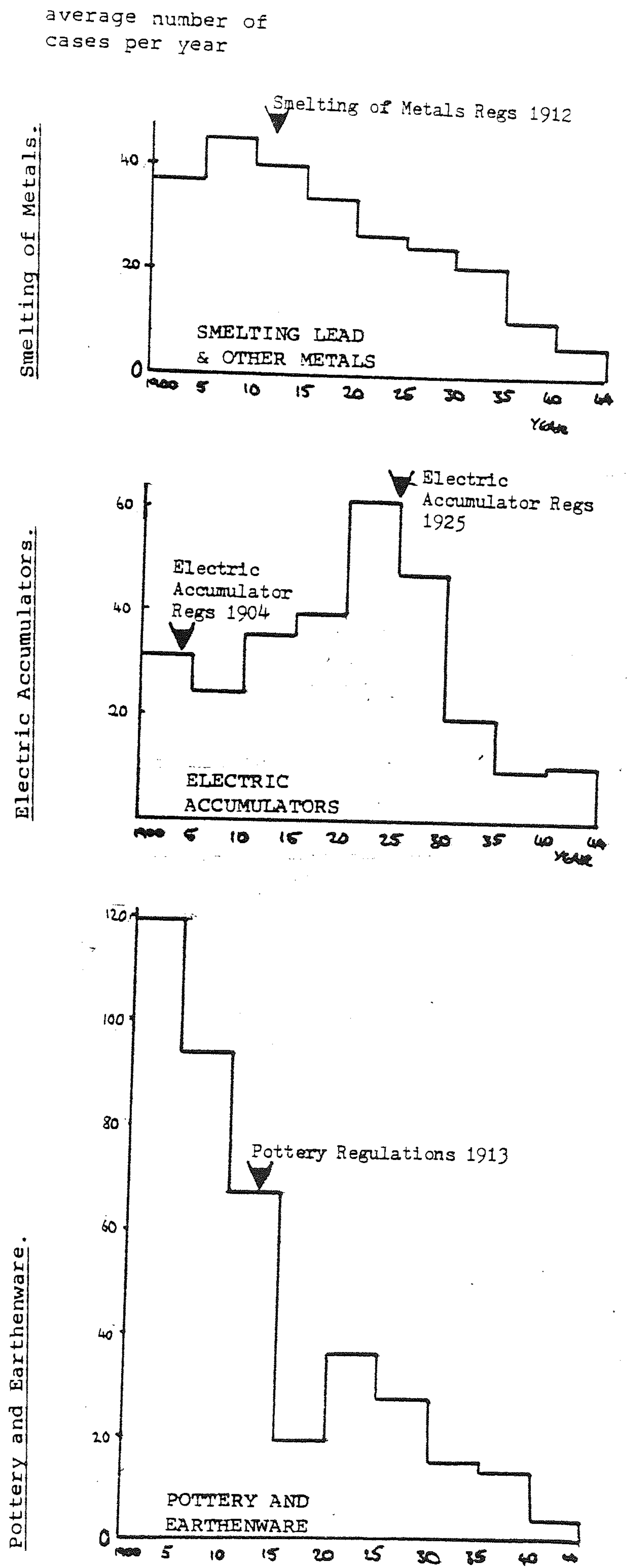
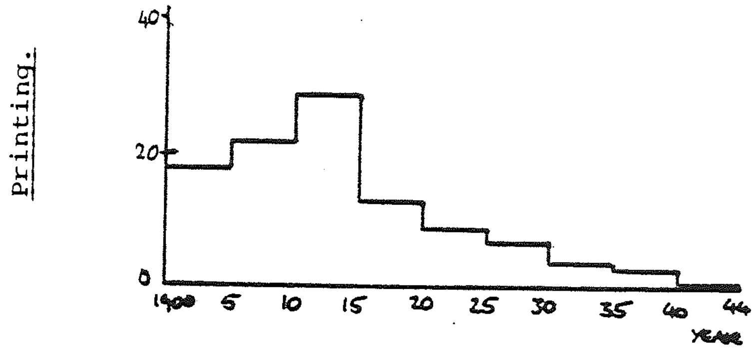


Figure 6-21(b): Cases of Lead Poisoning in Major Lead Industries other than Paint Production and Use 1900 - 44.

b) Industries not subject to specific Regulations

average number of
cases per year

PRINTING



'OTHER INDUSTRIES'

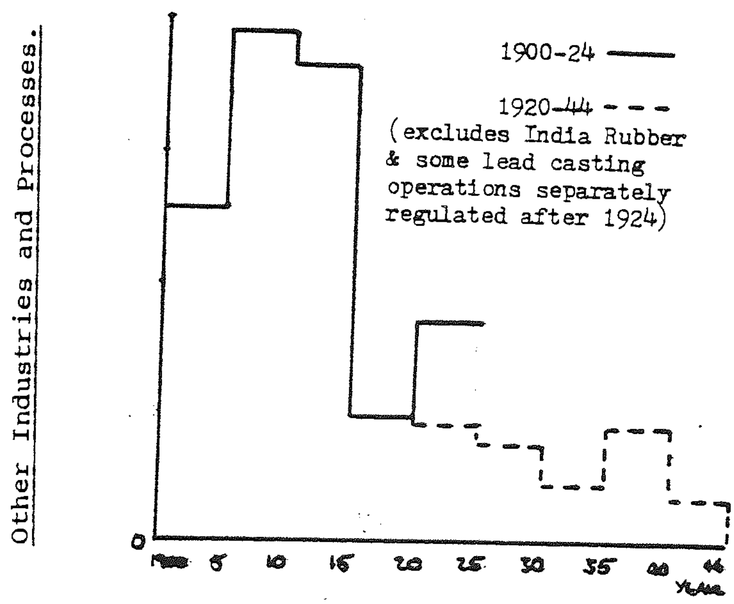


Figure 6-22(a): Cases of Lead Poisoning in Major Lead Industries Other than Paint Production and Use (Relative to levels in 1905-9, logarithmic scale) 1905-44.

a) Industries subject to specific Regulations.

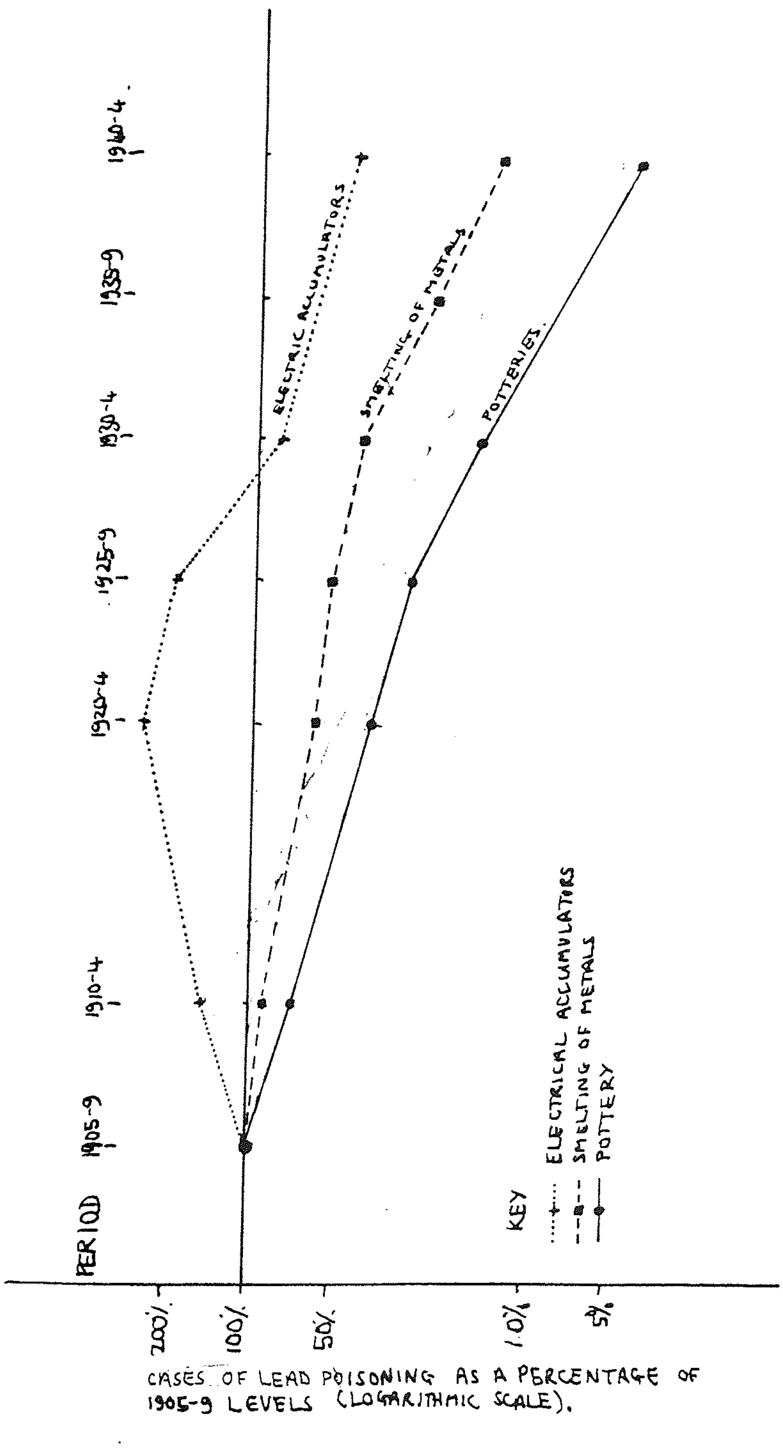
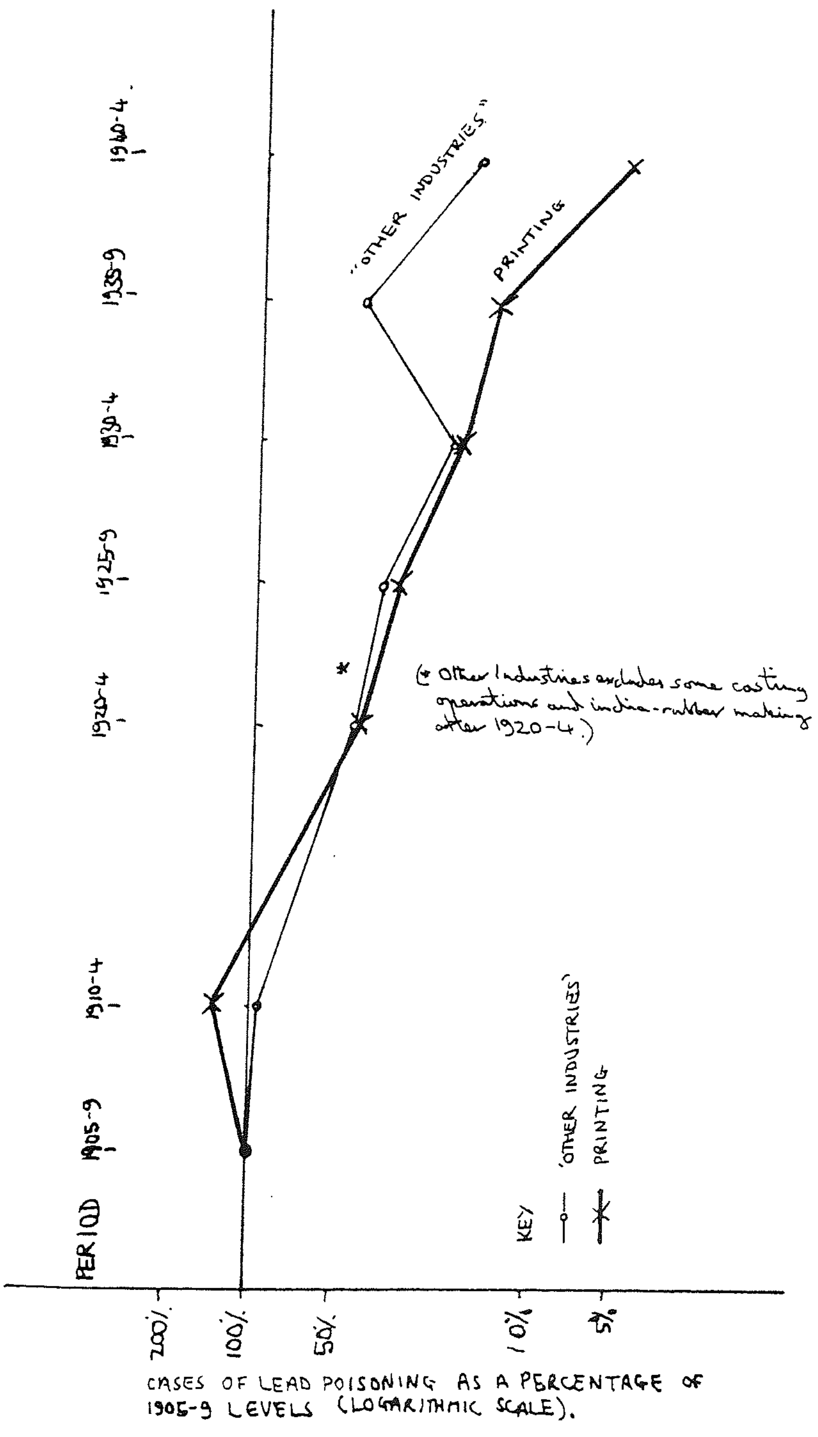


Figure 6-22(b): Cases of Lead Poisoning in Major Lead Industries Other than Paint Production and Use (Relative to levels in 1905-9, logarithmic scale) 1905-44.

b) Industries not subject to Regulations.



probably changes in technology/methods of working (rather than in materials consumption).

The most striking observation from this comparison is that the rate of reduction of lead poisoning in these industries is broadly similar. Industries not subject to specific Regulations show a rate of reduction in lead poisoning that is equal to or greater than that in industries subject to specific Regulations. The circumstances under which this control was being effected may have been somewhat different in industries not subject to Regulations - for example, Printing gave rise to a relatively small number of total cases of poisoning and had the lowest incidence of lead poisoning of all the lead processes distinguished by the H.M.F.I.

The incidence (1900-1913) and rate of control (1905-1909 to 1920-1924 and 1920-1924 to 1940-1944) of cases of lead poisoning in all these lead industries is shown in Table 6.21. In the case of paint making and use in which substitution of lead pigments played a major role, the rate of control of lead poisoning due to changes in technology/working methods (i.e. eliminating the effects of substitution of lead) is shown (for the periods 1900-1909 to 1920-1924 and 1920-1924 to 1945-1949). These were considered to provide a more appropriate basis for comparison with other industries. These figures are shown in Figure 6-23 with incidence plotted against the rate of control of lead poisoning.

Figure 6-23 in many ways reflects the whole history of regulation, both its political and technical aspects. Thus the industries with the highest incidence of lead poisoning between 1900-1913 show the highest rate of control between 1905-1909 and 1920-1924, reflecting their earlier and more stringent regulation etc.

In the 1920-1924 to 1940-1944 period, a different trend is noticeable. The highest rates of control of lead poisoning are associated with those

TABLE 6.21. Lead Poisoning in Major Lead Industries and Processes: Incidence of Lead Poisoning 1900-13, Rate of Reduction in Cases of Lead Poisoning 1905/9 to 1920/4 and 1940/4, and Rate of Reduction Attributable to changed Technology 1905/9 to 1920/4 and 1920/4 to 1945/9

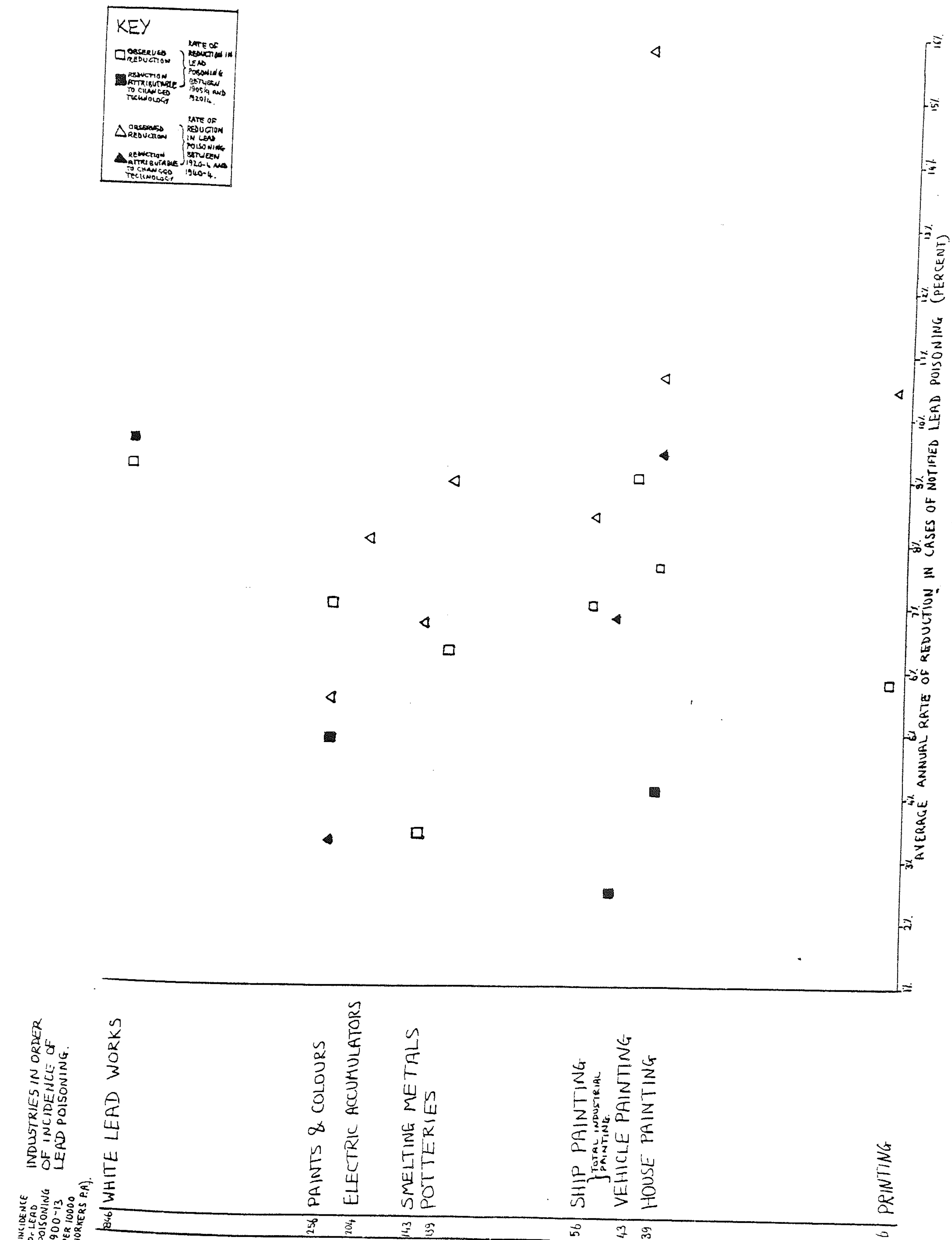
Industry	Incidence of Lead Poisoning 1900-13. (Cases Notified p.a. per 10,000 workers employed in lead processes 1911-14)	Average Annual Rate of Reduction in Number of Notified Cases of Lead Poisoning : 1905/9-1920/4 Percentage	1920/4-1940/4 Percentage	Rate of Reduction in Lead Poisoning Attributable to Changed Technology/Working Methods : 1905/9-1920/4 Percentage	1920/4-1945/9 Percentage
White Lead	846 +	9.1		9.5	
Paint Making	256 +	7	5.5	4.9	3.3
Electric Accumulators	204 +	-	8		
Smelting Metals	143 +	3.4	6.7		
Potteries	139 +	6.3	8.9		
Ship Painting	56 *	7	8.5		
Vehicle Painting	43 *	9	15.7		
Total Industry Painting		7.6	10.6	2.5	6.8
Housepainting (observed 12) Adjusted for under notification	39 *	7.6	9.3	4.1	9.4
Printing	6 +	5.8	10.4		

\+ Calculated by H.M.F.I. from numbers employed in lead process in 1913. G.B.Departmental Committee [Cd.7882], 1915, op.cit. p.79.

* Calculated for year 1900-1914 using employment data for 1911 from Appendix B-6.

23: **Rate of Reduction in Cases of Lead Poisoning Plotted Against Incidence of Lead Poisoning in Major Lead Industries.**

showing rate of reduction in HMFI notified cases of lead poisoning (percentage reduction per year) for the periods 1905/9 to 1920/4, (□) and 1920/4 to 1940/4 (△), and rate of reduction attributable to changed technology/working methods (in pigment & paint production and use only - percentage reduction per year) for the periods 1905/9 to 1920/4 (■) and 1920/4 to 1945/9 (▲). plotted against average incidence of lead poisoning per 10,000 workers in lead processes over the period 1900 to 1913/4.



industries which had the lowest incidence of poisoning in 1900-1913. Partly this may reflect the later introduction of Regulations for these industries (in the case of paint use in particular). However this group also includes industries not subject to specific Regulations: ship painting, printing and paint in other industries and other lead industries (the latter processes not shown because of the problems of assessing incidence). These high rates of reduction in poisoning are associated with the virtual elimination of lead poisoning in those industries with low poisoning incidence. They would appear to confirm the earlier suggestions of some kind of 'threshold effect' operating to facilitate reduction in recorded poisoning in such industries.

The most significant finding from this comparison regards the importance of informal pressures in controlling lead poisoning. High rates of reduction in lead poisoning are observable in those industries not subject to specific Regulations. The industries which were subject to specific Regulations prior to 1920-1924 typically exhibit a higher rate of control in the later than the earlier period. Assuming that compliance with these Regulations was achieved fairly rapidly, the acceleration in control would appear to be a consequence of the adoption of more stringent control measures (either by a more stringent interpretation of these Regulations or by the adoption of controls over and above those specifically required). This conclusion must not be taken as implying a lack of effectivity of Regulations. It will be recalled that prior to the introduction of the first wave of Special Rules and Regulations in the period 1890-1910, recorded lead poisoning was increasing across all sectors of industry. Instead, the introduction of specific Regulations must be seen as establishing standards which had a more general impact on industry, through informal regulatory pressures by the state enforcement agencies (under the general provisions of the Factory Acts etc.) as well as broader social pressures including trade unions, professional/engineering bodies/ standards etc.

The control of lead poisoning in white lead manufacture (and the pottery industry - although this is not fully represented in Figure 6-23 since the bulk of control took place between 1896 and 1905) represents a somewhat exceptional case, where very high rates of reduction in lead poisoning was a direct result of Special Rules and Regulations. These must be seen as setting a precedent for subsequent control in other industries.

'Voluntary control' (i.e. control prior to the introduction of specific Regulations) and informal regulation (e.g. control in paint using industries not subject to specific Regulations) appear to have been as significant as the direct impacts of Specific Regulations in effecting this reduction in lead poisoning.

The precise extrapolation of rates of control of working conditions from rates of control of lead poisoning in industries is made difficult by a tendency for industries with a lower incidence of poisoning to show rapid rates of reduction in the number of cases of lead poisoning reported as these become small. This may be a consequence of divergence between industries with 'high' and 'low' incidence of lead poisoning in terms of diagnosis and notification of lead poisoning (e.g. due to the existence of regulatory requirements for medical monitoring in the former) or alternatively a product of the existence of thresholds of lead absorption required to produce a given degree of observable lead poisoning. The number of cases of lead poisoning in the industries with higher incidence of lead poisoning shows an upward trend in the latter part of the Twentieth Century which is due to changes in the threshold of diagnosis of lead poisoning.

Conclusions Regarding the Control of Lead Poisoning from the Use of Lead Paint

The rate of reduction of lead poisoning from the use of lead paint was extremely rapid compared to many other factory based lead processes and industries. A significant element of this was the substitution of white lead pigments by 'lead free' pigments, particularly in industrial and decorative (for the interior of buildings) paints.

The rate of control of lead poisoning attributable to changes in paint technology and working methods (i.e. after eliminating the effects of substitution of white lead by lead free pigments) was broadly similar to that occurring in other lead industries. Higher rates of control of lead poisoning (in the case of white lead manufacture) seem to have been achieved by the convergence of regulatory pressures with the trend of commercial technological development of the industry, and to have been achieved through industrial capitalisation. The high rate of 'technological control' of lead poisoning seems to have been achieved in house-painting without substantial capital investment. Changes in working methods directed towards eliminating health hazards must have played a major role (although in later years - particularly after the Second World War the adoption of newer paint vehicles and the spread of 'Do-It-Yourself' painting must have been significant factors). In vehicle and other industrial painting, technological changes introduced for commercial reasons did appear to have a major effect (principally the introduction of stoving enamels and spray paints) - though their biggest effects on poisoning may have been indirect, through the more rapid substitution of white lead in these sectors.

The fears of the Factory Inspectorate and the conclusion of the 1911 Departmental Committee, that the strategy of Regulation would not be effective in controlling lead poisoning in painters, were not confirmed.

However this degree of control was only achieved by virtue of the substitution of white lead by 'lead free' pigments.

If there had been no substitution since 1907 of white lead by 'lead free' pigments in paint it can be estimated that there would have been 1,109 cases of lead poisoning amongst industrial painters between 1920 and 1964, as opposed to 347 observed. Similarly there would have been 1,437 cases in housepainters as opposed to 929 observed (if these latter figures are adjusted for under notification in housepainters they would be 2,485 and 1,606 respectively). Cases of lead poisoning in painters in 1960-1964 would be running at the level of 10 per year as opposed to 1½ per year.

Given the extent of substitution of white lead by lead free pigments, particularly in interior painting, the conditions in painting only a few years after 1927 (the deadline for Prohibition) would not have differed much from those required under the International Labour Convention - namely Regulation of the use of lead paints for exterior (protective) paints, and Internal Prohibition of the use of white lead paint for painting the interior of houses. Thus, although the British government failed to implement the International Labour Convention, effective compliance with its requirement of Internal Prohibition was substantially achieved in the years between 1924 and 1948 for commercial/technological reasons rather than for health considerations.

The strategy of total Prohibition of the use of white lead pigments in paints would, judging from the experience during the First World War, have rapidly led to the total elimination of lead poisoning amongst housepainters. The rejection of this strategy must be seen as having allowed not only the 1276 cases of poisoning recorded between 1920 and 1964, but also a considerable proportion of the 279 deaths that occurred amongst housepainters in this period.

The failure of the _Prohibition_ strategy had other consequences. The _Regulation_ strategy adopted was essentially a strategy for 'living with' the use of lead paint. Despite its initial success in eliminating frank occupational lead poisoning (over a forty year period) it became increasingly inadequate in the face of increasing knowledge and concern about the effects much lower levels of lead absorption on health. In this context, hazards to the 'consumers' of paint, particularly to children, became paramount.

Subsequent Concern and Regulatory Activity about the Hazards of Lead Paint

The decreasing levels of lead poisoning in painters were not matched by a decline in concern about the health hazards of lead paint. Figure 6-24 shows the number of references to the health hazards of lead appearing in a sample of the U.K. paint industry's abstracting service (World Surface Coatings Abstracts). For details of this measure see Chapter 2. Figure 6-24 also indicates the number of references to monitoring worker exposure (almost exclusively by means of biological measurement).

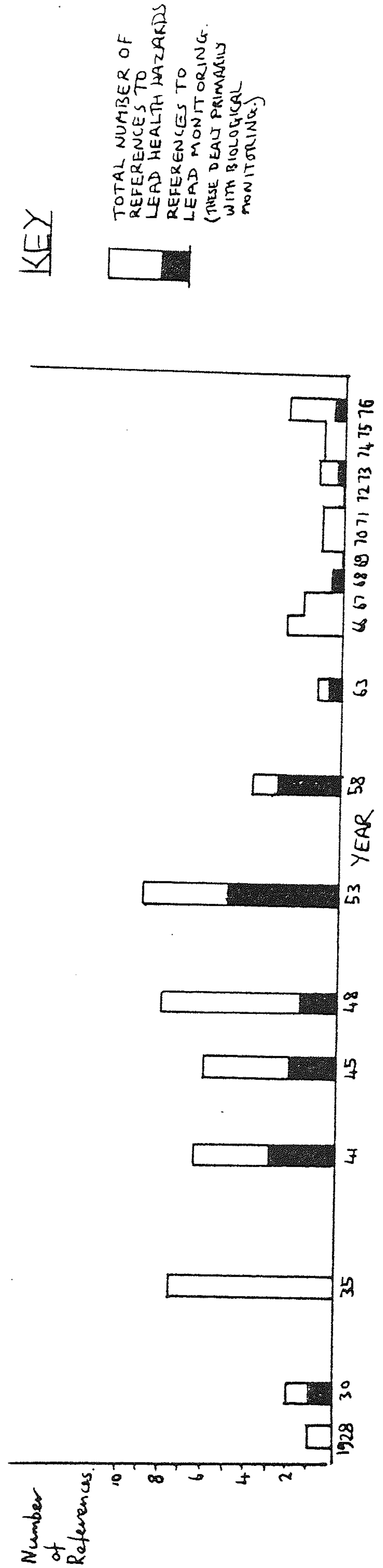
This indicates that concern about lead hazards in the paint industry increased after 1928-1930, and reached a peak in the period between 1935 and 1958. Between 1941 and 1958, biological monitoring is a major topic of this attention.

In Figures 6-24 and 6-25, the sample used for the years from 1963 onwards only covers one sixth of total references for the year (compared to one third in the preceding years). Given this change of scale, it will be noted that concern about lead hazards has continued, albeit at slightly lower levels, up to the present day. References to regulation figured at the beginning of the period examined (regarding the regulation of occupational hazard following the Geneva Convention) and in the last decade (regarding regulation of hazards of lead in paint to consumers).

The re-emergence of concern about the hazards of lead paint in the post-war period reflects the intersection of two separate issues that were expressed but little developed at the time of the original regulatory debate :

- changes in the social and technical diagnosis of lead poisoning
- concern about the hazards to consumers.

Figure 6 - 24: World Surface Coatings Abstracts: References to Health Hazards of Lead, distinguishing references to (biological) monitoring of lead exposure 1928 - 1976.



These developments are the subject of a separate investigation.[57] Only a brief examination will therefore be attempted here.

<u>Changes in the diagnosis of 'lead poisoning'</u>

The changes in the techniques of diagnosis of 'lead poisoning' were discussed at the beginning of this chapter. The falling levels of frank lead poisoning drew attention to individual variability as a factor in the occurrence of poisoning and necessitated a shift from lead poisoning to lead absorption as the basis of occupational hygiene controls.[58] The adoption of biological monitoring rather than pathological physical symptoms as the basis for medical suspension of workers can be seen as providing the basis for investigation of the effects on health and well-being of levels of lead exposure below those that would lead to clinical lead poisoning. The scientific/technical changes coincided with changes in the social acceptability of ill-health to bring about a broadening of the criteria for diagnosis of impairment to health to include 'sub-clinical poisoning' (physiological effects which do not amount to frank lead poisoning).

Given the falling quantities of lead consumed in paint in the post-war period, these changes in the threshold of diagnosis of lead poisoning did not create a crisis for the painting industry. Reversals in the downward trend of lead poisoning amongst painters in the post-war period (attributable to changes in diagnosis) were only temporary.

There was however a shift in attention about lead paint hazards, from the (typically low) lead content of paints currently being applied, to the possible high lead content of old paint that had to be removed from painted surfaces. For example, the removal of old paint from structural steel work had caused several cases of lead poisoning.[59]

Since the late 1950s, white lead has not figured in reviews of health hazards in the paint making and applying industry (although the continuing lead poisoning risk from making lead chromate based paints has been noted).[60] However, the introduction of more stringent U.S. Federal standards for workplace exposure to lead, based on concern about sub-clinical effects of lead on workers and on 'the unborn foetus' did lead to a crisis in lead pigment manufacture. Six women workers in American Cyanamid's lead pigment plant in Virginia were forced to accept sterilisation to avoid transfer to lower paid work not involving lead exposure. This incident provoked a considerable controversy about the basis of setting occupational health standards, and in particular about a hygiene strategy based on medical monitoring and exclusion of susceptible workers, rather than control of exposure to toxic materials to levels below which damage to health would occur amongst the entire workforce.[61]

These moves towards more stringent standards for exposure to lead at work in U.S. Legislation have not been matched in Britain where the main emphasis has been on consolidation and harmonisation of pre-existing regulatory requirements. The various sets of Regulations on lead processes, under the Factory Acts were repealed in 1980 and were replaced by a single set of Regulations under the 1974 Health and Safety at Work Act.[62] These replaced the specific (and by then outdated) provisions of the old Regulations with broad duties incorporating basic principle of industrial hygiene - the nature of controls to be determined on the basis of airborne lead levels and biological monitoring (blood lead levels).

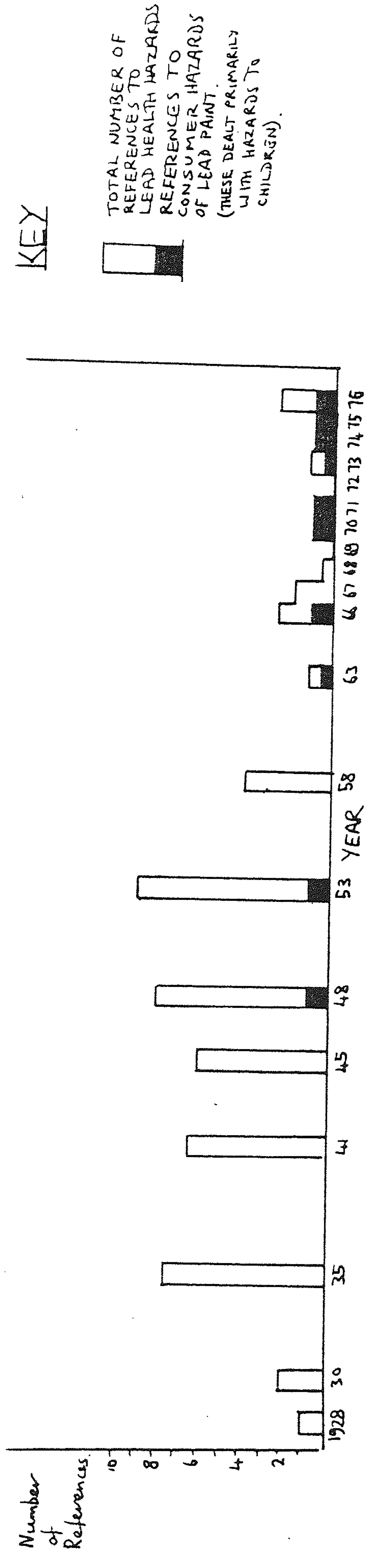
An Approved Code of Practice on the Control of Lead at Work gives authoritative guidance on interpreting these Regulations. Amongst the activities listed in this code as liable to give rise to significant lead exposure if controls are not applied, the code lists welding and cutting of lead painted surfaces, the manufacture of lead colours and paints, and spraying lead paints (other than those based on low solubility lead compounds). Activities listed as unlikely to give rise to significant lead exposure include brush painting with lead paint, and painting by any means with low solubility lead paints.[63] In the latter cases the requirements of the Regulations for airborne lead measurements and medical surveillance are exempted and many of the control measures would not be required unless there are reasons to believe that workers are liable to be exposed to significant levels of lead. The test for soluble lead content of paint etc. is the same as that required under the Lead Paint Act. Thus the 1980 Regulations do not extend the coverage of the previous Regulations for the use of lead paint, and in some ways can be seen as diluting some of their specific provisions, although this will depend on the detailed interpretation of the new Regulations.

Concern about hazards to Consumers

As noted in Chapter 4, consideration of the hazards to consumers did not figure in the regulatory debate about lead paints in the first quarter of the Twentieth Century, even though cases of lead poisoning amongst consumers of paint (i.e. the public) had been recorded in this period. The group most at risk were children, whose special susceptibility to lead had been long established. The habit of young children of chewing small objects (pica) had resulted in lead poisoning from the ingestion of flakes of lead paint from toys, furniture and the interior surfaces of buildings painted with lead based paints.

The number of references to the hazards of lead paint to consumers appearing in World Surface Coatings Abstracts is shown in Figure 6-25. Although the number of such references per year was low, it would appear that concern

Figure 6 - 25: World Surface Coating Abstracts: References to Consumer Hazards of Lead in Paints. 1928 - 1976.



about hazards to consumers of lead paint (overwhelmingly to children) emerged after the Second World War and became the major focus of paint industry attention to lead paint hazards during the 1970s.

Apparently, one of the first moves to control the hazards of lead paint in children occurred in the city of Baltimore, U.S.A. in 1959, when a local regulation was adopted requiring tins of paint containing more than 1% of lead to be marked with a label warning against the use of such paints on the interior of buildings in which children resided, as well as on furniture and toys. This followed the discovery of 744 cases of lead poisoning (including 123 fatalities) amongst children in that city between 1931 and 1959.[64]

Cases of frank lead poisoning in children from the ingestion of lead paint in Britain rapidly came to light. Systematic surveys conducted subsequently indicated that old lead paintwork in the home was the most common cause of severe lead poisoning in children accounting for one third of all cases.[65] Between 1968 and 1976 in England and Wales, thirteen deaths of children were certified as due to lead poisoning, of which four were specifically attributed to lead paint.[66] Hospital admissions of children with lead poisoning in Britain were estimated as in the order of one hundred per year in this period.[67]

It became clear that the chewing of paintwork by children was a major source of lead poisoning, resulting in severe symptoms (e.g. brain damage).[68] Moreover, the number and severity of cases of lead poisoning in children substantially exceeded the number of cases of occupational lead poisoning from the use of lead paint. These severe cases of frank lead poisoning represent just 'the tip of the iceberg'. Though mass screening of lead exposure/absorbtion in children due to lead paint has not been carried out in Britain, the results of such surveys in America indicate that substantial numbers of children may be suffering from elevated blood lead levels, sufficiently high in some cases (attributed to lead based paint in older housing) to represent an immediate risk to health. Thus one survey of pre-school children in American cities found 7.4% with elevated blood lead levels, and 0.5% of children were categorised as in 'urgent risk' (blood lead levels in excess of 80 micrograms per decilitre).[69] It was estimated on the basis of these exposure levels that the number of children in Britain suffering mental retardation from asymptomatic lead poisoning might exceed one thousand per year.

The debate about the hazards to children's health from lead in paint has exhibited a shift which in some ways parallels but in others goes further than the developments in thinking about occupational lead hazards. Thus the existence of sub-clinical harm (e.g. mental retardation) in children from lead absorption at levels insufficient to cause symptoms of frank lead poisoning was suggested at an early stage.[71] More recent investigations associated with the controversy about environmental lead exposure, in particular from lead in petrol, have pointed to the existence of effects on health and well being from relatively small increases in lead exposure/absorbtion in children. Associations have been shown between behavioural disturbance and impaired intellectual development and elevated bodily lead levels in groups of children.[72] The difficulty of detecting such effects, which may only be apparent in populations of children, of distinguishing the effects of correlated socio-economic differences and of determining causality has led to a prolonged scientific controversy.[73] This has focused on the levels of lead absorption which should be considered hazardous in children. One analysis has seen this controversy as exemplarising occupational and cognitive differentiation between industrial and environmental health scientists. The former emphasised the concepts from occupational hygiene of thresholds of lead exposure required to produce clinical harm, and promoted lead absorption standards at which clinical harm in individuals would be eliminated. The 'environmentalists' criticised the concept of thresholds and concentrated on sub-clinical hazards that might only be apparent in exposed populations. They emphasised the departure from historical body lead burdens that had occurred as a result of industrial use of lead.[74] Recent scientific studies, in particular conducted in the U.S.A., have tended to sustain the "environmentalists' " position on lead hazards.[75]

The pattern of scientific development was reflected by the pattern of legislation to regulate exposure to lead. Following a report by the U.S. President's Scientific Advisory Committee in 1965 which observed that "the margin of safety between present levels (of lead exposure in the community) and deleterious levels is uncertain", more stringent legislature standards were introduced in the U.S.A., and a programme of surveillance and eradication of lead paint hazards was embarked upon. In 1971 the Lead Based Paint Poisoning Prevention Act was passed in the U.S.A. which limited the lead content of paint for domestic premises and consumer products to 1% of the dry film.[76] Following the observation that cases of lead poisoning amongst children had been associated with paint surfaces containing less than 1% of lead,[77] the U.S. Consumer Product Safety Commission (which took over authority for this Act from the Food and Drugs Agency) reduced the permissable level of lead to 0.5% in 1975 with a view to a further reduction to 0.06% by 1977 unless evidence could be produced that 0.5% was safe. The 0.06% standard was subsequently introduced and implemented by 1978 despite considerable opposition from the U.S. paint industry (certain industrial coatings were exempted).[78]

As noted earlier, the British paint industry seems to have attempted to take the initiative in its response to the question of lead poisoning in children. It sought to apply more stringent restrictions on the use of paint containing lead than those required under the Lead Paint Regulations, involving the provision of warning labels and the encouragement of substitution of lead in paints, to be effected by means of voluntary agreement and 'self-regulation' rather than by statutory controls.[79] One motivation behind this strategy, expressed to a greater or lesser degree, seems to have been to offset the threat of legislation which would substantially prohibit the use of lead in paints. Legislation of this sort was subsequently passed in other countries, notably the U.S.A.

Shortly after the regulation passed in Baltimore, a voluntary agreement was reached for warning labels to be attached to cans of paint containing more than 1% of lead in the dry film. This agreement was made in 1962 between the G.B.Ministry of Health and the Paintmakers Association of G.B. (which represented 80% of U.K. paint manufacturers) and came into force in 1963.[80] The agreement was subsequently renegotiated with the Home Office in 1972 and 1974 to include other toxic heavy metals and by rescinding a change in the 1963 agreement which allowed for excursions of an additional 0.5% of lead in samples of paint (as a percentage of dry film weight).

The labelling requirement of the 1927 Lead Paint Regulations operated only for paints containing lead soluble in dilute hydrochloric acid, and thereby exempted paints containing significant levels of low solubility lead compounds (e.g. lead sulphate or chromate). The Paintmakers Association agreement covered the entire lead content of paint including 'driers' and low solubility lead pigments.

There were clear benefits for the Paintmakers in adopting this control strategy. The reliance on warning labels preserved the right of the manufacturers to formulate their paints as they wished. At the same time, responsibility for the selection of paint materials was effectively transferred to the purchaser of the paint (whether a member of the general public or a painting employer). The agreement would facilitate, but not mandate a reduction in the lead content of paints, thereby offsetting pressures for statutory controls and avoiding the increased costs of the disruption to production and markets that might have resulted from a more rapid transition in the face of legislation. As a result of the agreement, the formulation of many paints was amended to bring them within the 1% lead limit.[81]

The view expressed by a paint industry representative was that lead poisoning in children had only been associated with older, high lead content paints, and that the agreement on warning labels would 'eliminate the danger to children'.[82] However, a resurgence of concern in the late 1960s about pica focused attention on to the continued use of white lead primers for wood. This prompted the Greater London Council and other local authorities to phase out the use of white lead primers for interior and exterior work. In the light of this tendency, the continued public concern about lead based paints and the moves to prohibit the use of lead based paints in the U.S.A., the Paintmakers Association advised member companies to discontinue production and sale of proprietory lead primers for wood (although such materials continued to be available for the building trade and to manufacturers where specifically requested).[83]

In contrast to these voluntary arrangements for controlling the use of paint for domestic and industrial use, specific Regulations have been passed to regulate the lead content of paint for toys etc.[84]

The Toys (Safety) Regulations 1967 limited the content of soluble lead (soluble in dilute hydrochloric acid) to 0.5% of the weight of the paint film in paints used for toys.[85] This limit was subsequently revised in 1974 to 0.25%.[86] At the same time, more stringent limits were set on paint for pencils etc. of 0.025%.[87] Apart from these provisions there are no other statutory limits on the lead content of paints in Britain, although the implementation of a forthcoming European Community Directive will require warning labels for cans of paint containing more than ½% of lead as a proportion of the liquid paint, (in practice this is the same limit as that established under the voluntary agreement with the Paint-makers Association which refers to 1% of lead as a percentage of the dry paint film).[88]

The recent discovery of paints containing up to 15% lead on sale in supermarkets without a warning notice has renewed calls for further statutory controls on lead based paints.[89] A Department of Health and Social Security report on 'Lead and Health' observed that although the regulatory strategy based on warning labels was important, these were "not always effective" since children might be exposed to lead paint used out of doors or from the domestic use of paint intended for industry. "Further steps" were recommended "to complete the elimination of this hazard".[90] The report did not suggest how this might be achieved. Such a goal might well require the total prohibition of lead-based paints.

Further control of the lead content of paints in Britain would seem likely in coming years. Although the paint industry would appear willing to accept more stringent enforcement of the existing arrangements, resistance would be likely against moves to further reduce the lead content of paints. The paint industry would, it appears, oppose such a development on the grounds that lead is still needed in 'driers' and in pigments for certain anticorrosive paints.[91] Where "viable alternatives .... with equal ... performance" are available the Paintmakers Association has been willing to recommend discontinuing the use of lead (as in the case of white lead primers), but would still oppose a ban on their manufacture and supply.[92] This position appears to be informed by a resistance to regulation on the one hand compounded by a belief that current paints do not pose an unacceptable lead hazard.

A representative of the U.K. Paint Research Association has argued that modern decorative paints, containing 0.5% lead in the dry film, cannot be regarded as a significant hazard, as a child would need to ingest 2000 square millimetres of paint on a regular basis to develop severe clinical poisoning.[93] It would seem that arguments about sub-clinical lead hazards in children have made little impact on the British Paint Industry.

Thus, although the British paint industry has been able to offset statutory controls over its products by instituting pre-emptive voluntary controls, the current situation may not be stable in the face of developments of knowledge and public concern about sub-clinical health hazards to children and others.[94] On current trends, any future controls may need to be statutorily based and may involve more direct control over paint formulations than was exerted under the voluntary agreements.

Consumer Hazard and the Regulatory Debate

The failure of the Prohibition strategy (both internal and total) led to the adoption of a regulatory strategy (Regulation) which involved 'living with' a hazardous material. It was thus highly vulnerable to changes in knowledge about the extent of the hazards of a material and in the social acceptability of harm. As in the case of many industrial hazards, the concern about the hazards of this material increased over the years.

This did not generate a crisis in the arrangements for dealing with occupational hazards to painters because of, inter-alia, the falling consumption of lead pigments in paint, as well as the low incidence of lead poisoning in painters. The picture in pigment and paint production was slightly different.

Notwithstanding the process of technological substitution of lead by lead free pigments, which became substantially complete shortly after the Second World War, the failure of the British government to implement <u>Internal Prohibition</u> resulted in the continued application of very large quantities of lead based paints to houses and industrial products over a considerable period of time. The extension of knowledge about lead poisoning resulted in the 'discovery' of hazards to the consumer, in particular children. On the basis of current knowledge about lead hazards, it would appear that the total burden of harm to consumers from lead paint over the years has certainly been comparable to occupational hazard, and by some estimates has been substantially greater. Concern about consumer hazards has consequently moved to the centre of the debate. It is of interest to note that <u>Prohibition</u> of lead in paint has been implemented in Britain and elsewhere to deal with consumer hazards (e.g. of paint for toys and pencils). In the U.S.A., a more general measure of <u>Prohibition</u> of lead from paint has been adopted.

In Britain, such measures have been obviated by the voluntary agreement of the paint making industry to adhere to controls which have had many of the same results as Prohibition (albeit somewhat more gradually and less completely). Moreover, it is suggested that more direct statutory control over lead paint content would not be unlikely in Britain in future years.

CHAPTER SEVEN

CONCLUSION

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Models of the regulatory process were discussed in the opening chapter, and a particular framework was advanced for the analysis of the regulation of workplace hazards. Subsequently this framework was applied to the process of development of regulation of the hazards from lead pigment and paint production and use in Britain. The major findings have been summarised in the preceding chapters and it is unnecessary to repeat them here.

Instead, this concluding chapter will examine possible alternative interpretations of the failure by the state to implement the proposal for Prohibition of the use of white lead paints produced in its own policy formation processes.

Finally a brief assessment will be made of :

i) the implications of this case study for the analysis of regulation.

ii) the lessons of this episode for those currently proposing the prohibition of use of highly toxic materials

The Interpretation of the Rejection of the Prohibition Strategy

This case study of the regulatory debate about white lead pigments has yielded some rather paradoxical findings. In particular, a regulatory policy developed by the state for prohibiting the use of white lead paints was initially diluted and eventually rejected by the state. Subsequently the use of white lead paints was substantially replaced by 'lead free' paints due to commercial and technological factors.

The non-implementation of prohibition of the use of white lead paint has been the subject of recent debate. An environmentalist has attributed this to the resistance of industry in pursuit of short-term economic gain.[1] A member of the painting trade saw the rejection of prohibition as a technical decision, deriving from "the unique protective qualities (of lead paint) especially useful in our climate".[2] The historical complexity of this period has been lost in both of these accounts, leaving two forms of determinism - one economical, the other technical. It is suggested that both of these views are incorrect.[3]

In Chapter 1, a framework for analysis was presented which emphasised the interaction between the political process and the economic and technological development of industry in the process of state regulation of industrial hazards. Regulatory policy formation and implementation were seen as involving a complex interplay between power and knowledge. This approach involves a departure both from those pluralist interpretations of regulation as a rational/technical decision making process or a simple mediation between interest groups, and from certain 'elite' or 'vulgar Marxist' theories which portray regulation as either illusory or representing the 'long term needs' of capital. The model presented represents an attempt to develop an adequate Marxist analysis of the regulation of industrial hazards, that takes into account subsequent developments of the regulatory process, in the light of recent theoretical developments concerning the relationship between 'the state' and 'society'.

Drawing on this model of the regulatory process, a more elaborate account has been developed of the regulatory debate about the use of lead paints. The outcome of the policy implementation process in this case would appear to support the view that the rejection of the Prohibition strategy for lead paints was a consequence of the political effectiveness of economically powerful groups. However this failure by the state to implement the strategy generated by its own policy formation processes was seen in turn as a result of the lack of consensus about the regulatory strategy within the state and broader society. This led to the primacy of the explicitly 'conflict resolving' arena of the state (Parliament, Government) in policy implementation. Given the contemporary national political situation, reflected in the balance of forces in Parliament, the interests of the white lead manufacturers prevailed.

Thus, while the industrial situation 'set the scene' around which the political processes developed, the eventual policy outcome was explained in terms of those political processes. The danger is recognised that an approach which takes the state policy formation/implementation processes as the central objects of analysis will overemphasize the causal role of these processes.

Indeed one plausible interpretation of the state's failure to implement the conclusions of its own policy formation process might involve down-grading the significance of state policy formation vis-a-vis economic power. It is therefore necessary to consider the explanatory power of alternative models which give more direct weight to economic factors in state regulation. The hypothesis will therefore be examined that Internal Prohibition was rejected because it involved an impermissible degree of state intervention against the economic interests of capital.

Some assessment of the role of economic factors can be obtained by inter-national comparison of the pattern of regulation of lead paint hazards and the economic importance of white lead and other materials in different countries.

International Comparison of Ratification of the 1921 International Labour Convention

Though Britain did not ratify the 1921 International Labour Convention on the use of white lead (which involved Internal Prohibition) twelve countries had done so by 30 September 1926. A further nine had approved or recommended ratification, while four had definitely refused at this stage. The position of the different member states at this time is summarised in Table 7.1.[4] By 1945, twenty seven had ratified the Convention,[5] and by 1982 this figure was fifty two (which is near the average for International Labour Conventions of this period).[6]

Some assessment of the role of economic and other factors in the success or failure of implementation of Internal Prohibition can be obtained from an international comparison of the pattern of implementation of the Convention. Table 7.2 shows the progress by 1926 and 1982 amongst major industrialised nations in implementing the convention in order of their level of production and consumption of white lead in 1911 (also shown).

Excluding the U.S.A. and the U.S.S.R., which were not members of the League of Nations/International Labour Organisation, it can be seen that the two largest consumers and producers of white lead, Britain and Germany, both failed to ratify the 1921 Convention. The other major European states, which consumed/produced lower levels of white lead did ratify the Convention. The failure of Canada, India and Australia to ratify would appear to be related to their position as major lead extractors rather than as white lead producers/consumers.

Table 7.3. shows further information on these nations, in particular their production of lead and zinc metal in the periods 1909-1913 and 1924. The figures for lead and zinc ore production do not specify the metal content of the ore and are partially estimated, and may therefore not be directly comparable with metal production or ore production in other countries.[7] Considerable inter-year variation can be noted in lead and zinc production and extraction, not least in Australia where zinc ore extracting in the immediate post-war years is at very low levels.[8]

These figures indicate that Canada, Australia and India, which were not significant producers or consumers of white lead, but did not ratify the 1921 Convention, had substantial interests in lead ore and metal production.

TABLE 7.1. Progress by Member States at 30 September 1926 in Ratifying the 1921 International Labour Convention on the Use of White Lead in Paint.

STATES RATIFYING THE 1921 CONVENTION

Aston University

Source: International Labour Organisation 'White Lead', I.L.O., Geneva, 1927.

TABLE 7.2. Progress in Ratifying the 1921 International Labour Convention on White Lead amongst Major Industrial Nations showing White Lead Production and Consumption 1911

Aston University

Illustration removed for copyright restrictions

Sources:	I.L.O., White Lead, I.L.O., Geneva, 1927.	4	I.L.O., Chart of Ratifications of International Labour Conventions, I.L.O., Geneva, 1982.	6	I.L.O., White Lead I.L.O., Geneva, 1927	4	Table 7.3.

TABLE 7.3. International Comparison of Production and Consumption of White Lead Pigment and of Production of Lead and Zinc Metal and Ores by Major Nations according to their Response to the I.L.O. Convention on White Lead

Countries grouped according to their response to I.L.O. Convention on White Lead	WHITE LEAD Production 1911 Thousand tons a)	WHITE LEAD Consumption 1909-13 Period Thousand Tons	WHITE LEAD Consumption 1924-4 Period Thousand Tons	White Lead as a percentage of total White Pigment consumption 1909-13 Period %	White Lead as a percentage of total White Pigment consumption 1921-4 Period %	LEAD METAL Production 1909-13 Thous. Tons b)	LEAD METAL Production 1924 Thous. Tons b)	ZINC METAL Production 1913 Thous. Tons b)	ZINC METAL Production 1924 Thous. Tons b)	LEAD ORE Production 1911-2 Thous. Tons j)	LEAD ORE Production 1919 Thous. Tons j)	ZINC ORE Production 1911-2 Thous. Tons j)	ZINC ORE Production 1919 Thous. Tons j)
NOT PARTY TO INTERNATIONAL LABOUR ORGANISATION/LEAGUE OF NATIONS													
U.S.A.	120		175[e]		40[e]	401	570	315	470				
U.S.S.R.	14.5												
NOT RATIFYING I.L.O. CONVENTION													
Britain	55	50[c]	33,3[c]	75[c].	40[c]	31	5	26	48				
Germany [k]	36.5	26.7[d]				86	66	109	41	143		301	
Canada	2.5					17	76	N/A	25				
Australia	0 [h]					116	130	4[h]	11[h]	300[h] [i]	163[h] [i]	192[h] [i]	32[h] [i]
India						6	53	N/A	N/A				
RATIFYING I.L.O. CONVENTION													
France	20	18[f]	14[f]			29	21	68	57				
Belgium	15					54	54	204	163				
Italy	4.5					22	22	N/A	6				
Holland	2.5					0	0	24	18				
Spain	2.5					199	142	6	13		178		10
Sweden	0	0.6[g]		1.3[g]		1.2	0.6	2	4				
Norway	0	0.1[g]		0.6[g]		0	0	0.2	1				

NOTES TO TABLE 7.3.

a) C.A.Klein, Oil and Colour Trade Journal, 6/13 December 1913, p.1973.

b) International Labour Organisation, White Lead, 1927, op.cit.,pp.274-5.

c) Figures for U.K. pigment production and consumption taken from Chapter 3.

d) I.L.O., 1927, op.cit., p.268 - cites net white lead exports by Germany of 10,800 tons.

e) J.Parish, Journal of the Oil and Colour Chemists Association, 1925, (10), p.374. Figures for U.S. sales assumed to be approximately equal to consumption.

f) P.R.O., LAB 14/211: Memorandum to Board of Trade from White Lead Corroders, 7 May 1924. Average consumption for 1909-1913 and 1921-1922.

g) Based on pigment imports for Sweden 1911 and Norway 1912, and statement that these countries do not produce lead or zinc pigments. I.L.O., 1927, op.cit., p.268 -.

h) Figures for New South Wales only (which includes the Broken Hill lead and zinc mines). White lead production estimated from employment in white lead works. (zero in 1911, 102 in 1921) as zero in 1911 and 2300 tons in 1921 (assuming labour productivity is the same as U.K. white lead works). I.L.O., 1927, op.cit., p.319-21.

i) Figures for Australian ore production estimated from metal production and ore exports (assumes ore contains 50% recoverable metal). Lead ore exports 112,000 tons in 1911, 2,400 tons in 1919, Zinc ore exports 189,000 tons in 1911, 18,000 tons in 1919.

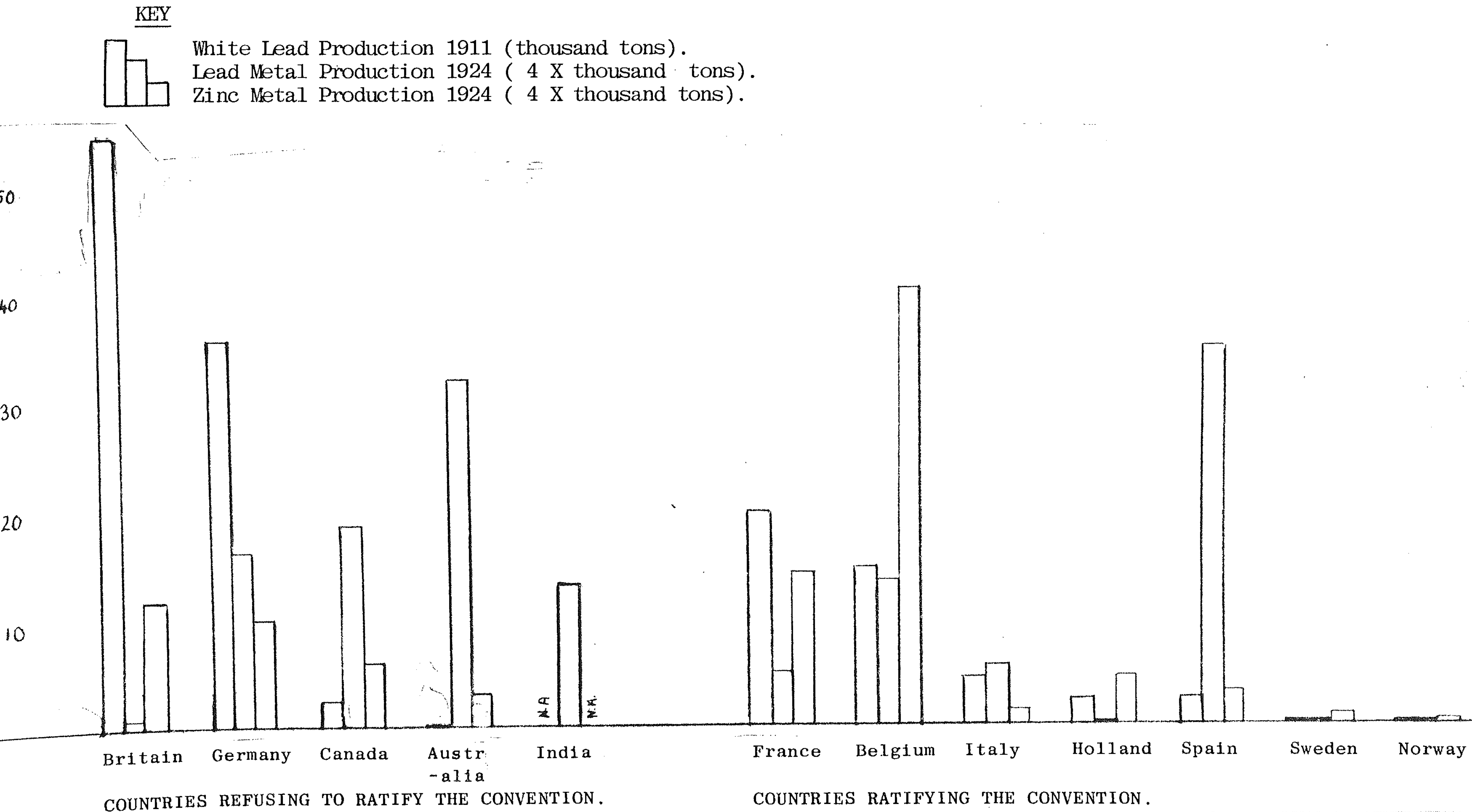
j) I.L.O., 1927, op.cit., pp.269, 319-21, 361.

k) Annexation of German territories after the First World War reduced her existing productive and extractive capacities for lead and zinc metal and ore by over 50%. I.L.O., 1927, op.cit., p.269.

Australia in addition was a major zinc extractor, though zinc ore was a 'by product' of its lead mines at Broken Hill, New South Wales. France and Belgium, which produced the largest amounts of white lead pigments of those countries ratifying the 1921 Convention, had zinc metal production facilities which far exceeded their lead production. It would thus appear that the possession of a significant lead extraction/refinement industry was a significant factor in discouraging ratification of the 1921 Convention, while possession of an even larger zinc extraction/refinement industry increased a state's willingness to ratify. The main figures are summarised in Figure 7-1 which shows white lead production (1911), lead metal production (1924) and zinc metal production (1924) of the major nations according to their response to the 1921 International Labour Convention.

These figures would appear to indicate that it was not only the size of the white lead industry that shaped a state's response, but also its relative importance compared to the lead and zinc extraction and refinement industries. In other words, state regulatory response would appear to be influenced not simply by the impacts of intervention on the regulated industry, but on the balance between the contradictory interests of different sections of capital.

There are however significant exceptions to the pattern that would be expected on the basis of simple economic considerations. For example, Spain ratified the 1921 Convention despite being a major lead extractor, with a negligible zinc industry (unlike the other lead mining countries). Conversely Germany failed to ratify the 1921 Convention despite having probably the largest European zinc industry and despite being a major exporter of zinc pigments. German exports of zinc oxide and lithopone increased from 25,000 tons in 1910 to 42,000 tons in 1913, while white lead exports remained static at around 10,000 tons.[9] These exceptions gure 7-1: Comparison of Production of White Lead (1911) and Lead and Zinc Metal (1924) of Major Nations according to their Response to the 1921 International Labour Convention on White Lead.



are an important reminder that state regulatory activity was not economically determined, but was conducted through political activity (even though economic forces appear to have been a very important factor).

Thus far, the pattern of regulation in different countries conforms closely to what would be predicted by a variety of 'class' theories of state political activity. Whilst it would be presumptous to attempt to determine the validity of a particular theoretical approach from a single 'regional instance', some observations can be made about the adequacy of certain approaches, in particular those which see the state as representing, in a far-seeing way, the long-term, general interests of capital. These will be assessed in the light of the rejection of the Prohibition strategy in Britain.

As was demonstrated in Chapter 3, by the time the British state eventually rejected <u>Internal Prohibition</u>, the process of competitive technological substitution of white lead by 'lead free' pigments had long been established, and was well on the way to completion. Consumption of zinc pigments escalated and the U.K. zinc pigment industry experienced dramatic growth for commercial/technological reasons. There is very good reason to believe that the conditions that would have been required under <u>Internal Prohibition</u> were substantially achieved in Britain for commercial reasons relatively few years after the rejection of state regulation to mandate these changes. Thus the state failed to implement a regulatory strategy that would have conformed to (and probably accelerated) the medium-term commercial development of the industry. By this failure to implement the recommendations of its own policy formation process, the state incurred political and ideological costs. In the longer term, the regulatory strategy that was adopted in place of <u>Internal Prohibition</u> (i.e. total <u>Regulation</u>) itself contained contradictions because it involved 'living with' highly toxic materials in a situation in which engineering controls could not be applied. This strategy was thus thrown into crisis by changes in the diagnosis of harm from lead, and changes in the social acceptability of that harm which resulted eventually in the introduction of measures of Prohibition to deal with consumer risk from paint. Whilst both of these trends were observable at the time of the regulatory debate it could be argued that the means to predict their long term significance were not available. However, this underlines some of the difficulties associated with such 'far seeing' models of the state. A measure of Prohibition would appear to have been 'functional' for the state by resolving the political pressures towards regulation in a way which conformed to the long term development of capital. However this is precisely the move that the state was unable to carry through.

The case study that has been conducted highlights the problematic nature of the state's regulatory project : the limitations of knowledge and scope of intervention by the state, and the difficulties of 'distilling' an effective, achievable policy out of the conflicting sectional interests with which it dealt. The failure to overcome these problems was expressed in this case study in a rupture between state policy formation and implementation. Whilst the scale of the economic impact of Prohibition on a sector of capital, and the relative scale of the various industrial sectors affected, have been indicated by the international comparison as important factors in the eventual regulatory outcome, these cannot be seen as the only factors at work. If it was the case that these economic considerations were overwhelmingly unfavourable to any measure of Prohibition, then the reasons for the breakdown of the 'selectivity' of state policy formation must be analysed.

An examination of the process of regulatory development in this case suggests that the outcome was not (economically) predetermined but was contingent on a range of factors, including economic ones. The reasons for the failure of the Prohibition strategy were discussed in Chapter 5. They will be reviewed briefly below in comparison to the methods of regulatory development that proved 'successful' in regulating the hazards of pigment and paint production.

Reasons for the Failure of the Prohibition Strategy in Comparison with 'Normal' Methods of Regulation

It was found that in the 'normal' process of developing Regulations that operated for example in the case of Regulations for lead pigment and paint production, the process of policy formation and implementation was conducted on a consensual basis, involving a single sector of the state, representatives of the regulated industry and to a lesser extent the workforce. The technical elaboration and political mediation of the controls to be required were compressed into a single process. This process of negotiation served to limit the economic and technological impact of regulation and to win acceptance by the regulated industry of the costs of control.

The measures that were required under Regulations were typically derived from 'best' industrial practice thereby ensuring their technical feasibility and demonstrating their economic viability. The existence of a significant degree of pre-regulatory compliance also served to mobilise pressures for 'equality of conditions of exploitation' which partially neutralised industrial resistance to regulation (the latter was particularly visible in the development of the Regulations that were eventually applied to the use of lead paints).

The Factory Inspectorate were able to play a leading role in this process of regulatory development from their detailed knowledge of industrial practice in the industry to be regulated and from the experience of regulating similar hazards in other industries. This knowledge base enabled the Inspectorate to over-ride certain types of objections from the industry being regulated - for example, that control measures were not feasible or that regulation was unnecessary because of the absence of risk in some sections of the industry. It was possible for the Inspectorate to negotiate concessions without prejudicing its overall regulatory strategy. In this way, the development of open conflict about regulatory strategy could be avoided. The balancing between economic interests and the pressures for regulation in the development of Regulations was conducted through closed channels. The conflicts of interest were largely obscured and regulation was presented as a technical matter, to be resolved within the Home Office/Factory Department without recourse to the explicitly political arenas of the state.

In contrast to this established model of development of Regulations, the implementation of the Prohibition strategy raised new, and potentially more profound problems in particular of the technical elaboration of control measures and their impacts, and for the negotiation of a mutually acceptable compromise. These are summarised below.

The economic impact of Prohibition : These would not only be large, but would also be unevenly distributed - in particular to an industry that was not being directly regulated - namely the white lead manufacturers. White lead manufacturing facilities were highly dedicated and could not be transferred to other products; there were few other markets than paint for white lead. In practice the British White Lead industry would have been substantially curtailed or eliminated. In addition there was uncertainty about the wider costs of Prohibition for the lead extracting industry due to reduced demand for lead and for the consumer due to the problems of formulating 'lead free' paints.

Internal Prohibition would have minimised these costs. However the white lead manufacturers were successful in projecting the (probably incorrect) view that Internal Prohibition would involve substantial economic costs.

The Legitimate role of the State: Prohibition involved state intervention that would have substantial economic impacts. Moreoever it involved state intervention in the direction of industrial development (though in the event, such changes later took place for technological and commercial reasons). This was an extension of the current extent of state intervention, which the opponents of Prohibition held to be beyond the legitimate role of the state. It also posed for the state the problem of resolving questions about the technical and economic viability of substitute pigments and the economic impact of Prohibition.

Complexity of Interests involved (and Problems in negotiating an agreed strategy):

The regulatory strategy based on Prohibition affected a much wider range of parties than conventional regulation, including pigment manufacturers, paint makers, painting employees and operatives, raw material suppliers and 'the consumer' as opposed to simply workers and employers in the regulated industry. Moreover the costs and benefits of prohibition were very unevenly distributed between these parties. Development of a consensus on policy was made extremely difficult by the problems of negotiating and the inherent difficulty of making 'trade-offs' between different parties.

The different industries and groups involved were unevenly balanced in terms of their economic importance, industrial concentration, (political) organisation/representation, and resources (especially technical). This unevenness was accentuated when the groups resolved themselves into alliances, supporting and opposing Prohibition. The breadth of the anti-prohibition alliance seems to have been an important factor behind its success in overcoming the Prohibition lobby (which was internally divided). Differences in the strategy adopted by the groups at the centre of each alliance (White Lead Manufacturers, Painting workers) were seen as having played an important role in shaping the development of the alliance.

The different impacts of Prohibition on a wide range of industries thus posed a structural obstacle to the achievement of a consensual position, while the uneven political development of the two lobbies did not favour the resolution of the conflict on an equitable basis.

The 1911 Departmental Committee gained support for Prohibition from the painting workers, some paint makers, medical/technical experts, and sections of the master painters. The white lead corroders participated in the Committee from a disadvantageous position. While the Departmental Committee succeeded in winning over or neutralising most of the groups directly involved in painting, it did not succeed with the white lead manufacturers.

The total Prohibition strategy was not consensually derived amongst all the affected industries and groups. It was replaced by the compromise position of Internal Prohibition. Though this was a 'half way house' between the two positions (Prohibition and Regulation) its adoption had a number of ideological effects (in particular it involved acceptance of the technical feasibility of Regulation and its enforcement) which provided an opportunity for the white lead makers to undermine it.

Scientific Underpinning of strategies (and the Problem of maintaining consensus):

The administration (Home Office and Factory Department) favoured the control strategies developed by its successive departmental committees (of 1911 and 1921). However it was unable to maintain/enforce consensus around the prohibition strategies, partly because of the uneven impacts of prohibition and the unequal political situation, but also, very importantly, because it failed to resolve the conflicting estimates of the problems associated with the alternative control strategies.

This in part reflects the Department's lack of knowledge and expertise over the process of painting (compared to their intimate knowledge of the factory processes that lay within the Department's jurisdiction), also posed broader questions (e.g. regarding the quality of the product) than the normal style of regulation (e.g. the application of engineering controls to a dusty process).

At that time, systematic knowledge on these matters was not available from industry. Paint formulation was primarily craft based, conducted by craftsmen in the painting industry. The paint making industry was small, decentralised and had limited technical and other resources (in contrast to pigment making). The development of paint technology was very limited, and within this there was much greater experience of formulating paint from the traditional material, white lead, than 'lead free' pigments. Methods for formulating and evaluating paints were just beginning to be developed and they had not been standardised. Given the context of this lack of systematic evaluation of paint performance, there were widely conflicting assessments of the utility of lead and 'lead free' paints (in which the interest and orientation of the assessor played a major role).

The lack of systematic, impartial knowledge was itself a consequence of political decisions about the legitimate scope of state involvement. During the 1893 Departmental Committee's Enquiry into the hazards of white lead manufacture, the state rejected suggestions that it should conduct research to develop lead substitutes on the grounds that this was a responsibility of industry. The 1921 Departmental Committee on Industrial Paints (the Norman Committee) recommended such a programme of research but this was never put into practice (in the unfulfilled expectation that the industry was about to carry out this work).

The debate about Prohibition focused on a much wider range of questions than simply the controversy about paint performance, especially during its latter stages. Legitimation of the Factory Department's opposition to Regulation was problematic as it was indirectly derived (since the Department did not inspect the industry) from first principles of industrial hygiene and the experience in other countries, and this opposition was compromised by the Geneva convention.

Moreover, as the debate progressed, it increasingly revolved around areas that were further removed from the Factory Department's sphere of expertise (e.g. the wider economic costs of Prohibition). Other sections of the state administration became drawn into the debate which had responsibility for economic issues (e.g. trade, colonial interests) which had been won to support the white lead lobby's position.

The failure of the Factory Department and the wider Prohibition lobby to produce comprehensive scientific/technical validation for Prohibition provided a space in which the white lead lobby were able to promote Regulation on wider grounds than simple self-interest (thereby enhancing its ability to win allies). Moreover the support for Prohibition from the expert community which had been evident in 1911 and in the early days of the Prohibition campaign at an international level[10] became more circumspect.

The absence of a scientifically validated consensus about the regulatory strategy to be adopted, and the continuation of a sharp controversy on the subject, left the resolution of the regulatory debate to the representative structures of the state (government, parliament). In these structures, the political influence of the economically powerful industrial interests prevailed, leading to the rejection of Prohibition and the eventual implementation of Regulation. The regulatory strategy adopted was the one which involved the least degree of state intervention in industry and constrained the action of these interests to the minimum extent.

Models of the Regulatory Process

The model of the regulatory process that has been developed and applied to the case of state regulation of lead pigment and paint hazards is thus able to account not only for the significance of 'economic'factors (including the size and structure of the affected industrial interests as well as the economic impact of Prohibition) but also why this was expressed in this case of Prohibition in a conflict between regulatory policy formation and implementation. This account focuses attention on the form of representation and strategy of the different affected parties and the role of knowledge in the process of development of state regulation over hazards.

In contrast, models of the regulatory process which infer a more direct effectivity of economic considerations, and which downgrade the explanatory status of the policy formation and broader political process, have to confront several problems which are adequately explained by our framework. They must explain why a conflict between policy formation and policy implementation does not arise in all cases where a regulatory strategy involved a significant economic impact. This could be attributed to 'selectivity' of state policy making (i.e. by implying that the policy formation process is insubstantial and merely reflects the underlying economic forces). However if the latter argument holds, the breakdown of selectivity in the case of Prohibition must be explained.

Conversely, 'pluralist' models of regulation fare no better than 'economic determinist' ones. The phenomena observed bear little resemblance to the model of regulation as a technical/rational process - in particular, the rejection of Prohibition conflicted with the state's rational policy formation processes. An alternative 'pluralist' explanation of the rejection of Prohibition would emphasise the failure of consensus around the regulatory strategy to be adopted for lead paints, but can say little about the roots of this failure, and in particular why the numerically small white lead industry should have been able to be so effective in Britain (and yet not effective in other countries).

It is concluded that the model of the regulatory process that has been developed here represents a real advance over traditional approaches to the analysis of state regulation of industrial hazards, and in particular is able to account more effectively for the complex history of the regulation of the health hazards of lead pigment and paint production and use in Britain. This model was extensively elaborated in Chapter 1 and its detailed application to the analysis of lead pigment and paint hazards was discussed in Chapters 4 and 5. It is not necessary to repeat these accounts here.

It is suggested that the findings of this historical study have important implications for the current regulatory debate and analyses about state regulation of industrial hazards. Two aspects in particular will be discussed :

- the implications of this study for the analysis of regulation and in particular assessments of its economic, technological and health impacts.
- the implications for the current debate about the Prohibition strategy.

Implications of this study for the Analysis of State Regulation of Industrial Hazards and its Impacts.

State regulation of industrial hazards is seen as having a real impact, but subject to contradictions and limited in its scope. This has important implications for the study of the 'impact' of regulation.

The state, and in particular its administrative arm with responsibility for industrial hazards, the Factory Inspectorate, play an active role in the promulgation of state regulation. Indeed the state plays a major role in generating systematic knowledge about the nature and extent of hazards, which in turn stimulate political pressures for an extension of regulation. However the state's ability to act to regulate hazards is substantially limited by its exclusion from the right to direct industrial development. Resistance by capital to the extension of state regulation places limits on the extent of state intervention that is seen as legitimate at any stage. In addition the state's exclusion from production creates a problem for the state in obtaining certain information and technology needed for the development of an effective regulatory policy. The consensual method of regulatory development can be seen as an attempt to resolve this problem.

One of the consequences of this situation has been an interlocking of the processes of commercial technological development and of regulation of an industry. This must be taken into account in any assessment of the impacts of regulation on both hazards and technological development. As noted earlier, the political and technological requirements of the regulatory development process make it likely that the control measures required by regulations will already have achieved significant use within industry. In the case of the regulation of lead pigment and paints it was found that the direct impact of state regulation was not to force technological innovation, but rather to accelerate the diffusion of existing technologies. The greatest rate of control of hazards was found where there was a synergy between regulatory and economic pressures for the adoption of changed technology. It is suggested that these are probably a more general characteristic of the regulatory process adopted in this period.

However indirect and informal regulatory pressures are important. For example, the reduction in lead poisoning that took place under informal regulatory pressures was equal or greater in magnitude than that which followed the application of Regulations. Equally the application of Regulations to one industry would appear to have an effect on industries not subject to specific Regulations. It would appear that regulation of one process sets standards that achieve a more general impact both through informal pressures by the Factory Inspectorate and at a broader societal level. The indirect impacts of regulation not only affect the short-term process of technological change (e.g. by setting minimum standards to which new production systems are designed) but can also stimulate more profound changes. It is notable that concern about and regulation over hazards figured as a significant factor in the technological development of all aspects of paint technology. The rate and nature of the technological change appeared to vary according to the stimulus involved. Thus general concern about health hazards figured in the motivation of the Nineteenth Century 'inventors' of lead free pigments. However the technological and capital investment needed for the commercial development of production of these materials was not forthcoming. The latter development followed the establishment of a market for lead free pigments stimulated by concern about hazards to painters and the threat of Prohibition of lead pigments in the Twentieth Century. In the subsequent history of changes in paint technology, general concern about health hazards of other paint materials was reflected in evolutionary and incremental changes in materials choice and formulation. In contrast, recent, more stringent legislation about hazards appeared as a factor behind more rapid and profound changes in paint materials and application technology.

It is clear that studies of the economic, technological and health 'impact' of regulations have frequently overlooked the importance of the interaction between regulation and the commercial process of industrial/technological development that has been identified in the current study. This is linked to a more general failure to investigate the context and process of development of the regulations involved.

Related criticisms can also be made of studies of state regulation as an example of state policy formation in isolation from the process of industrial development. This historical investigation has also highlighted many of the weaknesses of the cost/benefit and risk/benefit approaches to regulation - in particular that costs and benefits of regulation are historical constructs and liable to change. For example, the continuous changes in 'diagnosis' and 'social acceptability' of harm from lead poisoning, resulting in substantial increases in concern about a given level of lead exposure, poses a profound problem for the risk-benefit approach. These models, and their limitations have been discussed further in Chapter 1.

The Prohibition Strategy

The defeat of the Prohibition strategy for regulating lead paint hazards, confirmed the model of state regulation of occupational hazards for the next thirty years and more. Though Regulations on 'Mule spinning' (1953) and 'Carcinogenic Substances' (1967) were introduced, which included measures of Prohibition of the use of carcinogenic materials that could cause severe harm by exposure to even small quantities of a material, they were applied in situations in which they had marginal impact because the use of these materials had already been virtually abandoned in favour of existing substitutes. Materials in widespread industrial use found to b carcinogenic have been subject to Regulation (e.g. Asbestos, Vinyl Chloride) or not subject to specific Regulations at all in Britain (e Benzene).

The demand for the Prohibition of industrial carcinogens and other materials posing the risk of severe and irreversible harm from exposure even at low levels, has emerged as a central theme of recent campaigns for improvements in the regulation of industrial hazards. The need for Prohibition has been justified on the grounds that it is technically impossible to define levels of exposure to carcinogens that do not increase the risk of cancer. Complete elimination of carcinogens can be the only certain strategy for eliminating this risk. In contrast, conventional Regulation strategies of occupational etc. hazards cannot totally eliminate the risk and are always vulnerable to lapses in enforcement.

The demand for Prohibition of carcinogens has faced considerable opposition from industrial and other groups and has made little headway in Britain. A fierce controversy has developed which has focused on medical/scientific issues - in particular the criteria by which the existence of a cancer etc. risk is assessed and around the standards which should be adopted for exposure to such materials (i.e. the espousal of exposure levels which involve an increase in risk that is either 'not detectable' or 'socially acceptable'). The political feasibility of achieving such a strategy has been subject to much less attention. The historical experience of the Prohibition strategy would appear to hold important lessons on this question.

This case study has demonstrated that the conditions for success of the Prohibition strategy for occupational hazards have been remarkably rare. The alternative, 'mainstream' method of regulating worker hazards revolving round the adoption of precautions to minimise the risks associated with hazardous materials (i.e. Regulation) is politically, economically and technically easier to achieve, although its effectiveness and reliability may be much lower (particularly in dispersed uses of toxic materials).

The regulation of consumer and environmental hazard shows a rather different picture. Although a major thrust of regulation of consumer hazards has revolved around the provision of warning information and advice about 'how to use dangerous products safely', the limitations of such an approach are obvious - particularly since the difficulties of regulating consumer behaviour are much greater than workplace behaviour.

The levels of risk to individuals subject to state regulation are generally substantially lower in the case of consumer hazards than worker hazards. As a result, actual or effective prohibition of the use of dangerous products has been a more frequent characteristic of the regulation of consumer than worker hazard. In the case of environmental hazards, Prohibition (partial or total) of use of toxic materials that are environmentally persistent has been adopted since other strategies would not be effective.

An examination of the history of regulation of lead pigment and paint hazards demonstrates the need for integration of the state's regulatory response to a hazardous product at all stages of its life-cycle, including extraction/preparation, processing, consumption and dispersal, particularly for materials that pose a hazard at several stages despite the transformations which it undergoes. In the case of lead pigments/paints systematic state regulation took place over an extended period, covering regulation of manufacture (1890-1921), worker hazard from use (1926-1927) and consumer hazard from use (1960 to the present day). Whilst the independent regulation of these different aspects of lead paint was relatively effective, Prohibition would have had the particular advantage of simultaneously controlling the hazard across all these stages.

Integration of the approach to state regulation would have significant political consequence. This study highlights the importance of the development of alliances between the groups supporting Prohibition - for example between workers pushing for the regulation of hazards faced at different phases in the product life-cycle. It would appear that alliance between consumer and worker interests could be particularly fruitful in attempts (especially by workers) to win Prohibition of materials. Such alliances are beginning to develop in Britain, in the case of asbestos for example.

The pattern of interests of different groups in the regulation of industrial hazard is extremely complex, and the development of alliances consists of more than simply a merging of groups whose interest converge. In the example of white lead the position of certain groups (e.g. industrial painting employers) was reversed during the regulatory debate. The involvement or neutralisation of social groups with ambiguous interests in Regulation/Prohibition was a striking feature of this episode. The changing strength of the Prohibition and White Lead lobbies in this period can be related to their ability to pose their position as a general, societal concern. In this process scientists and technologists played a key role. The successful alliances were not simply economic, but sought social and technological legitimacy (an observation which corresponds strongly to Gramsci's conception of hegemonic social forces).

However effective the political pressure for Prohibition the strategy still faces potentially profound economic and technical difficulties which may engender and make effective a powerful opposition. These may be readily overcome in certain circumstances - for example where a material has limited use (e.g. new industrial chemicals, or older materials which have substantially been replaced by newer more effective substitutes). The major problem arises in campaigns for Prohibition of materials that have achieved widespread use. In this case political pressure for Prohibition may well be unsuccessful where the technical difficulties and economic costs of substitution are substantial. A major determinant of these will be the degree of dedication of existing production and consumption processes to a specific material. Where suppliers of alternative materials exist who can provide a source of technological as well as political support, the opportunities for Prohibition may be greatly enhanced. However, the technological and industrial development of alternative materials may be limited. It is frequently the case that the bulk of industrial research and development will be tied to the production and application of existing materials (as was the case with lead pigments at the turn of the century).

Because of the economic and technological problems it entails, the immediate prospects for successful implementation of the Prohibition strategy may be poor, particularly in the case of a material in widespread industrial use and where the technical and commercial development of 'safer' alternatives is limited. The central problem remains that of the location of authority and expertise for industrial development within private industry (and its direction towards narrow economic objectives).

It must be noted that in the longer term a wide range of opportunities exist to bring about changes that could reduce the resistance to Prohibition - both by overcoming technological obstacles through research into the production and application of alternative materials and also by encouraging substitution (i.e. by setting up effective voluntary compliance in advance of Prohibition).

These opportunities will be briefly reviewed, distinguishing direct intervention by the state and indirect or partial influences.

Direct State Intervention

Whilst recent regulatory developments (e.g. the development of pro-active testing requirements and hygiene standards applicable in all industries) can be seen as increasing the breadth of state regulation and lifting general standards within which industry must develop, these moves have also involved a retreat by the state from the direct influence over the technology of industrial production that developed under Process-Specific Regulations.

Paradoxically this approach to state regulation of industrial hazards has coincided with the period in which the state has achieved its greatest (peacetime) degree of intervention in the economic and technological development of industry. Emphasis on the importance of rapid industrial technological advance has underpinned both of these developments.

This situation potentially offers much greater opportunities for the state to influence the technological development of industry to reduce industrial hazards. In the case of substituting hazardous materials this state intervention could encompass stimulating research into production and utilisation of alternative materials, and promoting their industrial development over that of more hazardous ones. At the same time the opportunities for the state to fulfill its own information needs for regulatory policy formation have been greatly enhanced. There is little indication of the emergence of state intervention along these lines, and such a development would conflict with recent trends in state industrial policy. However the need for state industrial support to be based on broader social criteria than narrow financial ones, and to be subject of democratic control has been the subject of increasing political attention.

Indirect/Partial Intervention

This may offer more immediate prospects for successful intervention. Industrial opposition to incremental measures of partial Prohibition may be harder to sustain than the national total measures. Thus on the continent, considerable headway was made by the Prohibition lobby in achieving action by the local state.

Similarly local trade union activity has been proposed to ban the use of carcinogens from the workplace. Consumer pressures may be significant. The local and national state is now a substantial consumer of materials. State bodies and other organisations subject to democratic control or sensitive to public pressure could have a significant effect on the consumption of hazardous materials (both these factors were of political as well as economic significance in the debate about regulation of white lead). State regulation and public concern about hazards must also be seen as having an indirect effect by increasing the likelihood of alternative materials being purchased.

The case study of white lead shows that such indirect pressures and the threat of increased regulation had important effects on the long term behaviour of industrial interests. Thus, health and the threat of extension of regulation as well as market concerns encouraged companies involved in other activities (including paint making firms, zinc metal firms and even white lead manufacturers) to diversify into lead free pigment manufacture and impaired confidence in the long term future of white lead.

It can be concluded that although the obstacles to campaigns for <u>Prohibition</u> are substantial, there are many potential opportunities by which these can be overcome. <u>Prohibition</u> is likely to remain a major concern of future regulatory debates. It is our belief that this study of historical campaign over <u>Prohibition</u> has a significant contribution to make in developing and clarifying this debate.

TECHNICAL APPENDICES

APPENDIX A.

TECHNICAL APPENDICES TO CHAPTER THREE

APPENDIX A-1

Information and Estimates on U.K.Production, Trade and Consumption, Price, and Consumption by the U.K. Paint Industry of Major White Pigments.

The information and estimates for U.K. Production, Imports, Exports, Consumption, Price, and Consumption by the U.K. Paint Industry of major white pigments are summarised in Tables A-1, 2, 3, 4 and 5. The source of the information is annotated (A-T). The key to sources of information is shown in Table A-6 (references relate to Chapter 2). Alternative information and their sources are also shown in parentheses. Where the values in these tables are based on estimates/calculations this is indicated by a numeral which refers to a set of notes reproduced below.

Notes on Estimates and Calculations of Pigment Consumption

White Lead

The economic importance of white lead at the turn of the century ensures its presence in the early official statistics. However the methods of surveying were poorly developed.

1. 1907 (A)

The 1907 Census of Production figures for white lead are inconsistent. White lead output by paint and colour manufacturers is recorded as 28,500 tons, and by lead manufacturers as 9,200 tons in Part III and 11,000 tons in Part IV. The latter figure has been used, yielding an estimate of U.K. production of 39,000 tons.

Production of other pigments is not recorded by weight but a figure for the value of other pigments produced indicate that white lead constitutes 69.7% of total pigment production (including coloured inorganic pigments).

2. 1924 (A)

The 1924 Census of Production gives domestic production of white lead as 40400 tons, yielding an estimate for domestic consumption of 33300.

However, the Census also records returns from paint firms making up 55% of the total industry who purchased 12,500 tons of white lead. Assuming that the remainder purchased white lead at the same rate, yields an estimate for paint industry purchases of 22,700 tons. This would account for 68% of domestic consumption of white lead. However this estimate is of limited certainty. [see note 16 - Lithopone]

3. 1924 (T)

The 1924 Trade figures only cover white lead imports and exports in dry form. White lead paste is included under a general category of

TABLE A-1. White Lead : U.K. Production, Trade, Consumption, Price and Consumption by the Paint Industry 1907-1978

YEAR	U.K. PRODUCTION	NOTES	IMPORTS	NOTES	EXPORTS	NOTES	U.K. CONSUMPTION	NOTES	PAINT CONSUMPTION	NOTES	PRICE	NOTES
1893											15	1893 DC
1907	39	1(A) [37.2 A]	14.9	T	20	T	33.9				22	A.C.
1910	58	E.iii 60-Ei	14.4	E.iii	20.2	E.iii	52	E.iii	49	E.iii	23	E.ii
1914											25.25	J
1924	40.4	A	6.7	3(T)	13.8	3(T)	33.3		22.7	2(A)	43	T
1930	26.9	A	11.7	A	6.6	A	32				41.6	P
1935	38	R.4	5.6	T	5.9	T	37.7				39	P
1937	36	R	5	T	4.3	T	36.7				49	P
1945	24	R [24.8 B]	0	T	3.3	T	21.7				58	P
1946	28.4	B	0	B	2.7	B	25.7				70	P
1947	26.6	B	0	B	1	B	25.6				110	P
1948	26	R [25.5 B]	0	B	2.9	T	23.1		14.8	C	119	R [110 C]
1949	20.5	B	0	B	3	B	17.5				119	
1950	24	B	0	B	4.8	B	19.2				131	P
1951	26.3	B [26 R]	0	B	4	B	22.3				183.8	P [155 A]
1952	9.5	B	0	B	1.3	B	8.2				169	P
1953	13.8	B	0	B	1.3	B	12.5				138.4	P
1954	14.8	B	0	T,B	1.5	T [1.7 B]	13.3		9.7	41% Dry White Lead	129.8	P [122-Paint Ind. Purchases
1955	14.4	B [14-R]	0	B	2.1	B	12.3				139.1	P
1958	10.9	5(A)	0	T	1.3	T	9.6				115.3	P
1963	7.5	A	0	T	1.7	T	5.8				96.8	A [83-T]
1968	6.5	6(A)	0	T	1.2	T	5.3				120	T
1973	2.3	A	0	T	1.5	T	0.8				204.9	A
1974	1.5	A	0	T	0.6	T	0.9				300.7	A
1975	1.2	A	0	7	0	7	1.2				281.7	A
1976	1	A	0	7	0	7	1				372	A
1977	0.9	A	0	7	0	7	0.9				506	A
1978	0.75	A	0	7	0	7	0.75				501	A
	THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		£/TON	

TABLE A-2. Zinc Oxide : U.K. Production, Trade, Consumption, Price and Consumption by the Paint Industry 1907-1974

YEAR	U.K. PRODUCTION	NOTES	IMPORTS	NOTES	EXPORTS	NOTES	U.K. CONSUMPTION	NOTES	PAINT CONSUMPTION	NOTES	PRICE	NOTES
1893										5% that of white lead	19	[1893 DC]
1907	0	8(S,N)	14.5	T	4.5	T	10				22.9	T
1910											25	E.ii
1914							25	S			31	J
1925	16	G	11	G	2	G	25		18.9	9(C)	44.8	P
1930			12	M			30	10(M)			39.1	P
1935	48	B,R,A.	0.8	T	13.3	T	34.7				28	P
1937	52	B,R,A.	0.9	B	15	B	37.9				30	P
1945	45	R [B-41.5]	0	T	11	T	34				38	P
1946	63.9	B	0	B	22.8	B	41.1				49	P
1947	60.9	B	0	B	11.2	B	49.7				70	P
1948	61.8	A,B, [65-R]	0	T	14.2	T,B	47.6		24.5	C	71.3	11(C,R).
1949	49	B	Neg.	B	12.4	B	38.6				86	P
1950	54.3	B	Neg.	B	13.5	B	40.8				110.7	P
1951	44.6	A [40-B,R]	0.1	T [2-B]	0.8	B,T	43.9	A/T [41.3-B]			165	A [189 P]
1952	29.9	B	0.1	B	1.6	B	19.4	B			175.8	P
1953	27.9	B	0	B	4	B	23.9				103	P
1954	31.5	A [34.9B]	0	T,B	5.7	T [6.5B]	25.8	A/T [28.4B]	6.9	A-Purchases by large paint firms	91.4	C [96.3-P] [87.5A]
1955	37.7	B,R.	0	B	6.6	B	30.4				105.6	P
1958	44.2	A	0	T	9	T	35.2				60.7	A [93.P]
1963	40.2	A	0.2	T	7	T	33.4		3.1	12(C)	70.1	A(11) [71-T]
1968	33	A	0	T	4.6	T	28.4		1.62	12(C)	97.7	A
1973	26.7	A	0.9	T	9.7	T	17.5				298.6	A
1974	22.2	A	3.5	T	14.5	T	11.2		1.1	13(K)	317.3	A
	THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		£/TON	

TABLE A-3. <u>Lithopone : U.K. Production, Trade, Consumption, Price and Consumption by the Industry 1907-1968</u>

YEAR	U.K. PRODUCTION	NOTES	IMPORTS	NOTES	EXPORTS	NOTES	U.K. CONSUMPTION	NOTES	PAINT CONSUMPTION	NOTES	PRICE	NOTES
1907	1.5	I(14)	5	15(H)	0	15(H)	6.5				19	Q
1910			11.7	15(H)							22	Eiv [0-19]
1914											24	J
1921-1925	12	F(14)	13.3	F	0.8	F	24.5	F	11.5	16(C)	18	P-1925
1930	17	M(14)	20.6	T	1.2	T	36.4				19.5	P[20-T]
1934	44	A									15	A
1935	37.8	B.A. [38R]	10.4	T	6.6	T	41.6				18	P [14.2 A]
1937	46.7	B [47R]	15.6	T	7.9	T	54.4				17	P [14.4 A]
1945	36	R	0	T	7.6	T	28.4				26	P [1940 20P [1944 27P
1946	45.3	1.7(M)	0.1	T	6.4	T	39				28	P
1947	42.8	17(M)	0.3	T	3.8	T	39.3				30	P
1948	52.1	A [52.1B] [52 R]	1.2	T [1 B]	4.8	T [4.6B]	48.5		33.3	C	32.9	C [34.7A] [32.8R]
1949	50.8	17(M)	10.5	B	5.1	B	57.4	B [56.2] [(M17)]			36	P
1950	53.0	17(M)	12.1	B	7.1	B	57	B [58] (M17)]			40.1	P
1951	53.3	A [53.3B] [53 R]	14.7	B,T	4	B,T	64	B			62.2	A [63.1P]
1952	31.5	B	4.2	B	3.3	B	32.4	B			64.8	P
1953	39.7	B	3.3	B	2	B	41	B			51.3	P
1954	44.5	A [52 B]	2.1	T,B	4.6	T [2.9B]	42	[51.2B]	30.3	C	55	A [52.6C] [51.3P]
1955	50	R [56.1B]	2.3	T,B	2.1	T,B	50.2				52	P [50R]
1958	34.5	A	4.4	T	3.4	T	35.5				59	A
1963	23.8	A	2.1	T	4.1	T	21.8		14.7	18(C)	54.4	A
1968	Negligible		Negligible		Negligible		Negligible		-		-	
	Thousand Tons		Thousand Tons		Thousand Tons		Thousand Tons		Thousand Tons		£/Ton	

TABLE A-4. Antimony Oxide : U.K.Production, Trade, Consumption, Price and Consumption by the Paint Industry 1937-1955

YEAR	U.K. PRODUCTION	NOTES	IMPORTS	NOTES	EXPORTS	NOTES	U.K. CONSUMPTION	NOTES	PAINT CONSUMPTION	NOTES	PRICE	NOTES
1937											62	P
1939											38	P
1945	1.9	B	0	B	0.3	B	1.6		1.2	B	112	P
1946	3.1	B	0	B	0.3	B	2.8		2.2	B	115	P
1947	3.4	B	0	B	0.5	B	2.9		2.3	B	150	P
1948	3.5	B	0	B	0.9	B	2.6		1.9	B [2-A]	168	C
1949	2.9	B	0	B	1.1	B	1.8		1.5	B		
1950	3.3	B	0	B	2.6	B	0.7	B	0.5	B		
1951	4.1	B	0	B	2.7	B	1.4	B	1.1	B		
1952	1.5	B	0	B	N/A	B	0.8	B	0.6	B		
1953	2.6	B	0	B	N/A	B	1.5	B	1.2	B		
1954	2.9	B	0	B	N/A	B	1.7	B	1.2	[C-1.45]	188.3	C
1955	2.9	B	0	B	N/A	B	1.7	B	1.1	B		
	THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		£/TON	

TABLE A-5. Titanium Dioxide : U.K.Production, Trade, Consumption, Price and Consumption by the Paint Industry 1930-1978

YEAR	U.K. PRODUCTION	NOTES	IMPORTS	NOTES	EXPORTS	NOTES	U.K. CONSUMPTION	NOTES	PAINT CONSUMPTION	NOTES	PRICE	NOTES
1916	0	R										
1930	0		0		0		0				0	
1933	0.3	L	0		0		0.3	L				
1935	3.3	B,L	-		0.7	B	2.6	19			83.3	L
1937	6.2	19	-		1.7	19	4.5	19			70	P
1945	9	R	-		1.8	19	7.2	19			96	P
1946	11.5		-		2.3	19	9.3	19			96	P
1947	14	19	-		1.6	19	12.4	19			97	P
1948	15.8	A	-		1.8	19	14	19	9.9	C	91	R [88.6A] Paint Purchases [87.6 M Chem. Sales]
1949	23.8	19	-		3.7	19	20.1	19			102	T
1950	32.2	19	-		7.6	19	24.6	19			102	T [147.6L]
1951	35.8	A	0.1	B	7.1	19	28.8	19			115	T [120A]
1952	35.5	19	0.1	B	6.9	19	28.7	19			130	T
1953	54.4	19	0.9	T	17.4	19	37.9	19			130	T
1954	63.5	A	5.9	T	19.6	19	49.8	19	30.1	C	130	T [155] [193]
1955	67.3	19	4.4	B	22.1	19	49.6	19			142	T [157.9 L]
1958	89.3	A	(1.5)		(-)	T(19)	90.8		61	R	168.4	A
1963	125	A	(3.9)	T	(0.3)	T(20) (19)	128.6		58.2	C(20)	163	A
1968	148	A	(4.4)	T	(0.4)	T(19)	152		74.3	C(20)	175	A
1973	213.7	A	21.2	T	87.5	T	147.4				248.5	A
1974	183	A	19.9	T	83	T	119.6				358	A
1975	157	A										
1976	191	A										
1977	198	A										
1978	205	A										
	THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		THOUSAND TONS		£/TON	

TABLE A-6. Key to Sources of Information on Pigment Consumption (for Tables A-1 - 5)

KEY	DESCRIPTION	REFERENCE	REFERENCE NO.IN CHAPTER 2
A	Census figures for Sales by U.K. Pigment Manufacturers	G.B.Department of Trade *op.cit.* G.B. Census of Production *op.cit.*	62 and 61
B	Estimates by British Titan Products.	G.E.Watts, 1956, *op.cit.*	60
C	Census figures for Purchases by larger paint firms	G.B.Census of Production *op.cit.*	61
D	Evidence to 1893 Departmental Committee	G.B.Home Department [C.7239], 1894, *op.cit.*	3
E	Evidence to 1911 Departmental Committees by i)Pisart, ii) Despierres, iii)Miller, iv)Line	G.B.Home Department [Cmd.631] 1920, *op.cit.*	7
F	Evidence to 1921 Departmental Committee	G.B.Home Office, 1923, *op.cit.*	4
G	Statement by Montague to House of Commons	G.B.Parliamentary Debates, 1926, *op.cit*	68
H	Figures for (lithopone) imports from Germany	International Labour Office, 1927, *op.cit.*	69
I	Industry data	F.Armitage, 1967, *op.cit.*	33
J	Industry data	A.S.Jennings, 1914, *op.cit.*	70
K	Industry data (Lead Development Agency)	R.Smith, 1979, *op.cit.*	71
L	Industry data (Laporte Industries)	R.J.Wiggington, 1979, *op.cit.*	72
M	Industry data (Imperial Metal)	Cocks and Walters, 1968, *op.cit.*	16
N	Industry data	Remington and Frances, 1954,*op.cit.*	6
O		Sir Thomas Oliver, 1911, *op.cit.*	23
P	Spot prices for Pigments. Industry data	*Chemical Trade Journal and Chemical Engineer*, 1935-48 and *Industrial and Engineering Chemist* 1949-55, *op.cit.*	67
Q	Industry data	M.Petit, 1907, *op.cit.*	27
R		J.T.Richmond, 1957, *op.cit.*	11
S	Industry data	A.S.Jennings, 1915, *op.cit.*	73
T	Import and Export figures	G.B.Customs and Excise	

paints and colours ground in oil and water. In subsequent years, trade in lead paste is shown separately from other colours in paste form.

The figure for trade in white lead paste have been estimated on the assumption that the proportion of white lead paste in total paste trade is the same for 1924 as for 1925. The figures are as follows: (thousand tons):

1924	1925	1926	1930	
0.1	1.8	3.1	3.15	Imports of paste-total
N/A	1.6	3	3.1	Imports of white lead paste
N/A	0.88	0.97	0.985	White lead paste as proportion of total paste imports
19.8	25.9	28.7	11.8	Exports of paste-total
N/A	6.6	10.1	5.2	Exports of white lead paste
N/A	0.25	0.35	0.44	White lead paste as proportion of total paste exports.

Extrapolation back to 1924 yields estimates of white lead paste imports of 100 tons and exports of 5,000 tons. The figures are consistent with paste imports in subsequent years.

Since recorded imports and exports of dry white lead in 1924 were 6,600 tons and 8,800 tons, total imports and exports of white lead (dry and paste) of 6,700 tons and 13,800 tons respectively.

4. 1935-54 (A)

Census of Production returns for 1935, 1937, 1948, 1951, for white lead production, classified under the chemical industry, cover only dry white lead, recorded as 15.1, 14.6, 11.4, 11.6 thousand tons respectively. Other sources have been used for total white lead production have been used for these years.

5. 1958 (A)

The 1958 Census aggregates output of white lead (dry and paste) with other inorganic lead compounds (28,100 tons together). The 1963 Census shows these separately - and white lead comprises 21% of output of total inorganic lead compounds (7,500 out of 35,900 tons). Assuming that the proportion of white lead to other lead compounds is approximately constant, yields an estimate for production of white lead in 1958 of 10,900. Though the assumption underlying this estimate is tenuous, the estimate lies mid-way between the figures for production of white lead (dry and paste) for 1954 and 1963, and is probably acceptable.

6. 1958 (A)

The 1968 Census of Production shows white lead output with a value of £781,000. The weight is not given but has been estimated, using the average value of exports of white lead (£120/ton), as 6,500 tons.

7. 1975-78 (T)

After 1975, the trade figures do not identify white lead imports and exports. These have been assumed to be negligible.

Zinc Oxide

Zinc oxide is the substitute for white lead for which the earliest production/consumption figures. One paint maker noted at the 1893 Departmental Committee that zinc oxide consumption in paints was only 5% that of white lead. (D).

8. 1907 (S,N)

For 1907 zinc oxide production is assumed to be negligible on the strength of the statement by Cruikshank-Smith that "before 1908, practically all zinc oxide was imported".(S), confirmed by Remington and Frances (N).

9. 1924 (C)

The 1924 Census of Production states that returns from paint firms making up 55% of the total used 10,400 tons of zinc oxide. If the remainder consumed zinc oxide at the same rate, total consumption by the paint industry would be estimated at 18,900 tons (75% of total zinc consumption). However this estimate is of low certainty (see Note 16 lithopone).

10. 1930 (M)

In 1930, Cocks and Walters state that U.K. Consumption of Zinc Oxide is some 30,000 tons of which 12,000 to 14,000 tons was imported. Assuming that exports were minimal yields an estimate for U.K. production of 16-18,000 tons. The latter has been used.

11. 1948 (A,C,P)

From 1948 onwards there is an increasing divergence between the price of zinc oxide used by the paint industry (indicated by the published price of pigment in trade journals (P) and the average cost of pigments purchased by painting firms.(C)) and the average value of zinc oxide produced by the chemical industry.(A) This divergence reflects the emergence of a separate major market for zinc oxide (chiefly as a filler in rubber for tyres etc.) and the declining levels of sales to the paint industry. In the 1948-58 period, where multiple figures exist for zinc oxide price, median values have been used. Subsequently figures for chemical industry sales have been used.

12. 1963-68 (C)

Figures for purchases of zinc oxide by the paint industry from the 1963 and 1968 Censuses of Production are by value, not weight. The weight of pigment has been estimated from the average value of zinc oxide sales by the chemical industry. In the light of Note 11 above, this may underestimate the price of pigment sales to the paint industry and thereby overestimate the weight of pigment consumption.

13. 1974 (K)

Since 1974, the proportion of zinc oxide used in paint has been estimated at 10% of total U.K. consumption of zinc oxide (K).

Lithopone

14. 1907-1930 (I,F,M)

There are no Census of Production figures for lithopone production until 1934/1935. However in 1921, it was claimed that there was only one U.K. lithopone factory (Orr's Zinc White Company), which was currently producing 12,000 tons of lithopone "for the paint trade".(F)

Between 1900 and 1907 the output of this factory was 30 tons per week (I), and in 1930 output was 17,000 tons (M). In 1935, this factory accounted for over 80% of U.K. lithopone production (see Table A-7). It has therefore been assumed that the output of this factory in the earlier years accounts for the overwhelming bulk of U.K. lithopone production.

15. 1909-13 (H)

The International Labour Office records the exports of lithopone from Germany to Britain as 3,600 tons in 1909 and 5,400 tons in 1913. The other major exporter of lithopone was Belgium but figures for its trade with Britain are not known. If it is assumed that Germany accounted for 50% of U.K. lithopone consumption and that there was a steady trend of imports in this period a very crude and uncertain estimate of U.K. lithopone imports can be produced of 5,000 tons in 1907 and 11,700 tons in 1910. (Exports were presumably zero).

16. 1924 (C)

The Census of Production for 1924 states that returns from paint firms, comprising 55% of all paint firms, used 6,400 tons of lithopone. The comparable figures for white lead and zinc oxide were 12,500 and 10,400 [accounting for 38% and 40% respectively of total U.K. consumption of these pigments].

If it is assumed that the paint firms making returns consumed lithopone at the same rate of those not making returns, it can be estimated that total consumption of lithopone in paints was 11,500 tons.

This estimate for consumption of lithopone in the paint industry represents 47% of the total domestic consumption of lithopone (estimated in 1921 at 24,500 tons). This percentage is lower than might be expected since the major use of lithopone at that time was in paints (50% alone was used in distempers). It would appear that this estimate of lithopone consumption by the U.K. paint industry is an underestimate.

The proportion of U.K. white lead and zinc oxide consumption accounted for by the paint industry estimated in the same way is 68% and 75% respectively. The figure for white lead is also, almost certainly, an underestimate, since in 1910, over 90% of white lead was consumed in paint making.(E) If it is assumed that paint industry consumption is under-estimated equally in the 1924 Census figures, and that 90% of white lead was used in paint making in 1924, an alternative set of estimates of paint industry consumption of lithopone, white lead and zinc oxide can be produced at 15,160, 19,600 and 24,630 tons respectively (accounting for 62%, 90% and 95% of total U.K. consumption respectively). This second set of estimates must be seen as an upper limit, and the first set as a lower limit of probable paint industry consumption. The latter estimates are recorded in Tables 6.1,2 and 3. This question is discussed further below.

17.1946-50 (M)

No figures are available for U.K. lithopone production for the years 1946, 1947, 1949, 1950. Figures do exist for the output of the largest lithopone producer, Imperial Metal (which took over Orr's Zinc White Co.), which accounts for some 80% of total production in this period.(M) The proportion of total lithopone production accounted for by Imperial Metal has been calculated in Table A-7. This proportion has been extrapolated for the years 1946, 1947, 1949 and 1950, assuming a linear trend between 1945 and 1948 and 1948 and 1951. An estimate of U.K. lithopone production has thereby been produced for these years.

18.1963 (C)

Purchases of lithopone by larger establishments in the paint industry are worth £801,000. Though the weight of lithopone is not given, it can be estimated from the average price of U.K. production of lithopone by the chemical industry (£54.4/ton) to be 14,700 tons.

After 1963, lithopone production and consumption virtually ceases.

Antimony Oxide

Figures for production and consumption of antimony oxide are available for only a few years, from the British Titan Products paper (B) and the 1948 and 1954 Censuses of production. Antimony Oxide was being marketed as a pigment for paints before 1921. However its use remained limited - it was more expensive than white lead though it had better covering power - and it was one of the first pigments to succumb to competition from Titanium Dioxide. The figures, where available, are reproduced in Table A-4.

TABLE A-7. Estimate of U.K. Lithopone Production from Lithopone output by Imperial Metal (formerly Orr's Zinc White Co.).

YEAR	U.K.PRODUCTION OF LITHOPONE (THOUSAND TONS) MOST RELIABLE ESTIMATE	IMPERIAL METAL, PRODUCTION OF LITHOPONE (THOUSAND TONS)	OUTPUT OF LITHOPONE BY IMPERIAL METAL AS PERCENTAGE OF TOTAL U.K. PRODUCTION. %	ESTIMATE OF IMPERIAL METAL LITHOPONE OUTPUT AS A PERCENTAGE OF TOTAL U.K. PRODUCTION %	ESTIMATED TOTAL U.K. OUTPUT OF LITHOPONE (THOUSAND TONS)
1935	37.8	30.7	81.2		
1937	46.7	35.3	75.6		
1938		30.8	-		
1944		29.3			
1945	36.	31.4	87.2		
1946		37.0		81.7	45.3
1947		32.6		76.1	42.8
1948	52.1	36.8	70.6		
1949		37.7		74.1	50.8
1950		41.2		77.6	53.0
1951	53.3	43.2	81.1		
1952	31.5	17.9	56.8		
1953	39.2	22.8	58.2		
1954	44.5 (*52)	24.3	54.6 (*46.7)		
1955	50. (*56.1)	24.4	48.8 (*43.1)		
1958	34.5	17.3	50.1		

(* figures for lithopone output considered less reliable).

Titanium Dioxide

19. 1935-55

The Paper from British Titan Products (B) gives detailed figures for its own production and exports between 1935 and 1955, and estimates the production and exports of the other British manufacturer, Laporte Industries. However these estimates differ for some years with figures supplied by Laporte (L) (available for 1935, 1940, 1945, 1950, 1955) and from the returns of the Censuses of Production (A) (available for 1948, 1951, 1954).

A set of revised estimates of Laporte's production and exports have been produced using a 'best-fit' curve method, prioritising the Laporte and census data where there was discrepancy. This gives the best picture of general trends, though it does not give an indication of reversals in this trend. Any inaccuracies involved are of minor significance due to the rapidly escalating levels of production and because Laporte Industries output was significantly smaller than B.T.P.

The adjusted estimates have been used to produce a best estimate of titanium dioxide consumption for 1935-1955. The various figures (data and estimates) are recorded in Table A-8.

20. 1955-78

In this period it is necessary to rely on official statistics alone. However there is a sharp discrepancy, between industry estimates of imports and particularly exports of titanium dioxide (which are substantial and increasing rapidly in 1955) and the figures on trade in titanium dioxide produced by the Customs and Excise between 1955 and 1968. The latter only cover pure titanium dioxide and ignore mixtures of pigments containing titanium dioxide (reduced titanium dioxide).

Figures for imports and exports of materials based on titanium dioxide are available from 1970 and show substantial levels of trade, particularly of exports, of materials based on titanium dioxide. These are shown in Table A-9.

It is difficult to estimate reliable figures for trade in titanium dioxide because no figures are available for the titanium dioxide content of pigment mixtures. Similarly there is uncertainty in the estimates of pigment prices (based on value and tonnage of chemical industry sales of titanium dioxide) and their use to calculate the weight of pigment consumed by the paint industry (1963, 1968) and pigment exports (1963) from figures for the value of these sales. No attempt has been made to correct for this factor, which is of minor significance for the subsequent analysis since by this stage, titanium dioxide consumption is growing very rapidly and comes to exceed all other white pigments.

TABLE A.8 : Estimated U.K. Production and Consumption of Titanium Dioxide (thousand tons) 1935-1955

Source: British Titan Products (B.T.P.) Figures for its production and exports of Titanium Dioxide, and B.T.P. estimates of total imports and Laporte Industries' production and exports (B)
- Laporte Industries Figures for its production of Titanium Dioxide (L)
- Census of Production (A) and other figures for U.K. production of Titanium Dioxide
- Customs and Excise figures for imports of Titanium Dioxide (T)

B.T.P. estimates have been revised on the basis of other data (L, A, T), to yield best estimates of U.K.production, trade and consumption of Titanium Dioxide.

YEAR	1935	1937	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
Best Estimate of Total Consumption	2.6	4.5	7.2	9.3	12.4	14	20.1	24.6	28.8	28.7	37.9	49.8	49.6
Best Estimate of Total Exports	0.7	1.7	1.8	2.3	1.6	1.8	3.7	7.6	7.1	6.9	17.4	19.6	22.1
Adjusted Estimate of Laporte Exports	-	0.1	0.2	0.2	0.3	0.4	0.4	0.4	0.8	1	2	2.5	3.2
B.T.P. Estimate of Laporte Exports (B)			0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	1	2.5	3.8
B.T.P. Estimate of Exports (B)	0.7	1.6	1.6	2.1	1.3	1.4	3.3	7.2	6.3	5.9	15.4	17.1	18.9
Customs and Excise Estimate of Imports (T)									N/A	0.05	0.9	5.9	
B.T.P. Estimate of Imports (B)				-	-	-	-	-	0.1	0.1	0.1	5.9	4.4
Best Estimate of Total Production	3.3	6.2	9	11.5	14	15.8	23.8	32.2	35.8	35.5	54.4	63.5	67.3
Total Production (A)						15.8			35.8			63.5	
Total Production (R)	4	6	9			16			36				50
Total Production = B.T.P. Production & Estimate Laporte Production		6.2		11.5	14		23.8			35.5	54.4		
B.T.P. Estimate of Total Production (B)			9	11.2	12.7	13.2	21.4	31	31	28.5	48.7	63.1	69.6
Adjusted Estimate of Laporte Production		1		2	3	4.5 (A)	4.4		7.8 (A)	10	11.6	13.1 (A)	
B.T.P. Estimate of Laporte Production (B)		-	1.7	1.7	1.7	1.9	2	3	3	3	5.9	12.7	15.8
Laporte Production (L)	0.6	(1.5 1940)	1.7					4.2					13.3
B.T.P. Production (B)	2.7	5.2	7.3	9.5	11	11.3	19.4	28	28	25.5	42.8	50.4	54

TABLE A-9. U.K.Imports and Exports of Titanium Dioxide and Materials Based on Titanium Dioxide 1958-1974 (thousand tons)

Source : G.B.Customs and Excise.

YEAR	IMPORTS			EXPORTS			
	Pure Titanium Dioxide	Materials based on Titanium Dioxide	Total Imports	Pure Titanium Dioxide	Materials based on Titanium Dioxide	Total Exports	Exports of Titanium Dioxide based mater:
1974	18.1	1.8	19.9	28	55	83	63.1
1973	6.6	14.6	21.2	6.5	81	87.5	66.3
1972	10	14	24	10	74	84	60
1971	13	8	21	10	57	67	46
1970	15.4	11	26.4	37.8	19.4	57.2	30.8
1968	4.4	N/A	N/A	0.4	N/A	N/A	N/A
1963	3.9			0.3			
1958	1.5			N/A			

APPENDIX A-2

Proportion of Pigments Consumed in Making Paint

Appendix A-1 contains figures for the quantity of the major white pigments used in making paints. The chief source of this information was the Census of Production (conducted in 1924, 1948, 1954, 1963, 1968)[61] which lists purchases of the major white pigments by larger paint firms only. There are three problems in the validity of these statistics:

i) They may not cover direct purchases by painting firms of raw materials to be mixed into paint on site - which was the predominant practice at the turn of the century and continued even after the Second World War (especially for white lead/linseed oil paints and lithopone based distempers). These pigments may not show up in the statistics unless they were purchased from a paint mixing firm. Thus, especially for earlier years, these figures may underestimate pigment consumption in paint.

ii) The statistic only covers purchases by larger firms employing 25 or more persons (except for 1924). The smaller firms accounted for 16% of the output (in financial terms) of the paint industry in 1930 and 1935, 10.8% in 1948, 9.4% in 1951, 8.7% in 1954 and 9.5% in 1968.[87] Thus a significant proportion of pigment consumption may be excluded from the Census statistic.

iii) The 1924 Census figures are only based on incomplete returns (covering 55% of paint making firms) and the statistical methods of estimation are poorly developed. The correction applied to these figures was discussed in Appendix A-1.

Some indication of the extent of underestimation is possible in the case of white lead.

The Census of Production figures show between 64-73% of white lead used in paint making whilst other sources (for 1910 and for the 1970s, see below) indicate the true figure to have been 90% or more. The implication is that between 20% and 40% of paint industry consumption of white lead is not recorded in the Census of Production figures. There is no information that would allow a similar correction to be made in the case of the other pigments. The consumption of the different pigments in paint making and other industries is discussed for each pigment in turn.

White Lead

The figures for white lead consumption in paint in 1910 are reliable. The only other significant use identified for white lead was in putty.

The subsequent estimates for the proportion of white lead used in paints are almost certainly significant underestimates. The Lead Development Association estimated that until the 1950s, at least 90% of white lead was used in making paints.[88]

Zinc Oxide

Around 1930, the primary outlet for zinc oxide was in paints (in particular enamels). However by the 1960s it was used mainly as a filler in rubber for tyres - an application that had been expanding steadily since it was developed by Dunlop in 1910. Growth in this application explains why the proportion of zinc oxide used by the paint industry falls from 1925 onwards, though the volume of zinc oxide consumed in paints probably increases between 1925 and 1945. Other applications of zinc oxide were in pharmaceuticals, cosmetics and ceramics and glass.[89]

Lithopone

The proportion of lithopone used in paint making is remarkably constant over this period right up until the eventual disappearance of the product altogether.

The other significant use of lithopone was in the linoleum industry.

It appears that lithopone was being displaced simultaneously in its various (paint and non-paint) applications by titanium dioxide.

Titanium Dioxide

The principal outlet for Titanium Dioxide was initially for paints, but in the 1950s increasing demand was noted in the rubber, elastic and linoleum industries and in vitreous enamels and ceramics (especially electrical resistors). Other applications were also noted in synthetic fibres, leather finishes, cosmetics, paper making where a highly opaque pigment provided colour without impairing material properties. Currently[90] the major non-paint use for titanium dioxide is as a filler in plastics.

Whilst the proportion of total titanium dioxide consumption used in paint falls below 50% in 1963 and 1968, this reflected the saturation of the paint market by titanium dioxide. Titanium dioxide as a proportion of white pigments used in paints rises from 33.9% in 1954 to 72.7% in 1963 and 93.3% in 1968.

It cannot be assumed that the Census of Production figures underestimate the consumption of the major pigments to an equal extent over this period. The uncorrected data have therefore been used (the sources are described in Appendix A-1).

Consumption of pigments in paint for 1963 and 1968 have been estimated for zinc oxide, lithopone and titanium dioxide from the value of purchases. The proportion of all white lead used in paints has been estimated as 70% to bring it in line with preceding years.

The figures for consumption of major white pigments in paints are presented in Table A-10 in Thousand tons per year and expressed as a percentage of total consumption of each pigment by all U.K. industries.

TABLE A-10. Consumption of White Lead, Zinc Oxide, Lithopone, Titanium Dioxide by the U.K. Paint Industry and by all U.K. Industries 1910-1968

YEAR	WHITE LEAD				ZINC OXIDE				LITHOPONE				TITANIUM DIOXIDE				TOTAL FOR MAJOR WHITE PIGMENTS		
	Total Cons.	Paint Cons.	%	Notes	Total Cons.	Paint Cons.	%	Notes	Total Cons.	Paint Cons.	%	Notes	Total Cons.	Paint Cons.	%	Notes	Total Cons.	Paint Cons.	%
1910	52	49	94.2																
1924*	33.3	22.7	68	U,E	25	18.9	75.6	U,E	24.5	11.5	53	U,E	0	0	0		82.8	53.1	64.1
1948	23.1	14.8	64.1		47.6	24.5	51.5		48.5	33.3	68.5		14	9.9	70.7		133.2	82.5	61.9
1954	13.3	9.7	72.9		25.8	6.9	26.7		42	30.3	72.1		49.8	30.1	60.4		130.9	77	67.8
1963	5.8	4	70	E	33.4	3.1	9.3	E	21.8	14.7	67	E	128.6	58.2	45.3	E	189.6	80	42.2
1968	5.3	3.7	70	E	28.4	1.62	5.7	E	0	0	0		152	74.3	48.9	E	185.7	79.6	42.9

KEY :

Tot.Cons. - Total U.K. Consumption of Pigment (Thousand Tons)

Paint Cons. - Consumption of Pigment by U.K. Paint Industry (Thousand Tons)

% - Percentage of Total Pigment Consumption used by Paint Industry

E Indicates Estimated Figure

U Indicates validity highly uncertain

* Figures for 1925 et seq. probably underestimate paint industry consumption

Source: Census of Production and Appendix A-1 and A-2

Table A-11 shows the relative consumption of each of the major white pigments (consumption of individual pigment as a percentage of consumption of all the major white pigments) for both consumption by the U.K. paint industry and for all U.K. industries (in this way the effects of underestimation of paint industry consumption of pigments are minimised).

Finally, Table A-12 shows the combined consumption of the major white pigments by the U.K. paint industry and all U.K. industries.

These data indicate that the volume of pigments consumed in paints has been relatively static, whilst consumption outside the paint industry has grown substantially (the latter accounts for 35.9% of white pigment consumption in 1924 and 57.1% by 1968). However there is considerable variation between industries. Thus paint consumption accounts for a high proportion of total U.K. consumption of white lead and lithopone throughout. The proportion of zinc oxide consumed in paints is initially high (1924) but falls rapidly and is as low as 5.7% by 1968.

These differences will be discussed later.

TABLE A-11. Relative Consumption of White Lead, Zinc Oxide, Lithopone, Titanium Dioxide 1924-1968 as a percentage of combined consumption of major white pigments.
- Total domestic consumption by all industries
- Consumption by U.K. paint industry.

YEAR	WHITE LEAD		ZINC OXIDE		LITHOPONE		TITANIUM	
	Total Cons.	Paint Cons.	Total Cons.	Paint Cons.	Total Cons.	Paint Cons.	Total Cons.	Paint Cons.
1924	40%	42.7%	30%	35.6%	30%	21.6%		
1948	17%	17.9%	35.7%	29.7%	36.4%	40.4%	10.5%	12%
1954	10%	12.6%	19.7%	9.0%	32.7%	39.3%	38%	39.1%
1963	3.1%	5%	17.6%	3,9%	11.5%	18.4%	67.8%	72.7%
1968	2.9%	4.6%	15.3%	2%	0%	0%	81.9%	93.3%

KEY :

Tot.Cons % - U.K. Consumption of Pigment (All Industries) as percentage of total U.K. consumption of major White Pigments.

Paint Cons% - Consumption of Pigment by U.K. paint industry as percentage of total consumption by paint industry of major White Pigments.

Source: Table A-10

TABLE A-12. Combined Consumption of Major White Pigments by U.K. Paint Industry and All U.K. Industries 1924-1974

THOUSAND TONS. (White Lead, Zinc Oxide, Lithopone, Titanium Dioxide)

YEAR	Consumption by all U.K. Industries	Consumption by Paint Industry
1924	82.8	53.1
1930	98.4	
1935	116.6	
1937	133.5	
1945	90.3	
1946	115.1	
1947	127	
1948	133.3	82.5
1949	131.6	
1950	141.6	
1951	159	
1952	88.7	
1953	115.3	
1954	130.9	77
1955	142.5	
1958	171.7	
1963	189.6	80
1968	185.7	79.6
1973	232.1	
1974	185.4	

Methods of Adjustment of Pigment Price for the Effects of Inflation

Two methods have been used to convert the historical prices of pigments to inflation adjusted prices, described as relative price and weighted price.

Relative Price

This is the price of a given pigment relative to the weighted average price of all the major white pigments sold in that period. This average price is calculated by dividing the total value of major white pigments consumed by the total weight of such pigments (white lead, zinc oxide, lithopone and after 1935, titanium dioxide).

This index has the advantage of picking out the factor underlying pigment choice, the price of a pigment relative to its competitors, and eliminating the effects of inflation.

It is 'unreal' insofar as the relative price of a pigment whose historical price may be stable can shift because of changes in the price and consumption of other pigments. By the same fact, shifts in the historical price of a pigment that dominates the market are not reflected in the relative price of that pigment, which converges to unity.

Because of these weaknesses, and because relative price can only be calculated for those years in which both price and consumption are known for all the major white pigments, a different method of accounting for inflation was also adopted.

Weighted Price

The 'real' price (i.e. the price of a pigment independent of inflation) of pigments is calculated by multiplying the historical price of the pigment multiplied by an "index of the internal purchasing power of the pound".[91] This index is derived from (the inverse of) the Cost of Living Index 1914-1938, and the Consumer Price Index 1938-1968.[91,92] The former is based on the prices of consumer products and services weighted according to the pattern of consumption of work class households; the latter is based on price of goods weighted according to the pattern of consumption of all households. The two indices are therefore not strictly comparable. For the years prior to 1914 the index of purchasing power was calculated from the index numbers of retail prices of food, coal and clothing. For the years after 1968, the index of purchasing power of the pound was calculated from the General Index of Retail Prices. This is derived from a much more complex set of weightings derived from data on the overall pattern of consumer purchases. However for the years 1962-1968 it deviates by less than 1% from the Consumer Price Index figures.

The figures for the index of internal purchasing power of the period are given in Table A-13.

TABLE A-13. Index of the Internal Purchasing Power of the Pound 1907-1974

Year	Index of Internal Purchasing Power of the Pound.
1974	49.8
1973	51.7
1968	83.3
1963	100
1958	110.6
1955	122.4
1954	126.6
1953	128.9
1952	131.1
1951	138.9
1950	151.5
1949	155.8
1948	159.5
1947	171.8
1946	183.5
1945	184 (Est'd)
1937	314
1935	339
1930	307
1924	277
1914	485
1910	492
1907	519.8

Source: G.B.Department of Employment, 1970, op.cit.[91]; 1975, op.cit.[92].

Since the relative prices of different goods and services may change over time, it is not acceptable to measure inflation from variation in price of a single good. However since the pattern of consumption also changes over time, price indices may also become unrepresentative over time. An additional problem arises because no single price index is available for the whole period, and it is necessary to use indices with four different bases. They are not strictly comparable. For example, the cost of manufactured goods has only figured significantly since the 1960s. For these reasons, the index of internal purchasing power of the pound is an imperfect adjustment factor for inflation, particularly over long periods of time. Wholesale price indices, produced from the censuses of production for manufactured goods and for chemical and allied products, are available for some of the period under study.[93] In the interwar years, the latter is some 20% lower than the Cost of Living Index, although the discrepancy is less marked since 1945 (the correlation coefficient between the census of production price index and the retail price index is very high 0.98).

Despite these possible errors in the weighted price index it was judged to be adequate for the current task of offsetting the order of magnitude shift in the historical prices of pigments in the period under examination.

The weighted price of pigments was calculated by multiplying the historical price per ton of each pigment by the index of internal purchasing power of the pound (1963=100) and dividing the product by 10,000 to give a price series revolving approximately around 1. The scale and the range of weighted prices (0.48 - 2.82) thus obtained is very similar to the series of relative prices (range 0.41 - 2.85).

The advantages and disadvantages of using 'weighted prices' are the reverse of the 'relative price' series. Weighted prices are not affected by changes in pigment consumption, and can be calculated where pigment consumption and price is not known for all pigments. Weighted prices are more 'real' in that they potentially show changes in the absolute price of pigments (i.e. changes in weighted price reflect more than changes in price relativities between pigments) although such changes may incorporate significant errors particularly in long term comparisons, and due to uneven timing of price inflation between types of goods.

Because of the complementary strengths and weaknesses of the two inflation adjustments used, subsequent calculations have been duplicated, using both sets of prices. This has made it possible to pinpoint any artefactual relationships that might arise from the use of one or other index.

The 'relative price' of the major white pigments (1924-1974) and the 'weighted price' (1907-1974) are presented in Tables A-14 and A-15. The former are plotted in Figure A-1 (c.f. figure 3-12; 'weighted' prices of major white pigments).

TABLE A-14. 'Relative Price' of Major White Pigments 1924-1974

Historical Price of Pigment per ton divided by Average historical Price of Major White Pigments per ton (Combined Value of Major White Pigments divided by Combined Tonnage of Pigments).

YEAR	WHITE LEAD	ZINC OXIDE	LITHOPONE	TITANIUM DIOXIDE
1924	1.19	1.24	0.50	-
1930	1.27	1.20	0.60	-
1935	1.33	0.96	0.62	2.85
1937	1.57	0.96	0.54	2.24
1945	1.33	0.87	0.60	2.20
1946	1.39	0.97	0.56	1.90
1947	1.61	1.02	0.44	1.42
1948	1.75	1.05	0.48	1.34
1949	1.68	1.21	0.51	1.44
1950	1.57	1.32	0.48	1.22
1951	1.57	1.40	0.53	0.98
1952	1.40	1.45	0.56	1.07
1953	1.42	1.05	0.53	1.34
1954	1.32	0.93	0.56	1.32
1955	1.36	1.03	0.51	1.38
1958	0.91	0.73	0.46	1.32
1963	0.73	0.53	0.41	1.23
1968	0.74	0.60	-	1.08
1973	0.81	1.18	-	0.98
1974	0.84	0.89	-	1.01

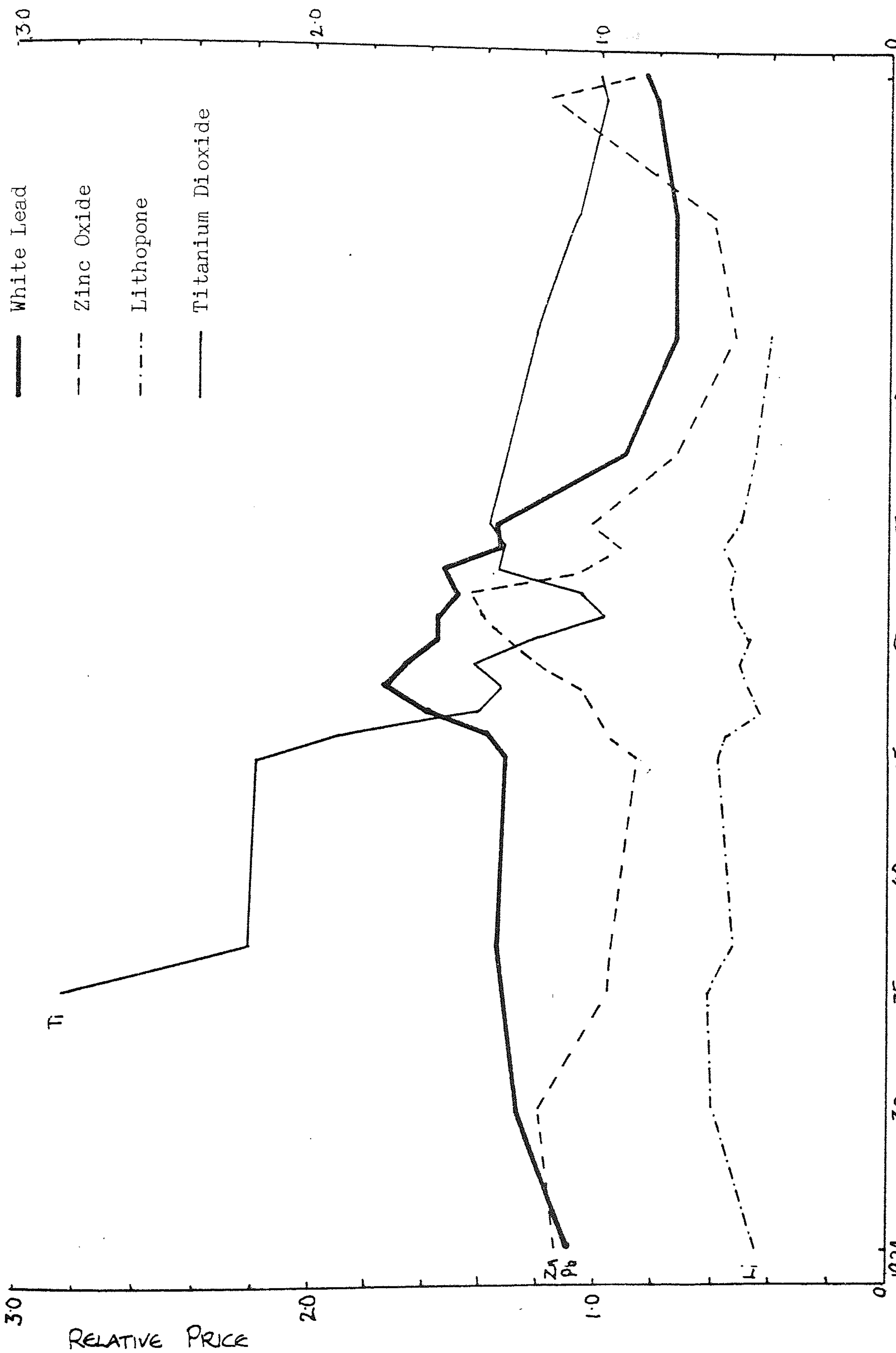
Calculated from data in Appendix A-1

TABLE A-15. 'Weighted Price' Major White Pigments 1907-1974

Year	WHITE LEAD	ZINC OXIDE	LITHOPONE	TITANIUM DIOXIDE
1907	1.14	1.19	0.99	-
1910	1.13	1.23	1.08	-
1914	1.22	1.50	1.16	-
1924	1.19	1.24	0.50	-
1930	1.26	1.20	0.60	-
1935	1.32	0.95	0.61	2.82
1937	1.54	0.94	0.53	2.20
1945	1.07	0.70	0.48	1.77
1946	1.30	0.90	0.51	1.76
1947	1.89	1.20	0.51	1.67
1948	1.90	1.14	0.52	1.45
1949	1.85	1.34	0.56	1.59
1950	1.99	1.68	0.61	1.54
1951	2.55	2.29	0.86	1.60
1952	2.22	2.30	0.85	1.70
1953	1.78	1.33	0.66	1.68
1954	1.64	1.16	0.70	1.65
1955	1.70	1.29	0.64	1.74
1958	1.28	0.67	0.65	1.86
1963	0.97	0.70	0.54	1.63
1968	1.00	0.81	-	1.46
1973	1.18	1.54	-	1.28
1974	1.47	1.58	-	1.78

Weighted Price produced by multiplying historical pigment cost by Index of Internal Purchasing Power of Pound (Table A-13) (divided by 10,000 to yield range of prices around 1.). Historical pigment cost from Appendix A-1.

Fig A-1 RELATIVE PRICE OF MAJOR WHITE PIGMENTS 1924 - 1974



(Cost per ton of pigment, divided by average value of all white pigment sales)

Source: Table A - 14

APPENDIX A-4.

Calculation of the Statistical Relationship between Market Share and Price of Major Pigments

The correlation coefficient and the regression equation between market share and price were calculated for the various white pigments, for the whole period 1924-1974 and for separate parts of that period (in particular distinguishing the period before and after titanium dioxide established a significant market share - the results shown below distinguish between 1924 1952 and 1952-1974. Use of a different 'mid-point' did produce moderate changes in the coefficients).

The figures for market share are for the relative consumption of pigments by all U.K. industries.

Both methods of inflation adjustment of price were used in the calculations (weighted price and relative price). For details of these see Appendix A-3.

TABLE A-16. Correlation Coefficient (R) between Market Share and Price of Major White Pigments. 1924-1952-1974

Using 'Relative Prices'

LEAD	ZINC	LITHOPONE	TITANIUM DIOXIDE	PERIOD
0.44	0.29	0.91	- 0.16	1924-1974
- 0.66	- 0.76	0.02	- 0.03	1924-1952
0.93	0.10	0.94	- 0.74	1952-1974
- 0.79				1924-1950

Using 'Weighted Prices'

LEAD	ZINC	LITHOPONE	TITANIUM DIOXIDE	PERIOD
- 0.13	- 0.21	0.84	- 0.15	1924-1974
- 0.84	- 0.79	0.55	0.27	1924-1952
0.74	- 0.09	0.92	- 0.48	1952-1974

TABLE A-17. Regression of Market Share on Price of Major White Pigments. 1924-1952-1974

Independent Variable - Pigment Price (x)
Dependent Variable - Market Share (y)
Regression equation - y = A + B(x) calculated.

* indicates that the standard error of the coefficient is greater than ½ value of the coefficient.

Relative Price

LEAD	ZINC	LITHOPONE	TITANIUM	COEFFICIENT	PERIOD
0.16*	0.10*	0.64	- 0.07*	B	1924-1974
0.05*	0.14*	0.02*	0.43	A	
- 0.32	- 0.18	0.01*	- 0.03*	B	1924-1952
0.68	0.52	0.36	0.11*	A	
0.13	0.02*	0.61	- 1.22	B	1952-1974
- 0.08	0.15*	0.01*	2.04	A	

Weighted Price

LEAD	ZINC	LITHOPONE	TITANIUM	COEFFICIENT	PERIOD
- 0.15	- 0.07	0.14*	0.03*	B	1924-1952
0.48	0.40	0.27	0.06*	A	
0.07	- 0.01*	0.04	- 0.93*	B	1952-1974
- 0.06*	0.18	- 0.01*	2.13	A	

APPENDIX A-5.

Discussion of Methodology : Weaknesses and Possible Developments of the Fisher-Pry Model.

This appendix deals with the weaknesses of the method adopted - in terms of further elaboration of similar models.

An alternative method is presented of calculation of substitution rate, on a hiding power rather than a weight basis.

An extension of the Fisher Pry methodology is proposed for an international comparison of the effects of regulation on substitution.

Limitations of Fisher Pry methodology for the purposes of this study are discussed particularly regarding incorporating pigment price and utility into our model. Models of technological substitution involving price and utility are reviewed and an alternative method of detecting the effects of these factors is suggested.

Weaknesses of the Method Adopted : in terms of further developments of similar models.

The Fisher-Pry model has provided a useful method of aggregating and summarising large volumes of consumption data. The method used, of treating each pigment separately and plotting its substitution rate against all their pigments, is simplified and can only be seen as a first approximation. In a multi-product market, an old product may be competitively substituted by an intermediate product, and both may subsequently be displaced by a newer more competitive product (at different rates).[109] In addition, there are difficulties in applying this model to total pigment consumption due to the internal differentiation of markets.[110] Whilst these problems are of little significance in the period in which titanium dioxide is displacing other pigments, they may be more significant in the preceding period. For example, it would seem that the lack of a clear trend for zinc oxide substitution in 1924-1945 might be a consequence of its competitively displacing white lead, while at the same time being displaced by lithopone.

Some confirmation that this was indeed the situation can be obtained from figures for white lead and zinc oxide consumption and estimates of lithopone consumption for 1907. These indicate that in the period 1907-1924, zinc oxide had a positive substitution rate (i.e. it was displacing white lead consumption), which appears to 'tail off' after 1924. These figures and estimates are discussed below.

Note on Pigment Consumption in 1907.

Figures are available for white lead and zinc oxide consumption in 1907. (33,900 and 10,000 tons respectively) and lithopone consumption has been estimated at 6,500 tons, though this estimate is highly uncertain. This yields an estimate of market share of white lead, zinc oxide and lithopone of 0.673, 0.198 and 0.128 respectively (Fisher-Pry coefficients 0.313, -0.576 and -0.836).

One method of checking the estimate of lithopone consumption is by extrapolating the value for 1907 from the Fisher-Pry plot for the 1924-1945 period which yields an estimate of the Fisher-Pry coefficient of white lead and lithopone of 0.175 and -0.525, equivalent to a relative consumption of 0.599 and 0.230. The trend for zinc oxide is unclear. However since the remainder of the market share must be zinc oxide, zinc oxide consumption would be estimated as having 0.171 of the market. Knowing the actual consumption of white lead and zinc oxide, the total white pigment market can be calculated as 56,600 tons or 58,500 tons respectively yielding estimates of lithopone consumption of 12,700 tons or 14,600 tons.

This method of extrapolation yields an estimate of lithopone consumption which is much higher than the original estimate, and substantially exceeds zinc oxide consumption. However, at this time lithopone was rarely mentioned as a pigment, unlike zinc oxide. This fact would be difficult to reconcile with a situation in which lithopone consumption exceeded that of zinc oxide. The second method of estimating is therefore rejected. However it provokes two observations :

i) The market share of zinc oxide in 1907 is estimated as 0.198 by the first method and as 0.171-7 by the second method. (Fisher-Pry co-efficient -0.576 and 0.668 to 0.686). Both of these are substantially lower than the market share of zinc oxide in the period 1924-1945 and indicate that zinc oxide was competitively substituting other white pigments (i.e. white lead) between 1907 and 1924 with a substitution rate in the Fisher-Pry plot of approximately 0.027

The positive substitution rate for zinc oxide in the 1907-1924 period and its 'levelling off' in the 1924-1945 period in the face of growing lithopone consumption would conform to the pattern expected in the Fisher-Pry and related models of technological substitution when a competitive challenger (zinc oxide for white lead) was overtaken by a more competitive new product (lithopone for zinc oxide and white lead).

ii) If the first estimate of lithopone consumption in 1907 (6,500 tons) is correct, the Fisher-Pry coefficients for lithopone and zinc oxide are lower and for white lead are higher than would be predicted by extrapolation from the Fisher-Pry plots for 1924-1945. This would indicate that the rate of displacement of white lead and its substitution by zinc oxide and lithopone were greater in the 1907-1924 period than the 1924-1945 period. This change in substitution rates could be explained by a variety of factors including shifts in the price differential between the pigments in this period (see figure 3.11), concern about the hazards of lead pigments/regulation of hazard, and internal differentiation or differential growth of pigment markets - for example, the existence of sectors of the paint market in which lead pigments were readily displaced by zinc pigments [e.g. distempers, other interior paints] or the growth of other markets readily penetrated by zinc pigments [e.g. zinc oxide for tyre making].

Calculation of Substitution Rate and Price of Major White Pigments on a Hiding Power Basis

The importance of price per unit hiding power (rather than price per ton) of pigments in explaining the rate of pigment substitution suggests an alternative method of charting the process of substitution. The preceding calculations have been based on weight of pigments consumed. However, one ton of titanium dioxide in paint could obscure up to ten times the area that could be covered by one ton of white lead.

The consumption of major white pigments has therefore been calculated on a hiding power basis = pigment consumption (tons) x relative hiding power of pigment.

The values used for Relative Hiding Power are

White Lead = 1, Zinc Oxide = 1.4,
Lithopone = 2, Titanium Dioxide = 8.

Relative Consumption (or market share, f) and the Fisher-Pry Coefficient and its regression on year (1900 = 0) have been calculated for consumption of major white pigment on a hiding power basis. The results are presented in Tables A-18 and A-19 and Figures A-2 and A-3.

'Pigment Price per unit of hiding power' has been calculated by dividing the weighted price of the pigment by the relative hiding power. The results are presented in Table A-20 and Figure A-4.

The effects of comparing price on a hiding power basis rather than a weight basis have already been discussed.

Pigment Substitution on a Hiding Power Basis

The effect of charting pigment substitution on hiding power, rather than a weight basis is to show those pigments with a higher hiding power as having a greater market share (titanium dioxide, and to a lesser extent lithopone).

The slope of the Fisher-Pry plot (of log f/1-f against year) for the various pigments is broadly similar. However, the transition period (resulting from the advent of titanium dioxide on the market) and the mid-point of substitution and displacement appear earlier (i.e. the substitution appears to take place earlier than in the Fisher-Pry plot of consumption on a weight basis). The reasons for this become clear from consideration of a simple substitution process between product A(new) and B(old), the Fisher-Pry equation has the following form (comparison on a weight basis).

$$\text{Log} \frac{f}{1-f} = \phi t + C = \log \frac{\text{Sales A (weight)}}{\text{Sales B (weight)}}$$

If product A is X times more effective on a weight basis then product B, (functional equivalence ratio = X. see below) the Fisher-Pry equation will be :

$$\text{Log} \frac{X : \text{Sales A}}{\text{Sales B}} = \phi t + C = \log X + \log \frac{\text{Sales A}}{\text{Sales B}}$$

$$\text{i.e. } \log \frac{\text{Sales A}}{\text{Sales B}} = \phi t + C - \log X.$$

In other words in this simple example, the slope of the Fisher-Pry plot is unaltered by considering consumption in units of functional equivalence (rather than weight) though the constant is altered.[111]

In a multiproduct substitution, considering substitution in units of functional equivalence (rather than weight) is more complex and can also affect the slope of the Fisher-Pry plot.

If product B is a group of all competing products other than A , if these products B_1, B_2, B_3 etc. have different functional equivalence ratios to A, and if their market share is changing relative to each other over time then the functional equivalence ratio between the whole group of Bs and A will change overtime (X is time dependent, rather than a constant).

TABLE A-18. Relative Consumption of Major White Pigments on Hiding Power Basis 1924-1974

Given by Consumption of Pigment on hiding power basis divided by Total Consumption of Major White Pigments on hiding power basis.

YEAR	WHITE LEAD	ZINC OXIDE	LITHOPONE	TITANIUM DIOXIDE
1924	0.282	0.299	0.419	0
1930	0.218	0.286	0.496	0
1935	0.199	0.255	0.437	0.109
1937	0.156	0.226	0.465	0.153
1945	0.118	0.259	0.309	0.314
1946	0.109	0.244	0.331	0.316
1947	0.094	0.255	0.288	0.363
1948	0.079	0.221	0.322	0.377
1949	0.051	0.149	0.333	0.467
1950	0.050	0.148	0.295	0.507
1951	0.050	0.139	0.289	0.522
1952	0.025	0.082	0.197	0.696
1953	0.029	0.078	0.190	0.703
1954	0.025	0.068	0.159	0.748
1955	0.022	0.077	0.182	0.718
1958	0.011	0.058	0.083	0.848
1963	0.005	0.042	0.039	0.915
1968	0.004	0.032	0	0.964
1973	0.001	0.014	0	0.985
1974	0.001	0.011	0	0.988

Consumption of Pigment on hiding power basis =
Consumption of Pigment (tons) x relative hiding power.

Values used for Relative Hiding Power of Major White Pigments
White Lead = 1, Zinc Oxide = 1.4, Lithopone = 2, Titanium Dioxide = 8.

TABLE A-19. Regression Line of Fisher-Pry Coefficient on Year (Independent Variable) for White Pigment Consumption on a Hiding Power Basis 1924-1974

White Lead

Residuals may be correlated.

	B.	Std. Error (B)
Year	-0.0596	± 0.00451
Constant	1.541	± 0.235

Multiple Regression = 0.9522 R^2=0.9066 S.D.Residuals = 0.256.

Zinc Oxide

Residuals may be correlated (5 runs observed cf 10.6 expected

	B.	Std.Error (B)
Year	-0.03381	± 0.0033689
Constant	0.79969	± 0.7577

Multiple Regression = 0.9211 R^2=0.8484. Std.Deviation of Residuals=0.

Lithopone (1924-1963)

	B	Std.Error (B)
Year	-0.02981	± 0.00489
Constant	0.93804	± 0.23436

Titanium Dioxide (1930-1974)

	B	Std.Error (B)
Year	0.074805	± 0.0021783
Constant	-3.661	± 0.11792

Multiple Regression 0.9933 R^2 = 0.9867

Standard Deviation of Residuals = 0.0967.

TABLE A-20. 'Weighted Price' per unit of Hiding Power of Major White Pigments. 1910-1974

Weighted Price (Price per 0.01 tons adjusted to 1963 values) divided by Relative Hiding Power (relative to white lead = 1).

Figures for hiding power used, White Lead = 1, Zinc Oxide = 1.4, Lithopone = 2, Titanium Dioxide [pre 1945] Anatase 8.

[N.B. after 1945, Titanium Dioxide could be produced in its Rutile form with a hiding power of 10.].

YEAR	WHITE LEAD	ZINC OXIDE	LITHOPONE	TITANIUM DIOXIDE
1910	1.13	1.07	0.54	
1914	1.22	0.88	0.44	
1924	1.19	0.89	0.25	
1930	1.26	0.85	0.30	
1935	1.32	0.68	0.31	0.36
1937	1.54	0.67	0.27	0.27
1945	1.07	0.50	0.24	0.22
1946	1.30	0.65	0.26	0.22
1947	1.89	0.86	0.26	0.21
1948	1.90	0.82	0.26	0.18
1949	1.85	0.95	0.28	0.20
1950	1.99	1.20	0.30	0.19
1951	2.55	1.64	0.43	0.20
1952	2.22	1.65	0.45	0.21
1953	1.78	0.95	0.33	0.21
1954	1.64	0.83	0.35	0.21
1955	1.70	0.92	0.32	0.22
1958	1.28	0.73	0.33	0.23
1963	0.97	0.50	0.27	0.20
1968	1.00	0.58	-	0.18
1973	1.18	1.23	-	0.18
1974	1.47	1.11	-	0.22

Fig A - 2 RELATIVE CONSUMPTION OF MAJOR WHITE PIGMENTS 1924 - 1974 ON HIDING POWER BASIS

(Consumption of Pigment in tons) x (Relative Hiding Power of Pigment) divided by sum of (Pigment Consumption) x (Hiding Power) for all Pigment

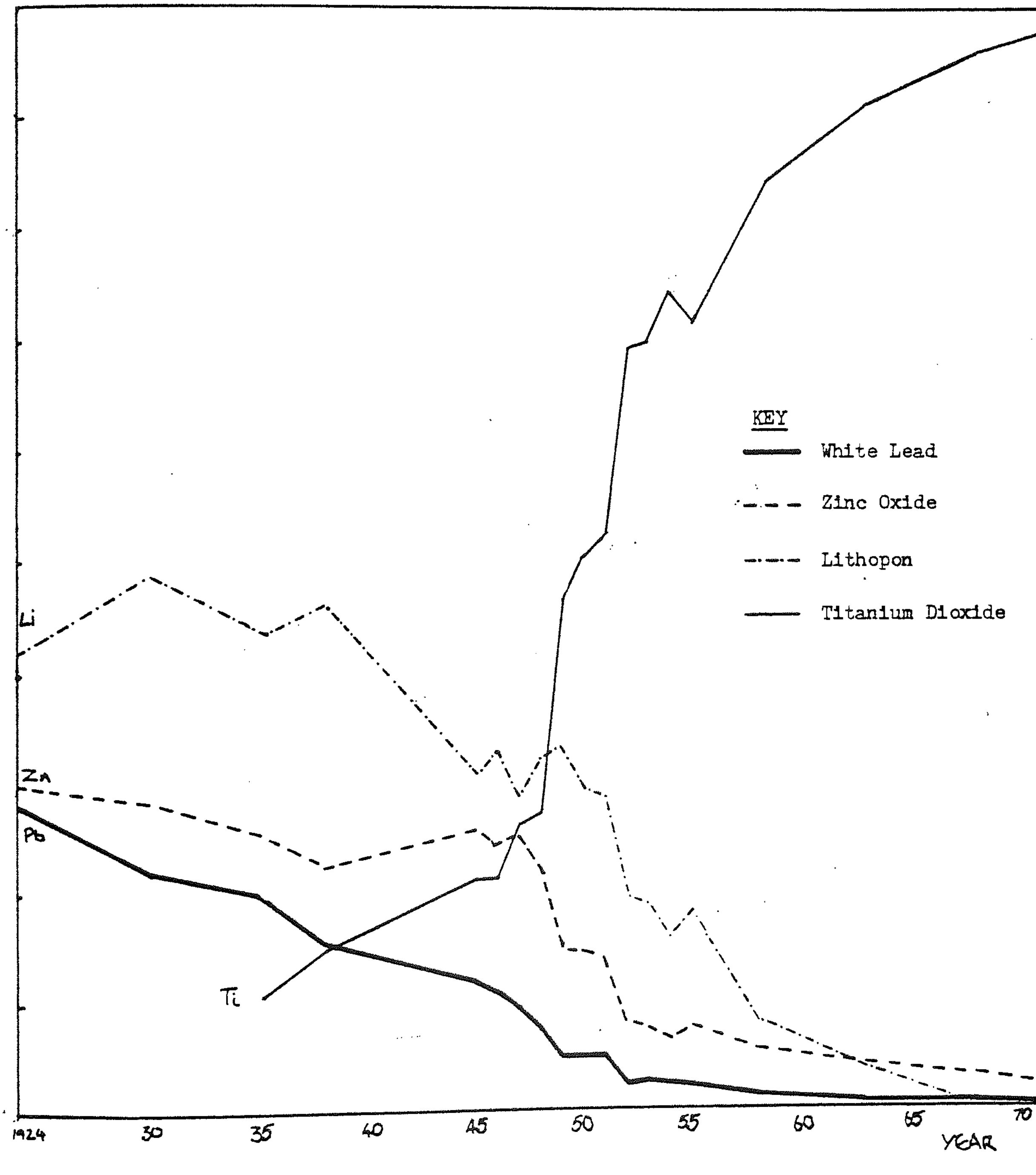


Figure A-3: 'Fisher-Pry' Plot of the Consumption of Major White Pigments on a Hiding Power Basis

(total pigment consumption in tons X relative hiding power of pigment.)

Plot of log(f/1-f) against year where f is the market share of the pigment on a hiding power basis.

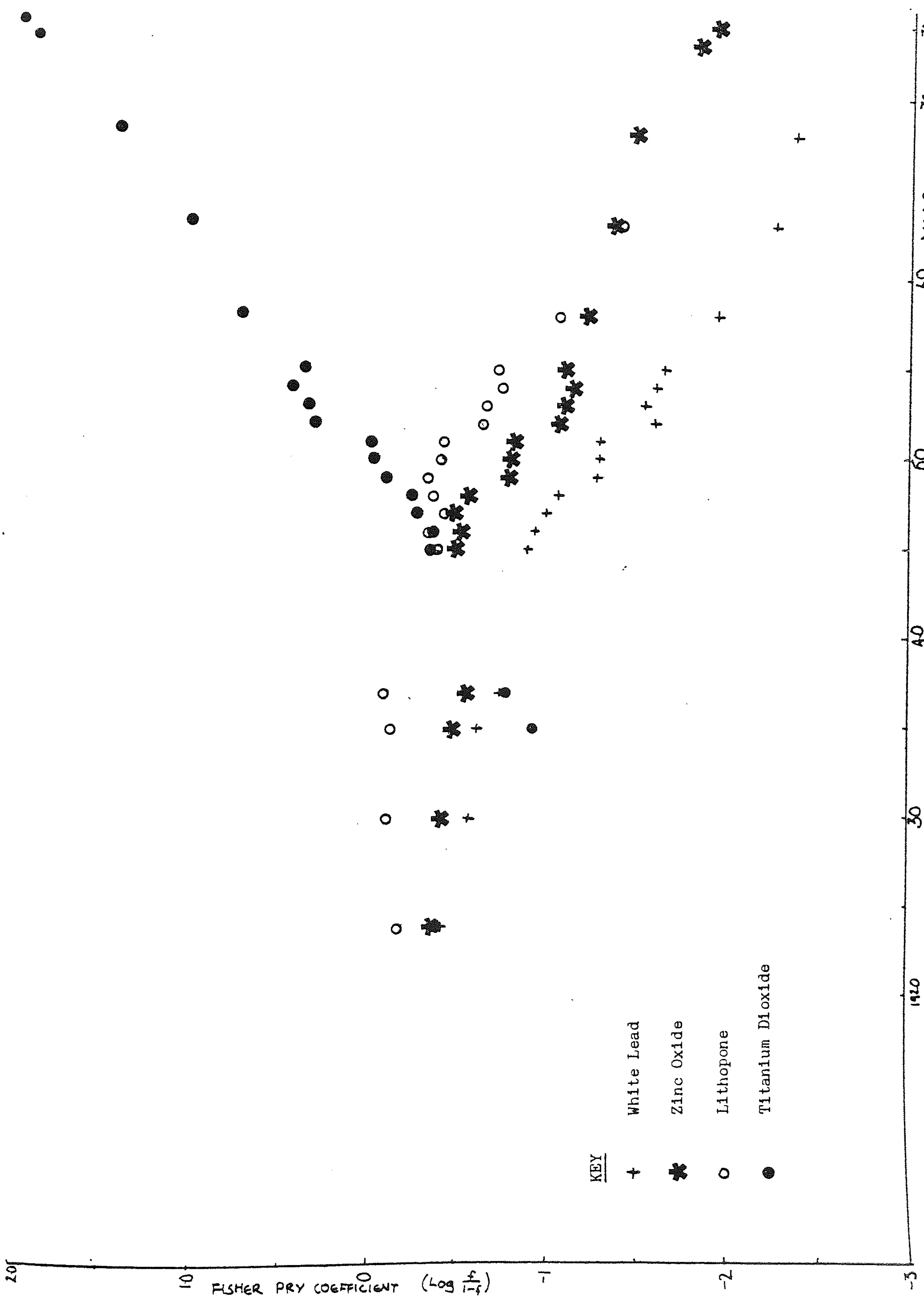
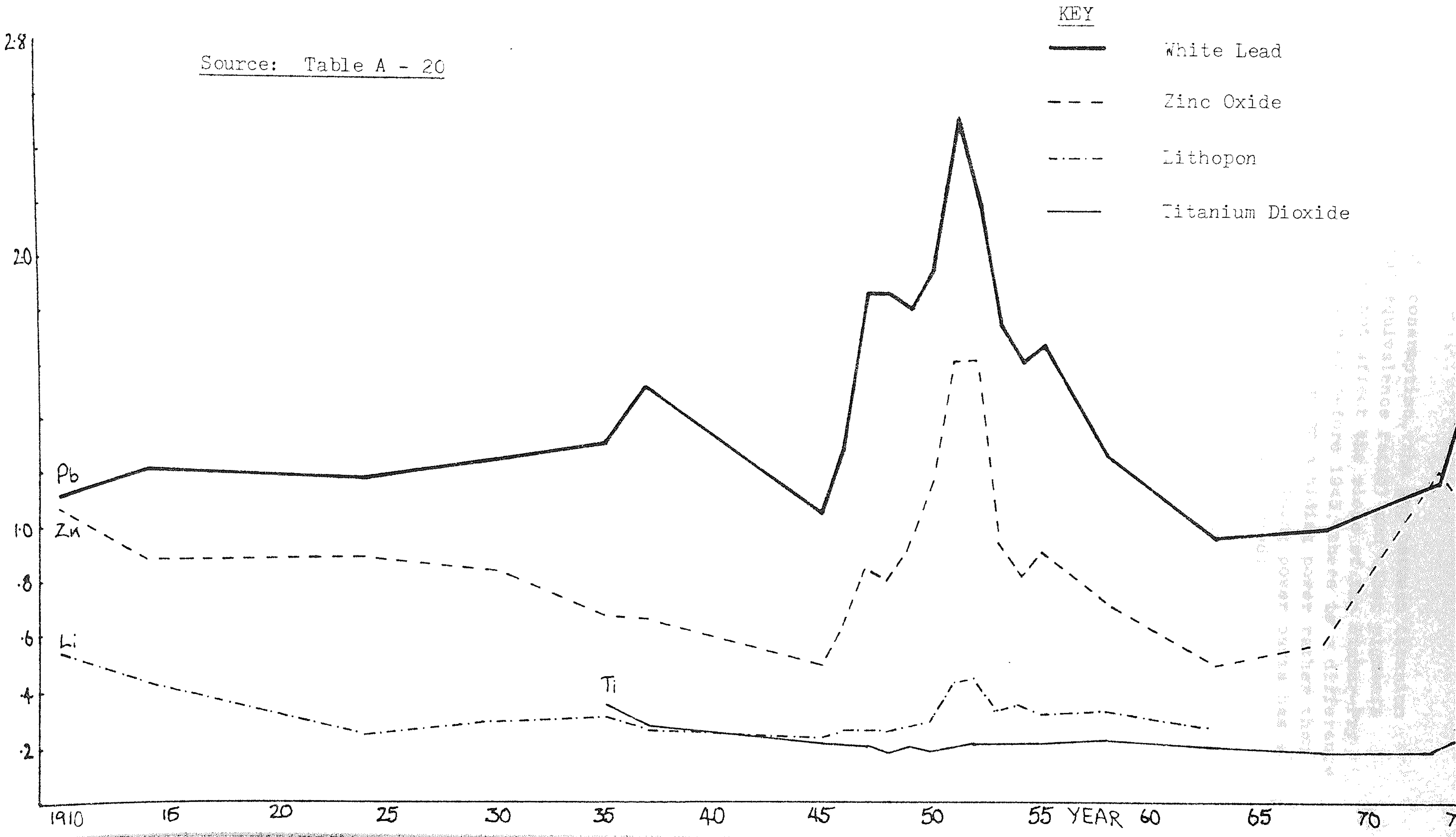


Fig A - 4 WEIGHTED PRICE, PER UNIT OF HIDING POWER, OF THE MAJOR WHITE PIGMENTS 1910 - 1974

Price per Ton, adjusted to 1963 values, divided by Relative Hiding Power (White Lead = 1.0)



In the example of white pigment consumption, the gap between titanium dioxide hiding power (functional equivalence ratio) and other pigments is so large that these effects do not affect the slope of the Fisher-Pry plot in the period after 1945. However before 1945, there is a difference in slope of the Fisher-Pry plots calculated on a hiding power rather than a weight basis (e.g. zinc oxide calculated on a hiding power basis has a clear negative substitution rate in the 1924-1945 period).

Notwithstanding these minor differences, calculation of Fisher-Pry plot on a hiding power rather than a weight basis does not require revision of the earlier observations and explanations of the pattern of pigment substitution.

Other Applications of the Fisher-Pry Model

As has been seen, the Fisher-Pry model can be applied to dramatic changes in the competitive environment caused for example by the entry of a new, competitive product on to the market. It has been used to study a range of factors affecting substitution rate.

Blackman has used this method to chart the effects of prescriptive regulations of adoption of an innovation (The substitution rate for seat belt installation in new cars was found to be an order of magnitude greater than the substitution rate for other automobile equipment not subject to regulations).[112]

The effective use of this method in international comparisons suggests a possible extension to this case study involving calculation of the rate of displacement of white lead. A comparison between those states ratifying the Geneva convention might provide an effective method for charting the relationship between already existing technological change and propensity to regulate, as well as the effectiveness of regulations. Unfortunately it has not been possible to obtain such data for other advanced countries in the period in question.

The exception is the United States of America. Here the process of substitution of one pigment seems to have followed a very similar pattern overall. Titanium dioxide seems to have been some 7-8 years earlier in its displacement of lead and zinc pigments from the paint market in the U.S.A. than the U.K. However, the substitution rate was virtually the same in both countries.

The U.S. pigment consumption data are presented and the substitution rates calculated in Appendix A-6.

Limitations of the Fisher-Pry model for the purposes of this study - modelling the role of price and pigment performance

Though the method adopted has been effective in modelling long term trends in pigment substitution which have been related to historical levels of price (on a weight and a hiding power basis), it does not make it possible to carry out a more detailed examination of short term trends and deviations because a combination of limitations of the method adopted and the data available.

i) Limitations arising from the lack of data

As noted already, average price relativities are markedly stable for long periods. The key exception was the period prior to 1930. It had been hoped to analyse this period in detail. However, it was only possible to obtain complete consumption data for one year in this period (1924).

If complete data had been available for this earlier period it would be possible to determine if there were any changes in substitution rate, that could in turn be related to the important changes that took place then, including changes in the relative price of lead and zinc, concern about health hazards of lead paint, changes in knowledge about paint formulation, changes in pigment markets.

On the basis of (partially estimated) consumption figures for 1907, it has been possible to indicate that there probably was a change in the rate of pigment consumption between 1907-1924 and 1924-1930 that would be consistent with the influence of the factors described above. However in the absence of more adequate data it has not been possible to determine the precise timing and extent of these changes, nor consequently, to identify the causes. (See note above and Appendix A-7).

ii) Limitations arising from the method adopted

The method adopted is not well suited to analysing short-term trends and deviations in substitution rate. Such trends are anyway largely obscured by the method of analysing not market share (f) but log f/1-f. This minimises the effect of moderately large changes in consumption levels - and is best suited to charting high magnitude changes.

The insensitivity of the Fisher-Pry and similar models to such smaller changes is linked to its overall objective - to measure the rate of response of a market to a static stimulus (a competitive innovation), or in other words, the 'learning curve of adoption of a technology'.

Though this rate of response can be related to other factors such as economic pressures, institutional context etc., these factors (in particular for this study, price and performance of a product) do not enter the dynamic modelling.

An examination was made of those attempts to model technological substitution which have addressed price/profitability and attempted to incorporate it into the modelling exercise. This also requires an assessment of the relative quality or utility of competing products (their ability to satisfy the "customer's" needs thereby determining the price they are willing to pay).[113]

Models of Technological Substitution Involving Price and Utility

Stern et al.[114] have presented a complex forecasting model which looks at perceived utility of a new product (plastic as opposed to glass bottles) in a variety of markets. This includes elaborate models (and assumptions) about the industrial development of the "challenger" and "defender". (technological development, investment, pricing strategies), which were not very appropriate for the current study. A simpler model by Ayres et al was produced to forecast the increasing use of aluminium in place of copper, in electrical applications, with changes in the utility adjusted price of using each metal.[115] The following relationship was postulated between output and price of old and new products.

$$\frac{QA}{QB} = \frac{QoA}{QoB} \times \left(\frac{PA}{PB}\right)^{-m}$$

where QA is the sales in money terms of products incorporating the innovation
QB is the sales in money terms of products not incorporating the innovation.

Qo indicates sales at the initial establishment of innovation
P is the utility adjusted price of product (A and B)
m is the price elasticity of demand.

The sigmoid diffusion curve characteristic of the Fisher-Pry and other models was assumed as deriving from an exponential decay in price ratios ($^{PA}/_{PB}$) over time.

$$\frac{PA}{PB} = \frac{PoA}{PoB}\, e^{-\frac{kt}{m}}$$

where k is the constant controlling substitution rate, + Po is price of A, B at initial establishment of innovation,

Yielding an equation for f market share = $\frac{QA}{QA+QB} = \frac{1}{1 + e^{[k(u-t)]}}$

where t is time elapsed since start up, and u is a measure of start up time

$$u = {}^{1}/_{k} \left(m \frac{PoA}{PoB} - m \frac{QoA}{QoB}\right)$$

Other factors delaying substitution (e.g. 'inertia' in the system which delays substitution) are noted, but not modelled.

Both the Ayres and the Stern models assume that if the old and new products have the same utility adjusted price,[116] demand for the two products will be the same. Neither consider preferences for a product not related to its utility. Utility is held to be a static property of a product. Their concepts of utility are little developed, and it is useful to examine them in more detail.

For Ayres, utility is effectively a physical, economically-measurable characteristic of a product. The role of knowledge in mediating between the physical properties and utility of a product is not elaborated. Ayres' concept of utility is no more than a method of ensuring that the prices and volumes of competing products are compared in terms of equivalent units of use, and has been described in a later paper as the "functional equivalency ratio" (FER).[117]

Stern uses a very much broader conception of utility; he measures perceived utility by assessing the value attributed to the various properties of competing products, by various users. Perceived utility determines the relationship between product price and consumption, and clearly encompasses in this model some non-technical considerations (e.g. in the assessment of glass or plastic bottles, tradition is one of the characteristics assessed as well as the values associated with for example the transparency or disposability of the bottle). Possible changes in the weightings for these properties due to changed user attitudes are not modelled; the development of new market structures is considered but held to be impossible to predict.

Both Ayres and Stern model the pattern of product substitution on price changes of the product. Once a new product has achieved a market niche, its further diffusion will be determined by improvements in production techniques reducing unit costs or by shortages of materials increasing the cost of the older product, and these changes in costs will bring about the sigmoid pattern of increasing market share (of the new product) with time.

The Ayres and Stern models, it would seem, have dealt with price and utility of factors determining product substitution, at the expense of the 'learning curve' effects that were the basis of the Fisher-Pry and similar models. Their assumptions about price behaviour do not fit with the very complex patterns found in pigment prices (though titanium dioxide prices do conform to Ayres' prediction of exponential decay over time after initial introduction, the other pigments do not).

To examine whether market share has the relationship to price that Ayres predicts, the 'price elasticity of demand', m, has been calculated using his formula

$$\frac{QA}{QB} = \frac{QoA}{QoB} \times \left(\frac{PA}{PB}\right)^{-m}$$

The notional price elasticity (m) of demand for white lead has been calculated using price per ton of pigment; and price per unit of hiding power. The results are shown in Figure A-5 plotted against year.

Not only does m vary substantially over time, but it changes sign in 1949 (a meaningless result, arising from the price of lead being forced down in the face of overwhelming competition from titanium dioxide), reinforcing the fact that price is a function of demand as well as a determinant of consumption.

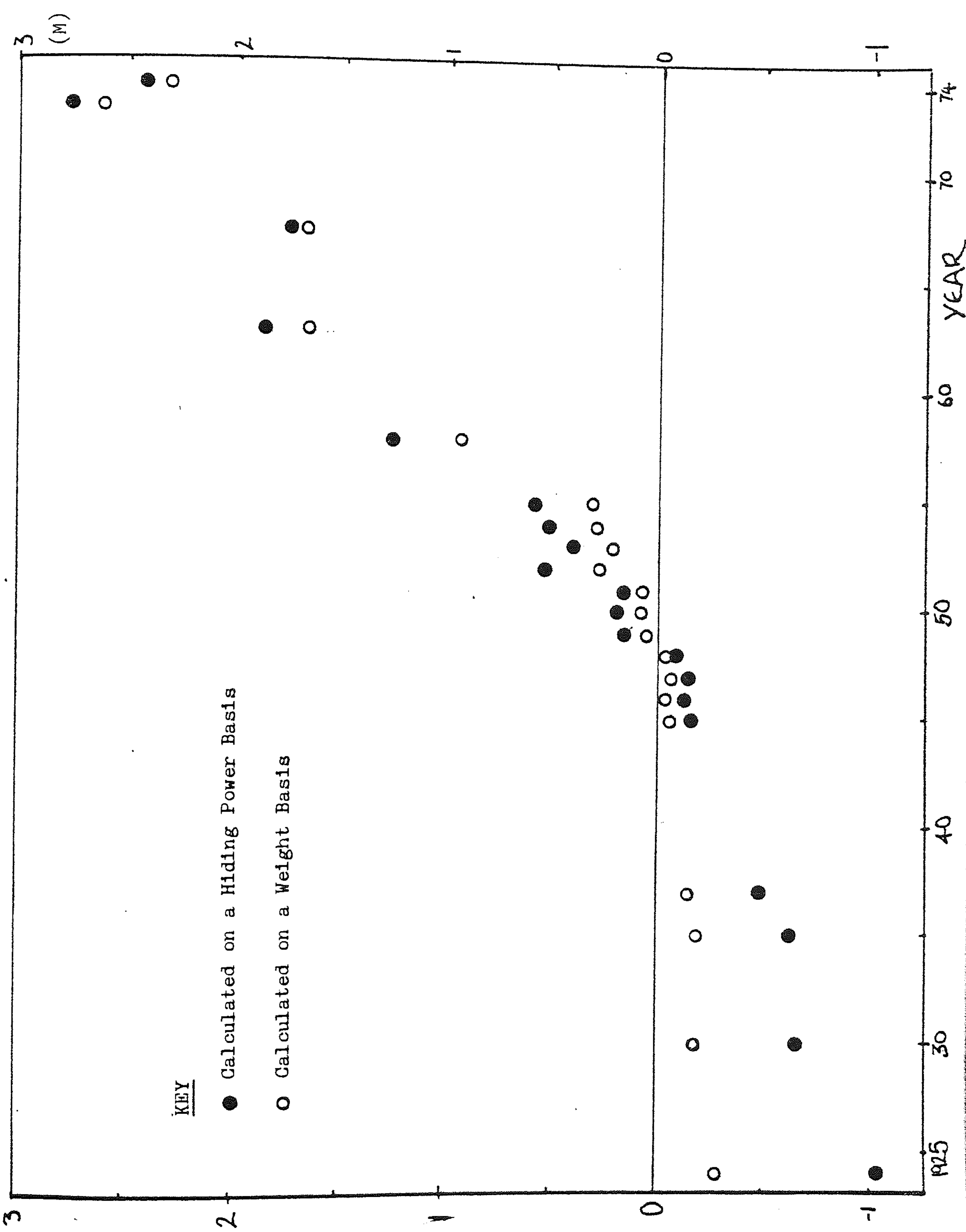
Ayres' model rests on an assumption of a simple relationship between price and market share that was found to be inadequate in the earlier examination of possible statistical relationships between these two factors.

An Alternative Method of Modelling Market Performance

The Ayres model was rejected because it did not conform to the observed relationship between pigment price and market share in this study. Moreover it gives little account to 'learning curve' effects - delays and problems in market adjustment.

The needs of this study differ somewhat from that of the 'technological forecasters' described above since it is retrospective. Data is therefore

Fig A - 5 NOTIONAL 'PRICE ELASTICITY OF DEMAND (M)' 1924 - 1974
CALCULATED USING AYRE'S FORMULA FOR CONSUMPTION OF WHITE LEAD:
On a Hiding Power and Weight Basis.



CALCULATED 'PRICE ELASTICITY OF DEMAND' (M) available on pigment price and market share, and their relationship would be determined empirically. An alternative method has therefore been outlined by which it might be possible to model the market behaviour of pigments and thereby throw light on the role of 'non-price' factors.

Saviotti et al. in their study of the tractor industry distinguish between two sorts of non-price factors in market performance :

Intrinsic (or technical) factors
Associative (non-technical) factors e.g. a manufacturer's distribution/maintenance network.118

In the case of tractors, the technical characteristics of a product, and their utilisation are relatively apparent. In the case of pigments (as in the example of synthetic rubber cited earlier) technical knowledge maybe needed to utilise the technical characteristics of the raw material.

It is therefore necessary to distinguish three types of non-price factor:

1) Physical properties (x) of a product - determining the (ultimate) relationship between volume units/prices of each material (i.e. Ayres' concept of utility/functional equivalence ratio').

2) Utilisation knowledge (y) - the ability to incorporate a product (in this case the pigment/raw material) to satisfy a need (in this case the production of effective paints).

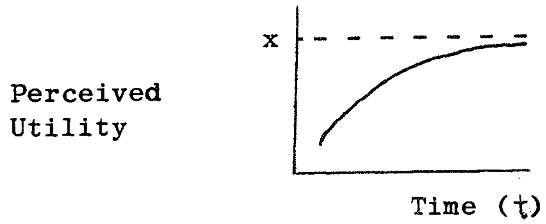
3) Associative factors - this case focuses on non-price factors determining the acceptability of the product to both the use and the final customer, including 'prejudice against/preference for' one product over another, and concern about health and safety/ legislation.

Whilst x is static (unless the product or the market changes), y and z are variable over time. y and z are typical 'learning curves', and are envisaged as operating initially as obstacles to substitution - in effect preventing full realisation of the product properties (x).in a new, little understood product. With continued experience of the product, these barriers to full utilisation of the product properties would diminish. This learning curve would be expected to follow a typical sigmoid pattern over time.

The three types of non-price factor can be conceived as operating together as a dynamic factor of perceived utility, (as opposed to Stern's static conception). The 'learning curve' could be described quantitatively by an equation of the form

$$\text{Perceived utility} = \frac{x}{(y+z)} = \frac{x}{1-e^{k(\mu-t)}}$$

k, μ are constants, equivalent to C, ϕ in the Fisher Pry curve.



Other factors might also affect this perceived utility. For example, concern about a health hazard or regulation might depress perceived utility.

For a mature product, perceived utility is constant over time unless other changes take place (product composition, product utilisation [e.g. in the case of paints, development of new vehicles or new applications], regulation and concern about health and safety etc.).

Apart from such identifiable factors, changes in market share would be determined by price.

If a precise model could be generated of the expected relationship between price and market share at a particular time for the different products it would be possible to determine the relative utilities of the different products and changes therein over time.

Unfortunately it has not proved possible to produce such a precise model because of the limitations of data etc. described earlier. On the basis of certain assumptions about the relationship between pigment price and market share, deviations from the assumed model become apparent that might be ascribed to non-price factors/changes in the perceived utility of a product. However the significance of such deviations is uncertain - not least because they would disappear if a modified relationship is assumed to exist between price and market share.

For example in the case of white lead, there would appear to be a linear relationship between price and market share of pigments in the period 1930-1948. The market share of white lead is slightly higher in 1924 and substantially higher in 1907 than would be expected on the basis of its price (given a linear relationship between these factors). This could be conceived as a reduction in 'perceived utility' of white lead between 1907, 1924 and 1930 which might be attributable to concern about hazards and regulation of lead paint, loss of preference for white lead, increased utilisation knowledge needed to incorporate non-lead pigments into paint.

However these observations are of marginal statistical significance and disappear for example, if a non-linear relationship (e.g. exponential) between market share and price is assumed. See Appendix A-7.

It has therefore not been possible to apply this model of the determinants of price and non-price factors to the data collected in this study. Despite its limitations, the Fisher-Pry model, based on modelling changes in pigment consumption over time, remains the most effective method of analysing the data.

Comparison of Pattern of Consumption and Substitution Rate of Major White Pigments between the U.K. and the U.S.A.

Table A-21 shows sales of major white pigments in the U.S.A.[119, 120] These data are plotted on Figure A-6. Figure A-7 from W. von Fisher shows similar data.[121] The data from 1923 - 1926 relate to sales of zinc oxide in all forms, whereas those from 1934-1940 relate to leaded zinc oxide only, which was almost exclusively used in paint making.[122]

Comparing U.S. sales of major white pigments[123] (Figures A-6 and 7) with U.K. consumption of these pigments (Figure 3-7) shows a substantially similar pattern of substitution with market domination shifting from white lead to lithopone (and presumably zinc oxide, though sales data on this material have only been obtained for a few years) and subsequently to titanium dioxide.

For example, U.S. production of lithopone first exceeds that of white lead in 1926. In Britain, lithopone consumption first exceeds that of white lead between 1924 and 1930.

The growth of titanium dioxide production/consumption appears to have taken place earlier in the U.S.A than Britain. This can be confirmed by calculating the substitution rate using the Fisher-Pry method. For example Fisher and Pry calculated that, in the substitution of lead and zinc pigments in the U.S. paint industry by titanium dioxide, the mid-point of the process was 1949 and the takeover time (time for the new product to grow from 10% to 90% of the market) was 26 years. Extrapolating from Figure 3-18 it would appear that the same substitution process in Britain (for pigment consumption in paints) reached its mid-point later (1957) even though the rate of market growth was slightly faster (takeover time approximately 19½ years).

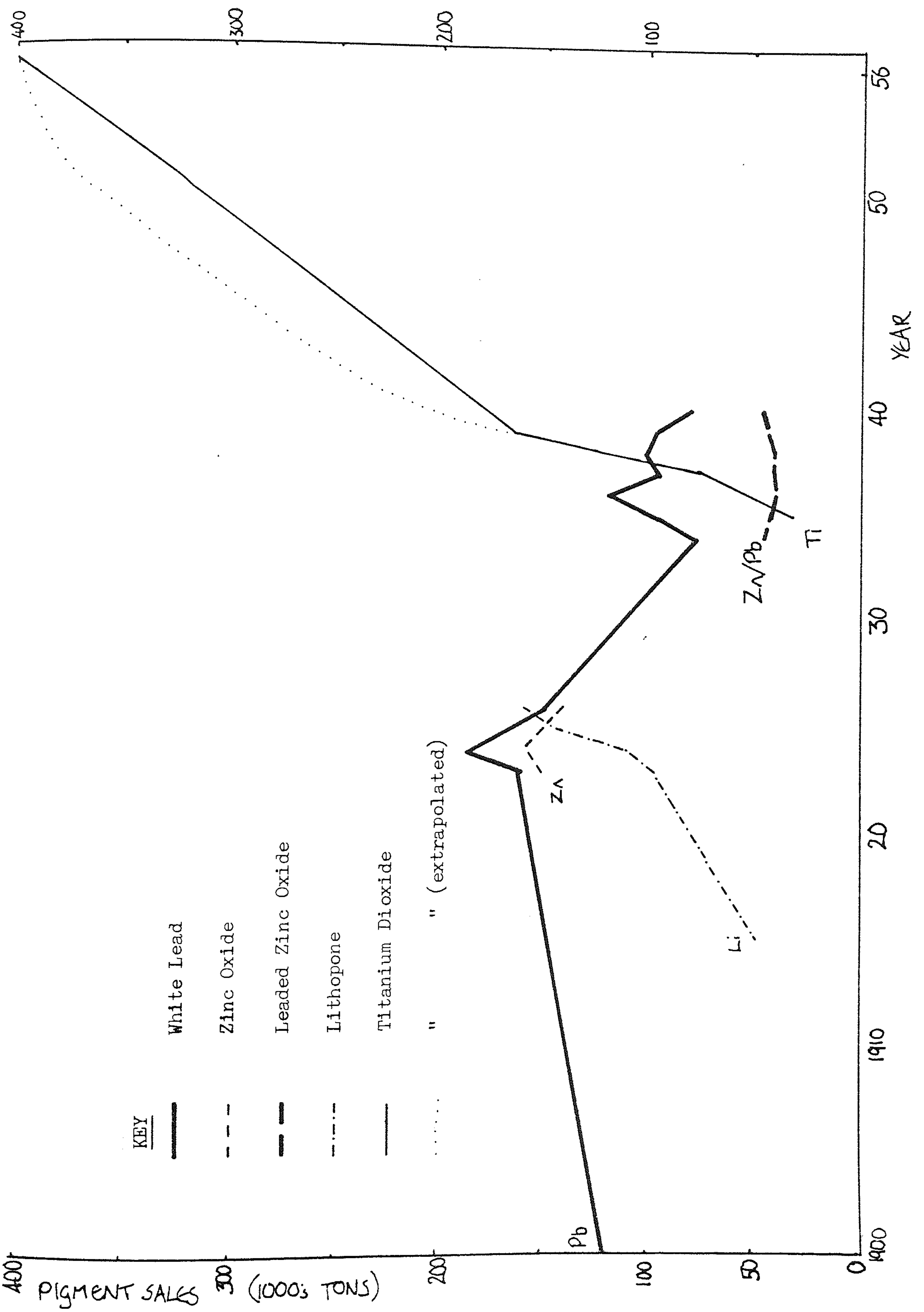
TABLE A-21. Sales of Major White Pigments in the U.S.A. 1900-1956 (Thousand Tons).

YEAR (source)	WHITE LEAD	LITHOPONE	ZINC OXIDE	LEADED ZINC OXIDE	TITANIUM DIOXIDE
1900 (a)	120				
1915 (b)		48.5			
1919 (b)		73.2			
1923 (c)	162.9	98.2	150.5		
1924 (c)	187.5	109.5	158.7		
1925 (b)		145.4			
1926 (b)	149.8	159.9	143		
1934 (d)	78.7			45.4	
1935 (d)	96.8			42.7	32
1936 (d)	118.4			40.5	
1937 (d)	98.2			40.3	75
1938 (d)	102.2			38.2	
1939 (d)	98.4			42.7	165
1940 (d)	80.5			45.4	
1956 (e)					400

Key to Sources :

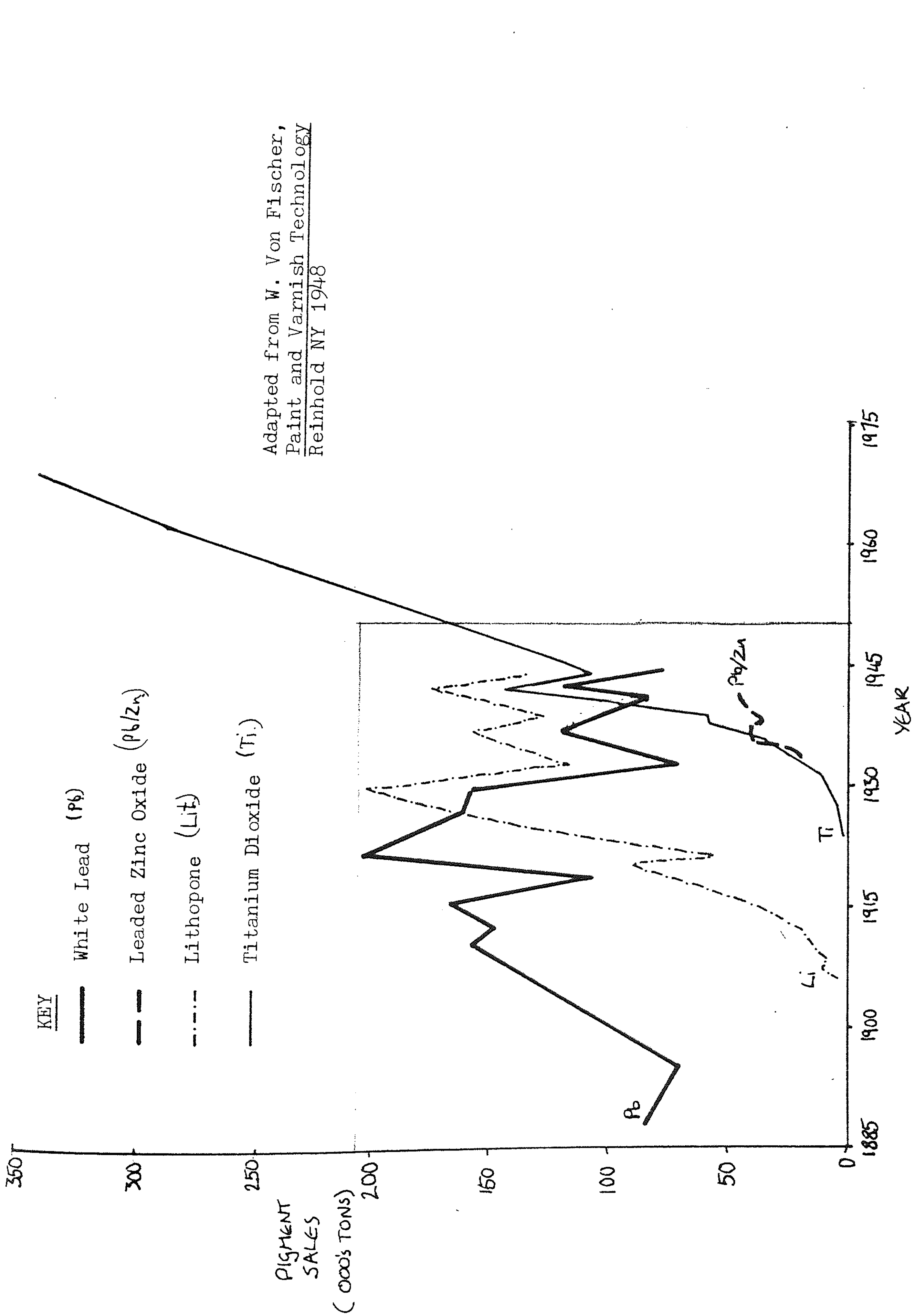
a) Myers and Long, 1975, op.cit.[1]
b) T.H.Zappert, 1927, op.cit.[119]
c) J.Parish, 1925, op.cit.[120]
d) J.J.Mattiello, 1942, op.cit.[5]
e) J.T.Richmond, 1957, op.cit.[11]

Fig A - 6 U.S. SALES OF MAJOR WHITE PIGMENTS 1900 - 1956



Source: Table A-19

Fig A - 7 U.S. SALES OF MAJOR WHITE PIGMENTS 1885 - 1945 1885 - 1968



Market Share and Relative Price of White Lead 1924-1948. An attempt to detect the effect of non-price factors

An attempt was made to establish whether concern about the health hazards of lead paint, and the Vehicle Painting Regulations and Lead Paint Regulations which came into force in 1926 and 1937, had a measurable influence on demand for white lead. The figures for ('relative' and 'weighted') price and market share of white lead were examined for 1924-1948. Before 1948 titanium dioxide has less than 10% of the market in weight terms and its impact on the competitive environment can probably be ignored.

In this period the relative consumption of white lead falls steadily while its price increases steadily (with the exception of the immediate post-war years when prices are depressed). However in 1924 relative consumption is markedly higher (see Figure 3-12).

The relationship between market share and price appears to be approximately linear. The linear regression of market share on price was calculated for this period (Appendix A-4). The 1924 value is an outlying value, on the threshold of statistical significance. Relative consumption of white lead in 1924 is approximately 20% higher than the level that might have been expected given its price, on the basis of the apparently linear relationship existing between price and market share in the 1930-1948 period.

The relative consumption of white lead has been calculated for 1907 (based on an estimate of lithopone consumption. See Appendix A-5: note. Though this estimate is uncertain, errors would have only a minor effect on relative consumption of white lead), and is almost twice the level that would be expected on the basis of price from the linear regression of market share on price (1930-1948).

If the assumption about the linear relationship between market share and pigment price is correct, there must have been a change in this relationship between 1907-1924 and 1930-1948, with a given level of pigment price being associated with higher levels of pigment consumption in the earlier than the later period. In other words, paint makers/users appear to have become less likely to buy white lead at a given price.

This change could be conceived as a result of changes in the 'perceived utility' of white lead - in the sense outlined in Appendix A-5. Thus the reduction in perceived utility of white lead between 1907, 1924 and 1930 would correspond to the model presented there and could be ascribed to changes in utilisation knowledge needed to incorporate other white pigments into effective paints (i.e. an increased perceived utility of other pigments) as well as associative factors in the form of loss of preference for, and concern about health hazards of white lead paint.

However the statistical significance of the linear regression between price and market share (and of the deviation in 1907, 1924) is low - particularly given the small number of observations involved. The assumption of a linear relationship may therefore be misleading. For example if a non-linear relationship (e.g. exponential) or if an adjustment period is allowed for (e.g. by introducing a lag between price and consumption levels in the regression calculations) a reasonable approximation to the observations can be obtained in which the 1907 and 1924 observations do not appear as outlying. Thus while there are indications of a change in the relationship between pigment price and pigment consumption prior to 1924, the nature of this relationship cannot be established with sufficient confidence to establish the magnitude and timing etc. of this change, (the level of zinc oxide consumption in 1907 also appears correspondingly depressed given its price in comparison with later years).

The 1907 observations also appear as deviating from the substitution rate established by the Fisher-Pry model for the 1924-1945 period (see note to Appendix A-5). In the 1907-1924 period white lead is shown as being more rapidly displaced (as a corrollary to its higher than expected market share) than in the 1924-1945 period. The reverse was noted for lithopone and zinc oxide. These changes in substitution rate could be explained in terms of concern about lead pigment hazards, changes in price differentials between pigments and internal differentiation of pigment consumption markets.

Thus, both methods of modelling pigment consumption indicate a change in the substitution process between 1907-1924 and 1930-1945. While changes in pigment price may be a factor, non-price price factors were also suggested as playing a role. However the data are limited and uncertain and it was not possible to establish the precise factors involved, nor their respective contribution to these changes.

APPENDIX B.

TECHNICAL APPENDICES TO CHAPTER SIX.

APPENDIX B-1

Estimate of Voluntary Notification of Lead Poisoning Amongst Housepainters 1900-1909.

Between 1900 and 1909 figures for notified lead poisoning for housepainters and plumbers were combined. After 1910 they have been given separately. (Figure for 1910 from ILO).[3]

For the purposes of this study housepainting poisoning has been estimated by assuming that the same ratio between housepainting and plumbing poisoning cases existed between 1900 and 1909 as between 1910 and 1914. The latter period has been taken because conditions change very substantially during the First World War and do not fully revert to pre-war conditions.

Though it may not be correct to assume that the material and social practices leading to poisoning and reporting of such poisoning in housepainters and plumbers remained the same or rather were affected in the same way for both groups, errors are likely to be small since housepainters make up the large majority of such cases.

The estimates, and the data from which they were derived are given in Table B-1.

TABLE B-1 Estimate of Voluntary Notification of lead poisoning to H.M.F.I. amongst Housepainters 1900-1909.

Sources: Annual Reports of the Chief Inspector of Factories, op.cit.
T.M.Legge, 1934, op.cit.
I.L.O. 1923, op.cit. *

Assessment of the Validity of the figures for Voluntary Notification of Lead Poisoning in Housepainters 1900-26.

Voluntary notification of lead poisoning amongst housepainters was believed to substantially underestimate the true levels of harm amongst housepainters. An attempt has been made to determine the extent of this under-reporting relative to compulsory notification of poisoning in housepainters after 1926 and relative to compulsory notification in other industries. Three methods were adopted to assess this under-reporting:

i) A comparison of the number of cases of poisoning notified amongst housepainters during voluntary notification (1900-26) and compulsory notification (1927-date) to the Factory Inspectorate (HMFI).

ii) Prediction of the expected number of cases of poisoning from the number of deaths from lead poisoning amongst housepainters (on the basis of the ratio of fatal to non-fatal poisoning in housepainting and in other industries over time).

iii) Comparison between notification to the H.M.F.I. of cases of lead poisoning and the number of Certificates of Disability and Suspension issued for housepainters and factory workers for lead poisoning under the Workmen's Compensation Acts.

The three approaches are described below. Only the latter two produced meaningful results/enabled estimates of under-reporting of poisoning in housepainters to be made.

A Comparison of Numbers of Cases of Lead Poisoning amongst Housepainters under Voluntary and Compulsory Notification

The simplest method of dealing with voluntary notifications would be to adjust the levels to bring them in line with those found under compulsory notification after 1927. However, it cannot be assumed that voluntary notification of lead poisoning amongst housepainters is a constant indicator of the levels of harm during the 1900-1926 period, nor comparable with compulsory notification amongst housepainters after 1927 (or for that matter other industries). Since it appears that voluntary notification was inspired by humanitarian concern or by ignorance amongst medical practitioners, it would be expected to be encouraged by public concern about lead paint hazards (e.g. in the period prior to and during the 1911 Departmental Committees and reduced by the attempts by the Factory Inspectorate to discourage this practice in 1900 and 1905-6. Indeed the number of cases of lead poisoning in the years 1901-2 and 1905-7 seem depressed from the otherwise steadily increasing number of voluntary notifications received prior to the First World War which would correspond to the anticipated effects of these factors. The application of a single correction factor to the statistics for voluntary notification for the whole 1900-1926 period would not be valid.

There are additional problems with such an approach.

i) the levels of lead poisoning prior to the Lead Paint Act 1926 fluctuate substantially, affected by the First World War, and apparently by the impending legislation.

ii) levels of lead poisoning after this Act also change rapidly.

It is thus not possible to determine an appropriate conversion factor. This method was therefore not used to estimate under-reporting with voluntary notification of lead poisoning amongst housepainters. An alternative method was examined for correcting the voluntary notification figures to allow for the fact that these were based on returns from medical practitioners alone (whereas under compulsory notification a significant proportion of returns were made by factory occupiers and some 30% of occupational diseases were reported by occupiers only during 1900-14). However, this approach was not able to account for the inconsistencies in voluntary notification rates and did not produce meaningful results. The results have therefore not been presented.

<u>Prediction of Expected Levels of Lead Poisoning from the number of Fatal Cases of Lead Poisoning in Housepainters.</u>

It is a paradigm of occupational accident and disease epidemiology that the rate of reporting of deaths from a particular cause is more reliable than morbidity rates, since they are more likely to be reported, and the threshold for diagnosis (i.e. death) is largely static. In contrast, reportage of poisoning will vary according to the arrangements (especially costs and benefits to the worker/doctor/employer) of reporting, and the threshold of diagnosis is less clearly defined and will vary (under the influence of social pressures, medical practice etc.).

The number of deaths from lead poisoning in housepainters are available, reported on a consistent basis throughout the period. This suggests two approaches to estimating the number of cases of lead poisoning that would be expected amongst housepainters (had voluntary notification been complete) from the numbers of fatal cases in housepainters on the basis of the ratio of deaths to poisoning cases observed i) in housepainters after 1927 (under compulsory notification) and ii) in other industries.

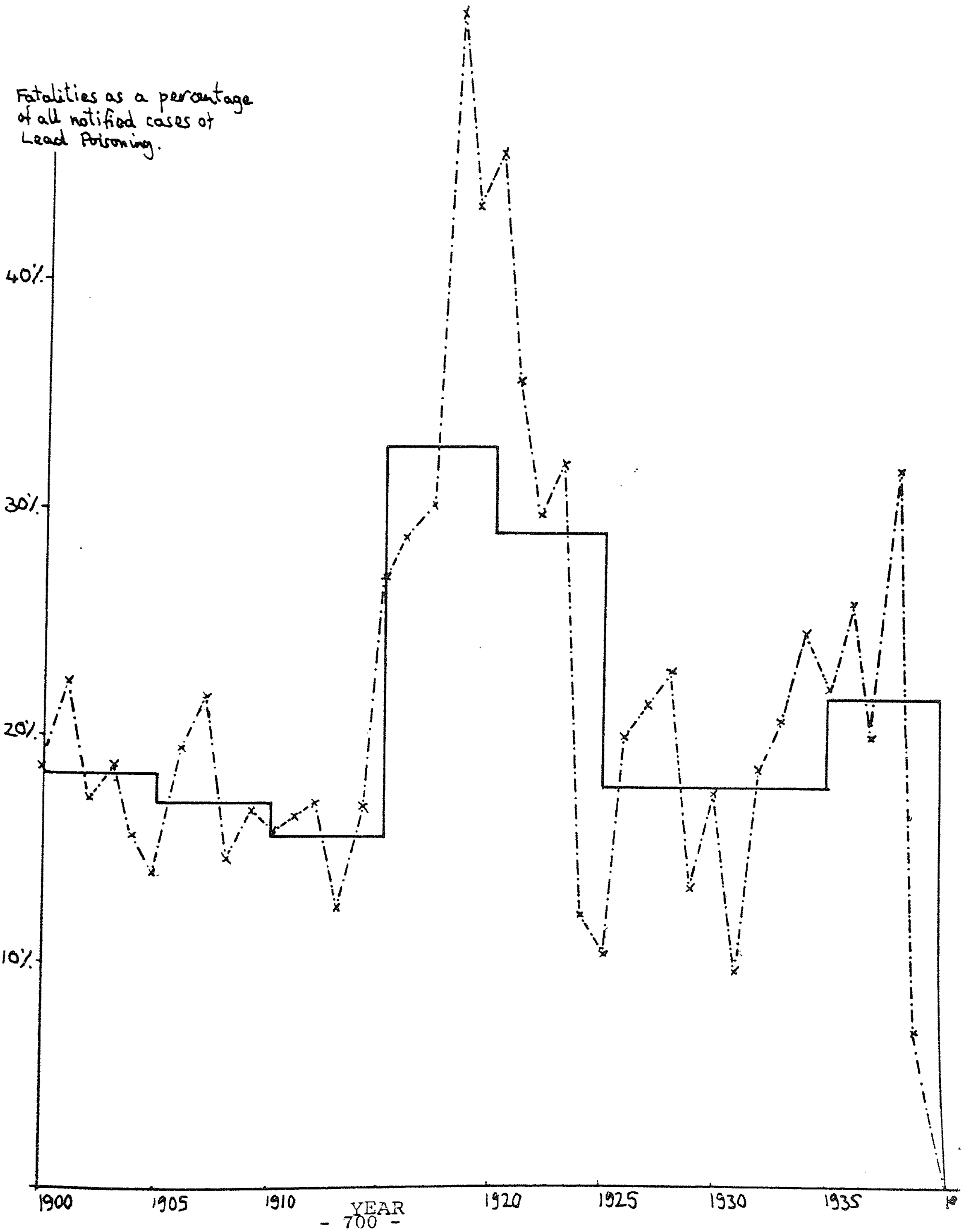
<u>Extrapolation from housepainters after 1927</u>. The ratio of recorded fatalities and cases of lead poisoning amongst housepainters is shown in Table B-2 and Figure B-1. It will be noted that the proportion of lead poisoning cases in housepainters that were fatal is falling gradually in the 1900-1914 period (which could indicate that voluntary notification was becoming more complete during this period). In the next decade the ratio becomes very high due to the disruption of the

TABLE B-2 Ratio of Deaths to Poisoning Cases Amongst Housepainters Notified to H.M.F.I.

Notes:

a) Prior to 1927. cases of poisoning notified on a voluntary basis only
b) Prior to 1910, deaths relate to England and Scotland
c) The ratio of fatalities to poisoning is only approximately the same as the percentage of cases that are fatal. Fatalities appear as both poisoning cases and fatalities UNLESS they were first reported as poisoning in the previous year.

Source: Annual Reports of Chief Inspector of Factories (estimates of poisoning for 1900-1909 from previous Table). Figures for fatalities amongst housepainters before 1910 from G.B. Home Department [Cd.7882] 1915 op.cit. and T.M.Legge, 1934, op.cit. Table 11 fig. 8 -1 : Lead Poisoning in Housepainters; Fatal cases expressed as a percentage of all cases of poisoning notified to HMFI. showing individual years and 5 year averages.



First World War, which reduced the consumption of lead pigments and resulted in a high degree of labour mobility. Fatal cases of lead poisoning (reflecting long-term exposure to/absorption of lead) fell to a much smaller degree than non-fatal cases (in which immediate exposure to lead played a greater role). A similar trend can be noted amongst industrial painters and in other lead industries. By 1924-5 the ratio of fatal to non-fatal cases reverts to levels comparable to pre-war years.

The years immediately following the introduction of compulsory notification amongst housepainters are marked by an increase in the ratio of fatalities to cases. This conflicts with the expectation that compulsory notification would increase the rate of reportage of cases of poisoning (but not affect fatalities) and thereby reduce the ratio of fatalities to cases. The increase in percentage of cases that were fatal continues until 1939, although the rapidly falling number of cases of lead poisoning result in increasing inter-year variation, and is only reversed in the Second World War, after which fatal lead poisoning in housepainters ceases.

A variety of factors can be advanced to explain the absence of a decrease in the ratio of fatal to non-fatal lead poisoning with the advent of compulsory notification of cases of poisoning for housepainters. As will be seen below, the immediate cause of this appears to be the implementation of controls over lead paint hazards during this period (with a similar effect to that noted during World War One on acute poisoning). However, a corollary to this is that the voluntary notification (at least immediately) prior to 1927 was comparable in its completeness to compulsory notification afterwards.

Extrapolation from other industries. This method of estimating number of cases of lead poisoning in housepainters was used at the time by Dr. Legge, Chief Medical Inspector of Factories.

At the 1911 Departmental Committee, Legge, estimated that if the ratio between deaths and poisoning cases was the same amongst housepainters as workers in factory based lead processes (275:6762, or 4.07%) then the expected number of cases of poisoning in the 1900-1909 period amongst housepainters would be 727 per year, compared to 197 per year observed under voluntary notification. This indicated that voluntary notification covered only 27% of the cases of poisoning that would have been reported under compulsory notification. (An even higher estimate is obtained if this extrapolation is carried out on the basis of lead poisoning amongst all factory workers - as opposed to those handling lead in specific lead processes).

This method provides an effective way of indicating the probable magnitude of cases of lead poisoning in housepainters. However the ratio between fatal and non-fatal cases of lead poisoning varies significantly across industries and over time. Figure 6-3 shows this ratio (deaths as a percentage of cases of poisoning notified) for housepainters, industrial painters, pigment and paint producers and for all industries (excluding housepainters). The major problem in such an endeavour is determining the most appropriate industrial grouping from which to extrapolate. In particular, as will be shown below, the ratio of deaths to cases is affected by the social arrangements for notifying poisoning and the character of the risk, and, most substantially by the application of controls to hazards, which differed between industries.

For the current task, of estimating the numbers of cases of poisoning amongst housepainters that would be expected had compulsory notification been in force in the 1900-1926 period, the problems are slightly different. It will be noted that the ratio of deaths to cases of lead poisoning in the 1930-1944 period is substantially greater amongst housepainters than other industrial groupings, even though lead poisoning in housepainters was by then compulsorily notifiable. This would appear to confirm the suggestion that there was lower rate of reporting of cases of lead poisoning in housepainters than other industries even under compulsory notification.

This low reporting rate of cases of lead poisoning in housepainting can be related to the dispersed and mobile nature of the industry. In comparison, estimates of notification of industrial injuries by the Factory Inspectorate in 1972 indicated that under-reporting in the building industry was as high as 50% of total injuries, compared to 27% for factory based occupations. Application of a correction factor based on this rate of excess under-reporting under compulsory notification of lead poisoning in housepainters would go some way towards (but not completely) eliminating the difference between the ratio of fatal to non-fatal lead poisoning in housepainting and other industries.

Given the finding that the relationship between fatal and non-fatal cases of lead poisoning is affected by the control of hazards (whether from regulation, technological change or industrial disruption during the war) and by the social organisation (of the industry, as well as the notification arrangements) an attempt has been made to estimate expected notification levels for housepainters from industrial painters. It is assumed that painting technology was broadly comparable between house and industrial painters (as regards the hazard of lead poisoning). This is probably a good assumption where paint was applied by hand. It is certainly not the case amongst industrial spray painters, whose numbers became significant during the 1920s. However industrial spray painters did not in general use lead paints, and would not contribute substantially to the numbers of lead poisoning, and can be considered to some extent a separate group. It will be shown below that by 1931 some 10% of industrial painters were spray painters. After this period, the characteristics of industrial painters must be seen as increasingly diverging from housepainters and these assumptions will be increasingly inadequate.

To the extent that the technology of painting is comparable, differences in the pattern of poisoning can be attributed to differences in social organisation between house and industrial painting.

Tables 6-3 and 6-4 present the number of cases of lead poisoning, and fatal lead poisoning amongst the different groups of painting workers for 5 year periods 1900-4 until 1970-4. These data are plotted in Figures 6-8 and 9. Deaths from lead poisoning in house and industrial painters show a remarkably similar distribution over the 1900-1940 period, with the former being some four times as great. This is confirmed by Figure 4-4 which shows the data on an annual basis.

The distribution of cases of lead poisoning amongst housepainters is broadly similar to that in industrial painters (see Figure 4-3). However in the 1900-1924 period the former are only 20% greater and in the 1925-1939 period are approximately 175% greater. This is what would be expected if compulsory notification of lead poisoning in housepainters was more complete than voluntary notification but less complete than compulsory notification in industrial painters. It would seem that the ratio of fatal to non-fatal lead poisoning in industrial painters provides a good basis for predicting the ratio of fatal to non-fatal lead poisoning in housepainters that would be expected if notification had been comparable to factory trades.

The expected number of cases of lead poisoning in housepainters (if notification had been complete) has been calculated by multiplying the number of fatal cases observed in housepainters by the ratio of fatal to non-fatal cases of lead poisoning in industrial painters (for five year periods from 1900-1929, and for the whole period 1930-1944). The results are presented in Table B-3.

Comparison between Cases of Lead Poisoning Notified to the Factory Inspectorate and Certificates of Disability and Suspension for Lead Poisoning under the Workmen's Compensation Act.

Lead poisoning in all industries, including housepainters, became eligible for Compensation under the Workmen's Compensation Act 1906. Figures are available for the number of Certificates of Suspension and Disablement issued by Certifying and Appointed Surgeons, for factory workers and for housepainters for the period 1908-14 and 1919-30. The basis of these figures is discussed in Appendix B-4. 1908 W.C.A. figures are incomplete, and not comparable with subsequent years.

The figures for numbers of Certificates issued have been compared with the Notified Cases of Lead Poisoning. The figures are presented in Table B-4 and Figure B-2a) and b). For all factory workers, W.C.A. Certificates are initially significantly lower than H.M.F.I. Notifications 1908-14; subsequently (after 1919) the level of W.C.A. Certifications increases relative to Notifications and becomes approximately equal to H.M.F.I. Notifications (notwithstanding inter-year variation). The relationship between Certification and Notification amongst housepainters is broadly similar but shows two differences:

i) In 1921-4, W.C.A. Certificates exceed (voluntary) notifications to the H.M.F.I. This indicates that voluntary notifications may be particularly depressed during this period.

ii) After 1927, (compulsory) notification to the Factory Inspectorate of lead poisoning in housepainters slightly exceeds W.C.A. Certification, indicating that notification has become more complete.

A set of estimates have been produced for the levels of H.M.F.I. notification of new cases of lead poisoning that would have been expected amongst housepainters if notification had been compulsory and the relationship between H.M.F.I. Notification and W.C.A. Certification had been the same amongst housepainters as amongst factory workers. For most years this gives a higher estimate of expected notification than that observed under voluntary notification.

TABLE B-3 Expected Number of Cases of Lead Poisoning Amongst Housepainters: Estimated from Deaths from Lead Poisoning amongst Housepainters on the basis of the Ratio of Fatal to Non-fatal Lead Poisoning in Industrial Painters 1900-1944

Lead Poisoning in Housepainters

Year	Expected number of cases	Observed number of cases	Estimated extent of under-reporting (in house, relative to industrial painters).
1900-4	3050	756	4.03
1905-9	2971	844	3.52
1910-14	2634	1081	2.44
1915-19	886	265	3.34
1920-24	966	256	3.77
1925-29	771	438	1.76
1930-34	[332] 440*	248	1.77
1935-39	[343] 280*	126	2.22
1940-44	[55] 50*	36	1.39
1930-1944	770	410	1.88

* Based on estimate from years 1930-1944.

1927-30	632	326	1.94

TABLE B-4 Cases of Lead Poisoning: Comparison between New Cases Notified to the Factory Inspectorate and Workmen's Compensation Act, Certificates of Disablement and Suspension issued by Certifying and Appointed Surgeons.

Notes: a) The 1908 figures excluded 52 cases forwarded by Appointed Surgeons.
b) After 1926, notification of poisoning is compulsory under the Lead Paint Act.

Source: G.B.Factory Department : Annual Report of the Chief Inspector of Factories
G.B.Home Office : Statistics of Compensation and of Proceedings under the Workmen's Compensation and the Employers Liability Acts (published annually).

Figure B-2a) Cases of Lead Poisoning amongst Factory Workers. Comparison between New Cases Notified to the Factory Inspectorate, and Workmen's Compensation Act Certificates of Disablement and Suspension.

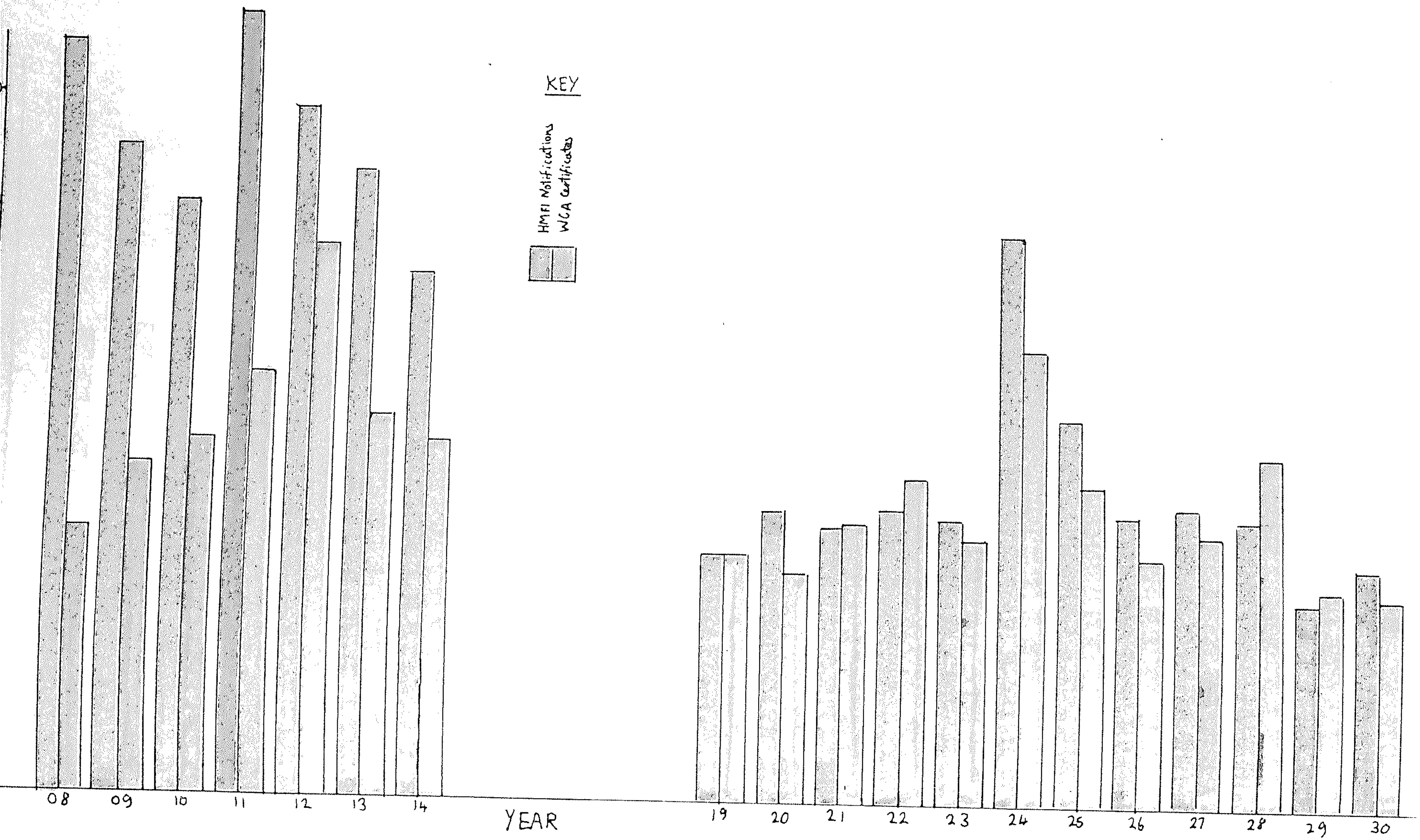


Figure B-2b) Cases of Lead Poisoning amongst Housepainters: Comparison between New Cases Notified to the Factory Inspectorate, and Workmen's Compensation Act Certificates of Disablement and Suspension.

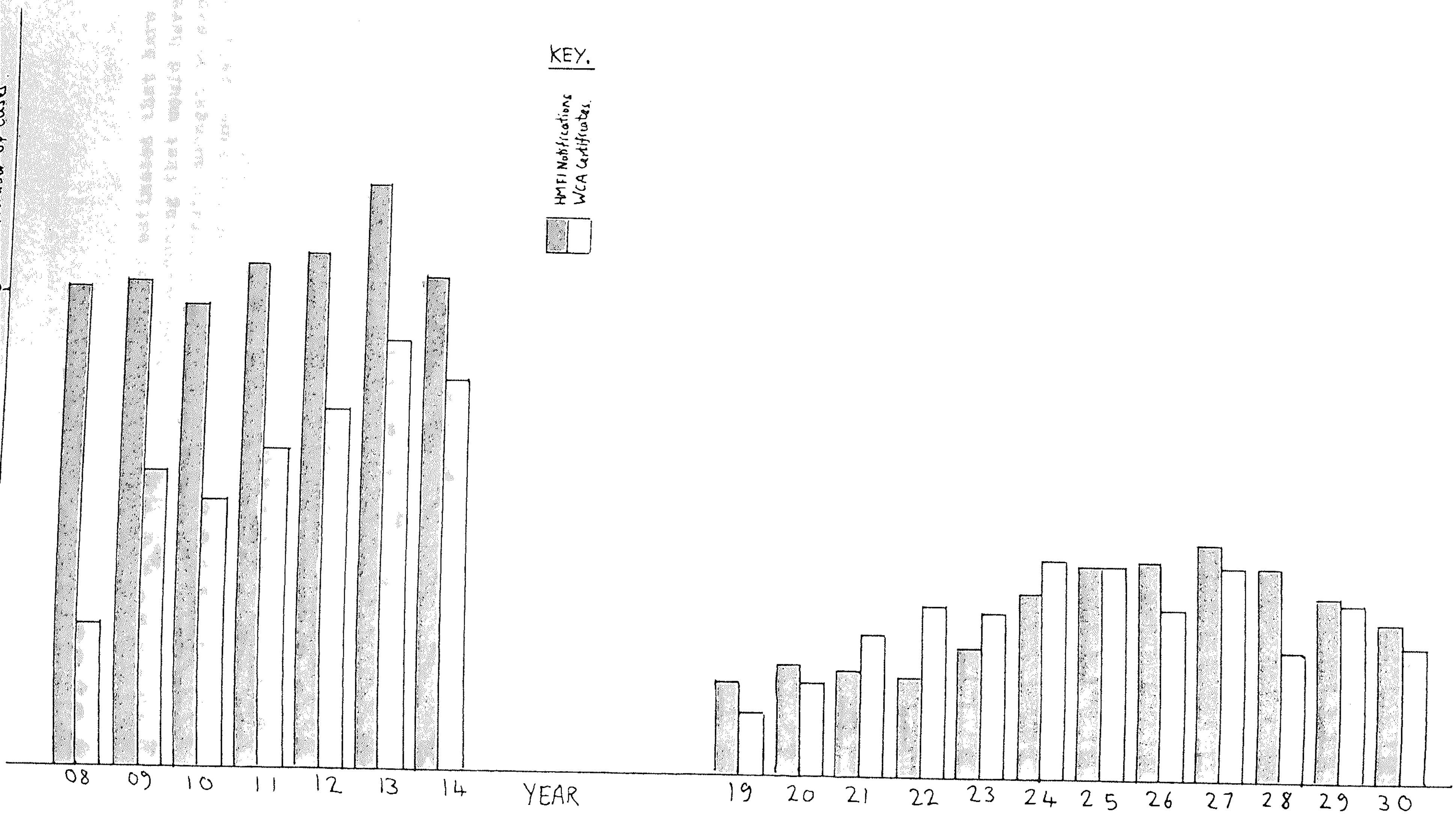


Figure 6-1 presents the most reliable sets of estimates that have been produced for the number of cases of lead poisoning that would have been expected to be notified to the Factory Inspectorate amongst housepainters, had the industry been subject to notification on the same basis as factory-based industries. Table B-5 shows the calculated extent of under-reporting (observed notifications divided by predicted notifications).

Both sets of estimates agree that there was substantial under-reporting of cases of lead poisoning in housepainters during voluntary notification, and that the extent of under-reporting varied over this period. In particular, it would appear that voluntary notification was less complete immediately prior to the introduction of the 1926 Lead Paint Bill (1920-4) than in the 1910-14 period (which coincided with the 1911 Departmental Committees on Lead Paint). The estimates based on fatal lead poisoning, which are probably more reliable than those based on W.C.A. Certificates, indicate :

i) that compulsory notification of cases of poisoning in housepainters after 1926 was less complete than in factory processes in this period (which would be expected on the basis of the decentralisation of this industry), and

ii) that voluntary notification only covered between 25-40% of the number of cases that would be expected to be notified amongst housepainters,

(in contrast the W.C.A. estimates indicate 67-92% of expected cases being notified, and an estimate based on the severity of notified poisoning indicates some 48% of expected cases being notified - see next Section).

TABLE B-5 Estimates of the Extent of Under-Reporting of Cases of Lead Poisoning in Housepainters (relative to the level that might be expected under compulsory notification in other industries).

Period.	Cases Notified as a Percentage of the Expected Number of Cases.		
	Estimated from number of Deaths from Lead Poisoning amongst Housepainters, extrapolated on the basis of the relationship between HMFI Notified lead poisoning cases and fatalities amongst industrial painters.	Estimated from the proportion of cases of lead poisoning that was classed as severe by Certifying Surgeons amongst Housepainters compared to all factory workers.	Estimated from No. of W.C.A. Certificates of Disability etc. issued for Lead Poisoning in Housepainters, extrapolated on the basis of the relationship between HMFI Notifications and W.C.A. Certificates for All Factories
	%	%	%
1900-04	24.8		
1905-09	28.4		
1910-14	41.2		92.3
1915-19	29.9		
1920-24	26.5	49 *	67.0
1925-29	56.8		112.9
1930-44	53.2		
1927-30	51.6		123.5

* See subsequent section on severity of lead poisoning cases.

Proportion of All Cases of Industrial Diseases Notified to the Factory Inspectorate.

Both factory occupiers and medical practitioners were required, under the Factory Acts, to notify cases of certain 'Notifiable' industrial diseases to the Inspectorate. For the periods 1900-14 and 1920-28 the statistics for cases of occupational poisoning notified to the Factory Inspectorate (from all notifiable diseases in factory workers) indicate the number of cases notified by medical practitioners and by factory occupiers. This allows an indicative estimate to be made of the number of cases going unreported.

Figures for 1900-14 are reported on the same basis. Lead poisoning (in 18 industries or processes) makes up the vast bulk of notified occupational poisoning (9494 cases out of 10571 in total, or 89.8%), the remainder being poisoning from Mercury, Phosphorous, Arsenic and Anthrax (in 3,2,2, and 5 industries/processes respectively). Over the next dozen years, a significant number of diseases were included in the schedule for compulsory notification. (Toxic Jaundice - 1915, Epitheliomatous Ulceration - 1920, Chrome Ulceration - 1920, Carbon Disulphide, Benzene and Aniline Poisoning - 1925, Lead poisoning in housepainters - 1927). For the period 1920-8, lead poisoning comprises a smaller proportion of total notified occupational diseases (2784 out of 4903 in total, or 56.8%) because of the inclusion of other notifiable diseases and the falling levels of lead poisoning. The 1920-8 period is therefore not used as a basis for estimating 'non-reporting' because it will be significantly affected by the reporting rate for other diseases.

These data are shown in Table B-6.

If the two events (notification of poisoning by a medical practitioner and notification by a factory occupier) are independent, an estimate can be made of the number of cases of poisoning that go unreported.

The results of this estimate are presented in Table B-7 which indicate that during 1900-14, 17½% of cases of industrial poisoning were not notified to the Factory Inspectorate. This must primarily reflect the situation in lead poisoning.

This estimate must be considered as a lower limit of the level of industrial (lead) poisoning which was not notified since, if there was any correlation between notification by doctors and by occupiers, it would be expected to be positive (e.g. because of the concentration of notified lead poisoning in lead processing firms, subject to constant examination by the Factory Inspectorate and factory doctors), which would yield a higher estimate of total industrial poisoning(T).

TABLE B-6 Numbers of Cases of Industrial Poisoning Notified by Medical Practitioners and by Factory Occupiers 1900-1928 showing total number of cases of all notifiable industrial diseases notified, and proportion of these that were due to lead poisoning.

	Year	Total Cases	Cases Notified by Occupiers	Cases Notified by Medical Practitioners	Proportion of cases of Notified Industrial Diseases that were due to Lead Poisoning %
	1900	1129	696	824	93.7
	1901	936	505	701	92.2
	1902	681	415	548	92.4
	1903	674	443	505	91.1
	1904	656	445	537	91.0
	1905	663	467	497	89.3
	1906	707	513	537	88.1
	1907	653	493	456	88.5
	1908	727	566	466	88.9
	1909	625	442	409	88.5
	1910	573	440	354	88.1
	1911	755	603	457	88.6
	1912	656	510	439	89.5
	1913	625	499	395	85.6
	1914	511	433	312	87.1
Includes Toxic Jaundice	1915 1916 1917 1918 1919		N.A.	N.A.	N.A.
Includes Epitheliomatous Ulceration + Chrome Ulceration	1920	476	399	201	51.1
	1921	318	262	153	72.3
	1922	374	295	150	65.8
	1923	510	350	225	66.1
	1924	711	544	330	68.3
Includes CS_2 Benzene + Aniline Poisoning	1925	632	461	344	51.6
	1926	568	405	286	42.6
Includes Lead Poisoning in Housepainters	1927	644	477	356	53.9
	1928	670	472	346	48.7
	1900-14	10571	7470	7437	89.8
	1920-28	4903	3665	2391	56.8
Both periods		15474	11135	9828	79.3

Source: Annual Report(s) of the Chief Inspector of Factories for the Year(s) 1900-1928

TABLE B-7 Estimated Total Number of Cases of Industrial Poisoning and Percentage of Cases Notified to the Factory Inspectorate (based on assumption that doctors and occupiers notified poisoning independently).

Year	Estimated Total Cases	Percentage reported	Year	Estimated Total Cases	Percentage reported
1900	1467	77	1920	647	73.6
1901	1311	71.4	1921	413	76.9
1902	806	84.4	1922	623	60.0
1903	816	82.5	1923	1211	42.1
1904	733	89.5	1924	1101	64.6
1905	771	86.0	1925	917	68.6
1906	803	88.0	1926	942	60.3
1907	759	86.0	1927	1005	66.1
1908	865	84.1	1928	1103	60.7
1909	800	78.1			
1910	705	81.3			
1911	904	83.6			
1912	764	85.8			
1913	733	85.3			
1914	577	88.5			
1900-1914	12812	82.5	1920-1928	7600	64.5

Estimate of total number of cases given by formula $T = \frac{A \times B}{(A+B-N)}$

where N=Number of cases Notifed, A=Number Notified by doctors, B= Number Notified by occupiers.

Information on Occupational Lead Poisoning arising from the System of Workmen's Compensation and comparison with H.M.F.I. Notification of Lead Poisoning.

The System of Workmen's Compensation

Workmen's compensation legislation was developed in the Nineteenth Century to allow a worker (or dependants) to receive compensation from an employer (or his insurance agents) for accidents in the course of employment resulting in disability or death without the need for the worker to sue for tort under common law. The 1906 Workmen's Compensation Act made lead poisoning (and certain other occupational diseases laid down in a schedule) compensatable in the same way, as a notional accident.

All industries were covered by this scheme for the first time (exceptions being police and armed forces, family employers, non-manual workers earning £250 per annum or more, home workers). This scheme continued until the Second World War, and the Royal Commission into Workmen's Compensation 1938-9 after which it was replaced with a State insurance scheme which came into operation on 9 July 1948. Despite revisions of the Act in 1923 and 1925 the principles for compensation remained substantially the same. Although the schedule of compensatable diseases was expanded, (by Orders esp. in 1913, 1919 and later schemes for silicosis), this did not affect lead poisoning claims which were payable in all occupations throughout this period. In 1923 the waiting period before which compensation could be claimed was reduced from two weeks (with the second week payable retrospectively) to 3 days. This would be expected to increase the number of claims, but the effect would be less in the case of lead poisoning - which tends to be prolonged - than with accidents or more temporary kinds of poisoning.

To gain compensation for an industrial disease a workman (or woman) must have been assessed as suffering from a disease on the compensation schedule which arose out of work activities. Either the Certifying Surgeon for the area (appointed under the 1901 Factories and Workshops Act and subsequent legislation - these were called Examining Surgeons under the 1937 Factories Act) would certify that the worker was disabled from carrying out his employment, or the Appointed Doctor for the Factory (appointed under Regulations made under the Factories Acts) could certify that the worker was suspended from his employment in accordance with the requirements of the Regulations on the grounds that he was suffering from the disease.

There was an increasing tendency for employers to pay compensation on the basis of the works doctor or the victim's family doctor. This practice had been noted in 1910 as one reason for the existence of a greater number of lead poisoning compensation cases than certificates issued by Certifying and Appointed Surgeons for that year in factories (324 as opposed to 278).

A Home Office Departmental Committee recommended that the system of paying compensation on the assessment of doctors other than Certifying and Appointed Surgeons (i.e. the worker's or employer's doctor) be formalised by agreement between worker and employer, and this was embodied in the Workmen's Compensation Act 1923. This might be expected to reduce the number of certificates issued by Certifying and Appointed Surgeons whilst increasing the number of claims for compensation. It will be considered below.

Statistics on Workmen's Compensation.

Statistics relating to Compensation for scheduled industrial diseases (including lead poisoning) were produced on the same basis between 1906 and 1939. These statistics are reported in the 'Annual Report of Statistics of Compensation and Proceedings under the Workmen's Compensation and the Employers Liability Act,' published by the Home Office from 1908 to 1938. These reports contain two tables which break down compensation activity for lead poisoning into industrial groupings, available from 1908-1914 and 1919-1930.

i) Cases of Industrial Disease for which Compensation was paid

This table gives the number a) of cases continued from previous years and b) of cases in which first payment was made during the current year. The cases are for Factories (divided into 11 groups) and 6 other major industrial groupings - mines, quarries, railways, docks, constructional work and shipping. These 7 groups employed in 1936 7.6 million out of an estimated 15-17 million workers covered by the W.C.A.

Figures are available between 1908 and 1938.

The most significant group excluded from the tables for the purposes of this study is building workers (including housepainters). Compensation paid outside these industries does not appear in these statistics.

Unfortunately the categories in which factory industries are subdivided do not conform to those existing under the Factories Acts and Regulations, nor to modern Standard Industrial Categories. For example the textile industry is subdivided into Cotton, Woollen and Worsted etc. and 'other textiles', the engineering industry is highly aggregated into Engine and Shipbuilding, and other metal work. Other categories within 'Factories' are Wood (cases of lead poisoning here may represent use of lead paints in furniture making), Metal Extraction, Paper and Printing (cases of lead poisoning in this group presumably derive from printing), China and Earthenware (highly comparable with F.I groupings), and Miscellaneous (which includes apparently pigment and paint production along with manufacture of other lead compounds, and a wide range of other industries). The definition of Factories under the Workmen's Compensation Act appears to be the same as that under the Factories Acts.

ii) Certificates of Disablement, Suspension &c given by Certifying and Appointed Surgeons in respect of disablement caused by industrial disease, for all occupations under the Act.

This table gives the number of certificates issued for the same seven industrial groupings as in the previous table but also includes Building (House painting), Agriculture and Telegraphy.

Thus the statistics for lead poisoning under the Workmen's Compensation Acts can be compared to the figures for H.M.F.I. Notified Lead Poisoning in four industrial groupings : "All Factories", Pottery and Earthenware, and Housepainting (available only for W.C.A. Certificates) where the groupings appear to be identical, and Printing (the W.C.A. figures refer to Paper and Printing Industries) where it is assumed that all lead poisoning derives from the same sector of the industry (i.e. Printing). This was used to assess the rate of voluntary H.M.F.I. notification of lead poisoning in housepainters. A comparison between these sets of figures is made to assess the significance of H.M.F.I. poisoning figures, and in particular changes in the diagnosis of lead poisoning

Comparison between Workmen's Compensation and H.M.F.I. Notification Statistics for Lead Poisoning

The statistics available for lead poisoning, for comparable industries, under the Workmen's Compensation Act and the Factories Act are presented in Table B-8. This shows the number of new and continued cases of compensation under the W.C.A., certificates of disability and suspension under the W.C.A., and cases of poisoning notified to H.M.F.I. in the periods 1908-14, 1919-30. The industrial groups covered are 'all factories', potteries, printing and housepainting (for which compensation figures are not available). The potteries are an example of an industry that was subject to Regulations that required periodic medical examinations; it was an industry involving high lead exposures (potentially) to large numbers of workers. In contrast, printing was not subject to special Regulations nor medical examinations, and only a small proportion of workers were exposed to lead hazards. The comparison between different groups allows the role of different medical compensation disease notification factors to be assessed.

The relationship between these different statistics is shown in Table B-9 and Figure 6-5. These show for the periods 1910-4, 1920-4, 1925-9, for the different industry groups, where available:

a) W.C.A. Certificates of Disability/Suspension as a Percentage of Cases of Poisoning Notified to H.M.F.I.

b) New Cases of W.C.A. Compensation as a Percentage of Cases of Poisoning Notified to H.M.F.I.

c) W.C.A. Certificates of Disability/Suspension as a Percentage of Total (New and Continued) Cases of Compensation. (Not shown in Figure).

TABLE B-8. Workman's Compensation Act Statistics for Lead Poisoning 1908-1914 1919-1938 in Industrial groupings comparable to H.M.F.I. Notified Lead Poisoning Cases

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* 1908 Figures for W.C.A. Certificates exclude 52 cases referred by Appointed Surgeons.

Source: G.B.Home Office, Annual Report of Statistics for Compensation and of Proceedings under the Workman's Compensation Acts.

TABLE B-9 The Relationship between statistics for Lead Poisoning under the Workmen's Compensation Acts (New Cases of Compensation and Certificates of Disability/Suspension) and the Factory Acts (Cases of Poisoning Notified to H.M.F.I. 1910-34. In All Factories, Printing, Potteries, Houspainting.

PERIOD	ALL FACTORIES	PRINTING	POTTERIES	HOUSE-PAINTING
	%	%	%	%
a) W.C.A. Certificates of Disability/Suspension as a Percentage of Cases of Poisoning Notified to H.M.F.I.				
1910-14	63.7	70.5	51.0	69.0
1920-24	84.3	81.4	69.4	127.0
1925-29	95.5	108.1	73.4	84.7
(1927-30	102	103.6	67.6	82.0)
b) New Cases of W.C.A. Compensation as a Percentage of Cases of Poisoning Notified to H.M.F.I.				
1910-14	65.2	47.4	87.3	N/A
1920-24	61.2	69.8	92.7	
1925-29	69.4	75.7	86.3	
(1927-30	73.4	78.5	95.9)	
1930-34	77.6	90	77.9	
c) W.C.A. Certificates of Disability/Suspension as a Percentage of W.C.A. New Cases of Compensation.				
1910-14	97.9	147.2	58.4	
1920-24	137.7	116.7	74.9	
1925-29	137.6	142.9	85	
(1927-30	139.0	132.0	70.5)	
d) W.C.A. Certificates of Disability/Suspension as a Percentage of Total (New and Continued) Cases of Compensation.				
1910-14	66.5	130.4	25.9	
1920-24	85.8	92.1	29.6	
1925-29	76.7	105.3	26.1	
(1927-30	81.8	87.9	22.6)	

Source: Table B-8.

A brief examination of the statistics for lead poisoning under the Workmen's Compensation Acts shows that

i) the relationship between the different statistics varies substantially between industries and over time.

ii) as a result the relationship between Notified Lead Poisoning under the Factories Act and the W.C.A. statistics is very variable.

iii) Activities under the W.C.A. become increasingly bound up with the apparatus for Notifying lead poisoning under the Factories Act.

It is therefore concluded that the W.C.A. statistics for lead poisoning do not provide an adequate basis for assessing changes in the significance of (and in particular, diagnostic practice that underly) Notification of lead poisoning to H.M.F.I.

It is possible to relate changes in the statistics for lead poisoning under the W.C.A. to changes in the arrangements for allowing compensation, and differences between industries. These have been analysed in detail. It is not necessary to present the results of this detailed analysis. The salient points will however be noted.

H.M.F.I. Notifications of Lead Poisoning and W.C.A. Certification of Disability/Suspension and New Cases of Compensation for Lead Poisoning.

Notification of Lead Poisoning is initially higher than W.C.A. Certificates of Disability/Suspension or W.C.A. New Cases of Compensation. This has been attributed to the fact that a worker diagnosed as suffering from lead poisoning was not necessarily disabled from working, and could be transferred to work away from lead. (A rather different pattern exists amongst housepainters under voluntary notification of lead poisoning, where certification of disability of suspension exceeds voluntary notifications [in 1920-4], reflecting the incompleteness of voluntary notification. See Appendix B-2).

Subsequently the number of W.C.A. Certificates and New Cases of Compensation increase relative to the number of cases of lead poisoning notified to H.M.F.I. This, it is suggested, indicates increasing integration of the systems of H.M.F.I. Notification and W.C.A. Compensation (with Certifying and Appointed Surgeons playing a central role in both).

The apparent excess of W.C.A. Certification over H.M.F.I. Notifications occurs at a time when levels of poisoning fall rapidly from year to year, and appear to be an artefact since H.M.F.I. figures relate to the year in which poisoning was contracted, whereas W.C.A. figures refer to the year in which compensation began to be paid.

W.C.A. Certificates of Disability/Suspension and W.C.A. New Cases of Compensation.

The fact that W.C.A. Certificates of Disability/Suspension were fewer than W.C.A. Cases of Compensation at the beginning of this period was explained by the willingness of some employers to pay compensation without a formal certificate, or on the basis of the works doctor. This is particularly notable in the pottery industry, in which the incidence of poisoning was high - indicating that these arrangements had become institutionalised.

However, the number of W.C.A. Certificates begins increasingly to exceed the number of W.C.A. New Cases of Compensation. It would appear that, following the recommendation of the Holman-Gregory Committee (subsequently embodies in the 1923 Workmen's Compensation Act), noted earlier, a substantial number of (certificated) cases of lead poisoning were receiving compensation through local agreements between employers and workers which was not reported to the Home Office.

Thus both the figures for W.C.A. Certification and W.C.A. Cases of Compensation vary over time (and between industries) in their completeness and, at certain stages exclude substantial amounts of lead poisoning. Whilst it has been possible to account for the relationship between these statistics, the variability between them is too great for a reliable prediction to be made, and in addition, the apparent convergence between W.C.A. Certification and H.M.F.I. Notification makes estimation of changes in the practice of notification impossible.

Statistics for Spells of Prescribed Industrial Disease for which Benefits were paid under the National Insurance (Industrial Injuries) Acts. 1951-1979

Under the National Insurance (Industrial Injuries) Act 1946 (and subsequent revisions) 'Workmen's Compensation' was administered by the state (currently the Department of Health and Social Security - DHSS) and funded by a levy of all employers/employees. The scheme covers everybody injured during paid employment, and provides for payment of benefits for industrial injury, disability and death. There is a schedule of diseases eligible for benefit, which was broadly similar to those existing under the Workmen's Compensation Acts and contemporary schemes, but has subsequently been extended. Lead poisoning has been eligible for benefits for injury (i.e. cases of disease) and disability throughout this period.

Statistics for Benefit Payments for Spells of Lead Poisoning broken down into the industry of employment have not been regularly published. However the D.H.S.S. have prepared an unpublished table, showing the number of new spells of lead poisoning for which benefit was paid, broken down into industries by Standard Industrial Classification (S.I.C.) for every year since 1951. This is reproduced as Table B-10.

There are two problems in using this data for comparison with cases of lead poisoning notified to the Factory Inspectorate:

i) The number of new spells of Prescribed Diseases are grouped according to the statistical year in which benefits were first paid which starts in June, whereas Factory Inspectorate Notifications are grouped by calendar year. To adjust for this discrepancy, the total number of H.M.F.I. Notifications for five calendar year periods have been compared with an estimated level of total National Insurance 'spells' for the same period comprising the 'middle' four statistical years plus the average of the first and last statistical years. (Halves have been rounded up in this calculation).

ii) The Standard Industrial Classifications are broad industrial groupings, classed by product/productive activity, containing upwards of one million workers. The Factory Inspectorate's figures for lead poisoning relate to very specific lead using industries or activities, reflecting the history of regulation of the hazard, typically employing a few thousand workers. Some of these lead processes will be distributed across a range of S.I.C. industries. The S.I.C.s also contain industrial activities not taking place in factories (or premises classed as factories under the Factory

TABLE B-10 Spells of Prescribed Disease Number 1, Lead Poisoning, Analysed by Standard Industrial Classification and Statistical Year, June to June

SHEET 1.

STANDARD INDUSTRIAL CLASSIFICATION	YEAR 1951-52	1952-53	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66
1. Agriculture, Forestry and Fishing															
2. Mining and Quarrying															
3. Food, Drink & Tobacco		1					1	1	1	1					
4. Coal & Petroleum Products													1		
5. Chemicals and Allied Industries	12	8	9	15	1	6	15	9	7	4	8	4	6	4	5
6. Metal Manufacture	12	17	6	11	9	8	6	11	15	32	10	21	29	13	17
7. Mechanical Engineering															
8. Instrument Engineering															
9. Electrical Engineering									18	14	12	16	28	26	31
10.Shipbuilding and Marine Engineering	15	19	15	12	19	14	10	9	1	3		1	4	2	2
11.Vehicles	2	2	2	2	1	2	4	6	1		2	2	6	7	13
12.Metal Goods Not Elsewhere Specified	7	4	10	15	14	23	10	23	12	8	6	16	8	16	10
13.Textiles															
14.Leather, Leather Goods and Fur															
15.Clothing & Footwear															
16.Bricks, Pottery, Glass Cement etc.									1	4	2				1
17.Timber, Furniture etc.				1	2	1					1	1			
18.Paper, Printing and Publishing					1	1			1	2		2		3	
19.Other Manufacturing Industries						1							1		
20.Construction	6	4	1	3	1	3	4	9	4	3	11	6	11	4	2
21.Gas, Electricity and Water	1		1		1									1	
22.Transport and Communications		1	1											1	1
23.Distributive Trades	1	2	1	1	3	3			3	4	3	10	2	5	9
24.Insurance, Banking Finance and Business Services											1				
25. Professional and Scientific Services										1					
26.Miscellaneous Services		1								1			1		5
27.Public Administration and Defence	1		1		1		2					1			
TOTALS	57	59	47	60	53	62	52	68	64	77	56	80	97	82	96

NOTE: The following spells were not classified. 1953-54. 1. 1954-55. 2. 1957-58. 1. 1958-59. 3.

	1951-52	1952-53	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66
3-20 Total for All Factories (Including Construction)	54	55	43	59	48	59	49	67	63	70	52	69	94	75	81

Department of Health and Social Security
HQ SR 8C
Newcastle upon Tyne

Source: Table PD2. Sample: 100%

TABLE B-10 Spells of Prescribed Disease Number 1, Lead Poisoning, Analysed by Standard Industrial Classification and Statistical Year, June to June

SHEET 2.

STANDARD INDUSTRIAL CLASSIFICATION	YEAR 1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	TOTAL
1. Agriculture, Forestry and Fishing														-
2. Mining and Quarrying							1			1	1			7
3. Food, Drink & Tobacco	1													3
4. Coal & Petroleum Products														-
5. Chemicals and Allied Industries	6	5	7	5	8	2	4	2	2	4	4	2		164
6. Metal Manufacture	29	15	31	36	36	51	16	13	9	8	5	5	2	483
7. Mechanical Engineering				4	1	4	7	5	2	2			2	27
8. Instrument Engineering				2										2
9. Electrical Engineering	28	26	23	11	12	15	4	5	5	3	1	8	2	288
10. Shipbuilding and Marine Engineering	4		1			1							1	143
11. Vehicles	6	3	3	2		2	1			1		1		71
12. Metal Goods not Elsewhere Specified	8	10	9	7	9	13	5	3	6	14	4	1	4	275
13. Textiles		1		2										3
14. Leather, Leather Goods and Fur														-
15. Clothing and Footwear														-
16. Bricks, Pottery, Glass Cement etc.		11	1	1		1	1	2	2	1	2			30
17. Timber, Furniture etc.					1									7
18. Paper, Printing and Publishing				1			1	1						13
19. Other Manufacturing Industries	1	3		4	3	5	1							19
20. Construction	11	7	10	17	5	7	11	12	4	3	3	3	7	172
21. Gas, Electricity and Water			1											5
22. Transport and Communications			1	2						1				8
23. Distributive Trades	2	12	17	4	3	4	8	10	6	11	4	5	6	139
24. Insurance, Banking Finance and Business Services														1
25. Professional and Scientific Services							1			1				3
26. Miscellaneous Services	1				1		1							11
27. Public Administration and Defence														6
TOTALS	97	93	104	98	79	105	62	53	36	50	24	25	24	
3-20 Total for All Factories (Including construction)	94	81	85	92	75	101	51	43	30	36	19	20	18	1800

Department of Health and Social Security
HQ SR8C
Newcastle upon Tyne.

Source: Table PD2. Sample: 100%

Acts). In addition, enterprises are classified according to their main productive activities and may include activities that would otherwise appear in other S.I.C.s (or other lead processes).

An attempt has been made to relate Factory Act Lead Processes (F.A.L.P.s) to S.I.C. Industries. This is presented in Table B-11. Because of the lack of correspondence between these two sets of categories, a direct comparison cannot be made in certain cases. In other cases a set of approximations can be made to allow a degree of comparability. These are briefly discussed.

<u>Shipbuilding</u> Between 1952 and 1974 only two cases of lead poisoning in shipbuilding were notified to H.M.F.I. compared to 126 new spells of P.D.I. in Shipbuilding and Marine Engineering. It seems likely that many of the latter cases are due to shipbreaking. However the distribution of spells of P.D.I. in S.I.C. 12 (when the contribution from F.A.L.P. 8 Vitreous Enamelling is subtracted) and S.I.C.23 does not parallel that in F.A.L.P. 3 - shipbreaking. It is not possible to make a meaningful comparison between D.H.S.S. returns for Spells of P.D.I. (lead poisoning) and cases of lead poisoning notified to H.M.F.I. in these industries.

<u>All Factories</u>: H.M.F.I. Notifications are equivalent to the sum of D.H.S.S. Spells in S.I.C.s 3-20 and some of S.I.C.s 21-23. (the latter due e.g. to cases in shipbreaking). Inclusion of S.I.C.s 21 and 22 make little difference to the relative magnitude of D.H.S.S. and H.M.F.I. figures. Inclusion of S.I.C.23 has a bigger effect and must be seen as providing an upper estimate of the number of spells of P.D.I. occurring in factory premises.

<u>Other Industries/Paint in Other Industries</u> (F.A.L.P.s 14/13) are distributed across S.I.C.s 3-20. This has little effect in the case of Other Industrial Painters (F.A.L.P.13), who have consequently been allocated to Construction S.I.C.20.

However H.M.F.I. Notified Lead Poisoning in other industries rose from 5.3 cases p.a. in 1952-4 (10.7% of total for all factories) to 27.4 cases p.a. in 1970-4 (37.0% of total). The distribution of these cases across S.I.C.s is not known.

Where an S.I.C. contains a major lead process, the effect of these dispersed cases of poisoning will probably be relatively small, and the number of spells of P.D.I. recorded by the D.H.S.S. would be expected to approximate to the levels of cases of poisoning Notified to H.M.F.I. In general the D.H.S.S. figures for P.D.I. in S.I.C.s would be expected to exceed the number of cases notified to H.M.F.I. for specific lead processes in that S.I.C. because they do not include these unallocated cases.

<u>Plumbing and Soldering</u> this F.A.L.P. might be distributed over a number of S.I.C.s However the numbers of cases notified to H.M.F.I. are very low and have all been allocated to S.I.C.20 - construction.

TABLE B-11 The Relationship between Factory Act Lead Processes and Standard Industrial Classification Industries

Factory Act Lead Process (FALP) specified in H.M.F.I. Notified Lead Poisoning Statistics	S.I.C. Industry(ies) in which lead process probably appears
1) Smelting of Metals	Mainly S.I.C. 6-Metal Manufacture
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... Warehouses, and some Public Utilities (e.g. Power Stations, but not work done in the streets by them)	... (as well as some from S.I.C.21 - Utilities, S.I.C. 22-Transport etc. and S.I.C.23-Distribution.)

Source : Annual Report(s) of the Chief Inspector of Factories
G.B.Central Statistical Office, Standard Industrial Classification, 3rd Edition, HMSO, London, 1968.

Vehicle Painting etc., this F.A.L.P.(II) did not give rise to any cases of notified lead poisoning in 1952-74, however significant, and increasing numbers of spells of P.D.I. were recorded by the D.H.S.S. in vehicles (S.I.C.11) - arising primarily from 'sanding' the metallic lead used to fill gaps in car bodies. This cannot be accounted for by F.A.L.P. 2 - plumbing and soldering, and presumably appears under F.A.L.P. 14 - lead in other industries.

The number of cases of H.M.F.I. Notified Lead Poisoning and D.H.S.S. New Spells of P.D.I. (lead poisoning victims receiving industrial injury benefits), where direct comparisons can be made between industrial groupings, are presented in Table B-12.

The same figures are shown in Table B-13 with D.H.S.S. Spells of P.D.I. expressed as a 'percentage' of H.M.F.I. Notified lead poisoning for each industry group/period. (N.B. in some of these it has been necessary to combine successive years to get a meaningful ratio).

The Relationship between H.M.F.I. Notified Lead Poisoning and D.H.S.S. Spells of P.D.I. (lead poisoning receiving benefit)

Amongst 'all factories', the numbers of cases of lead poisoning, indicated by these two sets of statistics, are broadly similar, with H.M.F.I. Notifications exceeding D.H.S.S. Spells by a small margin, particularly in the five year period preceding and following the 1964 Lead Processes Medical Examinations Regulations (in which, as noted earlier, the number of cases of notified lead poisoning rose sharply).

However, this situation is a product of two opposing trends. As shown in Table B-13 and Figure 6-6, in S.I.C. industries containing lead processes the number of Spells of D.H.S.S. P.D.I. (Benefits paid for lead poisoning) were initially fewer than H.M.F.I. Notifications of lead poisoning, but subsequently rose and came to exceed H.M.F.I. Notifications. In those S.I.C.s to which Factory Act Lead Processes cannot specifically be allocated, the reverse is the case, with H.M.F.I. Notifications of lead poisoning initially lower than, but coming to exceed D.H.S.S. Spells of P.D.I. This relationship can be observed both in groups of industries and individual industries.

The former group (industries containing specific lead processes) primarily represents industries subject to Regulations regarding lead hazards (and also subject to medical examination requirements), whereas the latter group (industries to which specific lead processes cannot be allocated) consists mainly of industries not subject to Regulations/ medical examination.

Caution must be exercised in interpreting these trends, which may be influenced by changes in categorisation. In addition, this period saw a marked increase in the contribution of 'other industries' to the total levels of lead poisoning notified to H.M.F.I. (i.e. the contribution of industries not subject to specific Regulations as lead processes). Moreover there are differences between industries which will be discussed below.

Amongst industries subject to Regulations, it would appear that claiming

No.1. recorded by the D.H.S.S. in comparable Industrial groupings. 1952-1974.

TABLE B-13 D.H.S.S. Recorded Spells of P.D.I. as a Percentage of H.M.F.I. Notified Cases of Lead Poisoning in comparable industry groupings, 5 year periods 1952-74.

Average

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Source: Annual Report(s) of the Chief Inspector of Factories
G.B., D.H.S.S., Table P.D.2 1980, op.cit.

benefits from the D.H.S.S. for Spells of P.D.I. was initially depressed (relative to H.M.F.I. Notifications of lead poisoning) in particular in S.I.C.9 (F.A.L.P.9) and S.I.C.16 (F.A.L.P.7). The increasing propensity to notify lead poisoning to H.M.F.I. in these industries in 1960-9, which was argued to have been a result of changes in methods of diagnosis/assessment of lead 'poisoning' for notification to H.M.F.I., seems to have been followed by an increase in propensity to claim Benefit from the D.H.S.S. for P.D.I., which results ultimately in the number of recorded Spells of P.D.I. exceeding H.M.F.I. Notifications. Thus while there may have been a lag between the two, changes in diagnosis and assessment of lead poisoning for H.M.F.I. Notification seem to have been matched by similar changes in D.H.S.S. diagnosis and assessment of P.D.I.

The eventual excess of the number of Spells of P.D.I. over H.M.F.I. Notified lead poisoning can be explained by the fact that the latter are drawn from a group containing many thousands of other workers in the S.I.C. industries as well as those employed in Factory Act Lead Processes.

The existence of the reverse of this relationship amongst industries not subject to Regulations regarding lead hazards is less easy to explain. It appears to be a consequence of an increasing propensity to notify lead poisoning in 'non-Regulated' industries, which is greater than the increase in Regulated industries (a reversal of the situation existing between 1900 and 1959). This could be attributed to changes in assessment of lead poisoning and completeness of notification (one factor promoting the latter, which appears to have affected non-Regulated industries was a survey of industrial lead hazards conducted by H.M.F.I. in 1971-2). However this does not seem to have been matched by changes in propensity to claim Benefit for P.D.I. in these industries. This anomaly may indicate that there were differences between industries in the likelihood of workers to claim Industrial Injury etc. benefit for P.D.I.

Differences between Industries containing Regulated Lead Processes can be noted in Table B-13. In particular, in the construction industry, the number of recorded spells of P.D.I. as a percentage of H.M.F.I. Notified lead poisoning is three to five times lower than in industries containing factory based lead processes subject to Regulations. The National Insurance Industrial Injuries Scheme is administered independently of industrial structure, and is presumably more constant across industries than H.M.F.I. Notification. This would indicate that only 20-30% of the cases of lead poisoning that would have been expected to be notified in the Construction Industry (if Notification had been conducted on the same basis as Regulated Factory Lead Processes) were in fact being notified. This estimate is broadly consistent with estimates from other sources. (See Appendix B-2).

Numbers Employed in Pigment and Paint Production and Use

Information on the numbers employed in pigment and paint production and use are available from three sources:

1. The Decennial Censuses of the Population for England and Wales for 1901, 1911, 1921, 1931 and 1951.

2. Returns submitted to the Factory Inspectorate by Factory occupiers under S130 of the 1901 Factory and Workshop Act (along with more specific surveys carried out by Inspectors). These of necessity only include premises covered by the Act (and registered with the Factory Inspectorate). Factory Inspectorate returns are available for 1901, 1903 (Coach painting), 1911, 1912, 1913, 1914.

3. Censuses of Production carried out by the O.P.C.S. (1907, 1924, 1930, 1968, 1951) which do provide some relevant information.
   Additional sources for individual industries have also been used, referenced separately.

Changes in the categorisation of occupations and industry categorisation in the censuses, as well as in the way that results are presented create some incongruities and ambiguity as to the number employed in paint production and use. In addition changes in surface coating technology and the status of certain kinds of labour make earlier distinctions invalid. For example, japanners (who merely applied lacquer in metal finishing etc.) were originally a distinct group from painters (who were craftsmen mixing pigment and oil to make paint to be applied by brush). Workers applying stoving enamels were categorised with jappanners and even with vitreous enamallers in some years, though they would be using lead and other paints. The advent of ready mixed paint and of paint spraying as the dominant method of applying industrial paints went hand in hand with the conversion of painting from skilled to semi-skilled work. However census occupational categories still separated paint sprayers from those applying paint with a brush.

It has been possible to chart the number involved in painting in the major trades under examination (Buildings, Vehicles, Ships) however the effect of incongruences in categorisation of occupations across different industries has made it impossible to get a meaningful figure for painters in other manufacturing industries and all other industries.

The available statistics are presented in the following pages for each industry in turn. Their interpretation is discussed, and the results are summarised in Table B-14.

Coverage of the Various Statistical Sources The Census of production only covered larger firms (employing over 11 workers) between 1924 and 1951. These are for England, Wales, Scotland and Northern Ireland.

[illegible] Numbers Employed in Pigment and Paint Production and Use 1901-1951.

	Lead Pigment Production White Red and Yellow Lead	White Lead Production alone.	Paint and Colour Making	Paint Makers Employed on 'Lead Processes' *	Total Paint & Pigment Production	House Painting	Ship Painting (excldg. spray painters)	Vehicle Painting (excldg. spray painters)	Other Indust. Paint. (excldg. spray painters).
1901	2016	1844	5646	1222	7662	138724	4359	13415	
1911	2689	2489	8590	1550	10495	159956	5002	16880	
1921	2152		15665	1508	17817	123625	5833	15709	38119
1931	1109		18512	1447	19621	144092	4277 (3819)	15971 (14816)	46918 (43596)
1951			16690	584		178918		23130 (16209)	33458 (22553)

* i.e. workers in direct contact with lead compounds.

(all Ireland for 1907). The returns to the Factory Inspectorate are for the same countries, and covered all firms (although the completeness of returns is not known),

The Census of Employment figures used are for all workers in England and Wales only. These have been the major source of information. The exclusion of Scotland and Ireland appears to have had little effect on numbers employed in the highly centralised paint and colour industries (91-94% of employment in the paint industry and 100% of the pigment industry was based in England and Wales between 1907 and 1951). The major industrial user of paint, the vehicle industry, was largely based in England and Wales (96% of U.K. employment in 1963), but this is less true of other industries e.g. shipbuilding (70%, 1907 and 75% 1951) and probably construction (and housepainting). However the Census of Employment figures provide almost all the information on numbers of house and industrial painters.

In practice the employment figures below relate to England and Wales only. However Census of Production and Factory Inspectorate figures for the United Kingdom have been used for employment in pigment, paint and vehicle manufacture. However this does not lead to problems of comparability since the numbers employed in Scotland and Ireland are very small.

Paint and Colour Makers

When paint was mixed by craft painters from raw materials paint manufacture was hardly a separate industry, more a raw material distributor or supplier. Pigment manufacture was often tied to firms mainly concerned with smelting the metal base.

The spread of ready mixed paints, based on synthetic resins, led to the development of the paint making industry which is now very much a part of the chemical industry, along with varnish, printing ink etc. manufacture.

The ambiguous status of paint and pigment manufacture is reflected in the Census data (both of production and employment) and other sources have been prioritised in earlier years.

1901 Census of Employment

6913 workers were engaged in the manufacture of colouring matter (Dye, Paint, Ink and Blacking).
8699 workers were employed as "Oil and Colourmen".
3075 workers were engaged in varnish manufacture.

These categories are too broad to be useful.

1901 F.I. Survey

This gives more direct information, which will be used in preference to the Census of Employment figures.

1824 workers from 27 returns (i.e. factories) engaged in white lead manufacture.
192 workers (16 returns) in red orange and yellow lead manufacture (total pigment makers 2016) and
5546 (351 returns) in paint and colour manufacture
1184 (133 returns) in varnish manufacture.

1907 Census of Production

This states that 1737 were engaged in white lead manufacture (of which 1155 were employed at lead smelters). 13476 were employed in paint, colour and varnish manufacture (10308 were operative workers).

1911 Census of Employment

11110 were engaged in Dye Paint and Ink and other Colour manufacture (this includes white lead and zinc pigment makers) 9573 were employed as "Oil and Colour men".

These categories are too broad to be useful.

1911 Departmental Committee [41]

The White Lead manufacturers claimed that 2489 people were employed in their industry. This figure is higher than the 1907 Census of Production figures i) because it includes non-manual workers and ii) because recorded production of white lead had increased by 50% in this period (although output per head remains approximately constant - at 22.5 tons per worker in 1907, and 23.3 tons per worker in 1911). This employment figure will be used in preference to the 1907 Census of Production and the 1911 Factory Inspectorate returns below - which only cover workers directly handling white lead.

Though no figures exist for employment in red and orange lead works, output was expanding and employment is assumed to be 200 - slightly greater than in 1901.

1911-1914 F.I. Surveys

These give the number of workers directly involved in lead processes (i.e. in handling lead compounds). They are therefore lower than other figures for employment, and not directly comparable. The proportion of workers directly involved in handling lead would be higher in white lead works than paint and colour works (where some would be involved in handling non-lead pigments, varnishes etc.).

Workers Involved in Lead Processes (Directly handling dry lead compounds)

	White Lead	Paint and Colour
1911	1405	1550
1912	1382	1485
1913	1201	1400
1914	1119	

1921 Census of Employment

Occupational tables show 30567 working as Makers of Paint, Oils etc. (though this category does not include white lead making - classed under "Chemical Processes") comprising 2980 employers, 1795 foremen, 2301 paint grinders, 4964 other skilled workers and 18527 other workers (this gives some indication of the small size of many firms - averaging 11 workers per employer). These figures seem high compared to 1911 and 1931 especially given the exclusion of white lead workers. They also do not tally with the Census of Employment Industrial tables which have been taken to be more reliable.

Workers in White Red Yellow etc. Lead Manufacture	2,152
Workers in Paint and Colour Makers	15,665
Workers in Varnish Makers	2,936

1924 Census of Production

13700 operatives and 6300 non-manual workers employed in Paint and Varnish Manufacture.

1931 Census of Employment

Industrial tables	White Red and Yellow Lead Manufacturers-Operatives 1109	Managers etc.	66
	Paint Colour and Varnish Makers Operatives 22214	Managers and Technicians	1820

1930 Census of Production

15900 operatives and 7600 non-manual workers employed in Paint and Varnish Manufacture

1948 Census of Production

21000 operatives and 13500 non-manual workers employed in Paint and Varnish Manufacture.

1951 Census of Employment

Paint and Colour industry now included within Chemical Industry categories.

1951 Census of Production

21700 operatives and 16000 non-manual workers employed in Paint and Varnish Manufacture.

Estimate of the Numbers Employed in Varnish Manufacture

The 1901 Factory Inspectorate and 1921 Census of Employment returns show the number of varnish makers as being about 20% of the total for paint and varnish manufacture. This has been used to estimate the number of workers in paint making alone for other years.

Number of Operatives in Paint Making

Year	1901	1907	1921	1924	1930	1931	1948	1951
Source	F.I.	C. of P.	C. of E.	C. of P	C. of P	C. of E.	C. of P.	C. of P.
Number of Paint and Varnish Operatives	6830	10308	18664	(13700?)	(15900?)	22200	21000	21700
Estimated number of Operatives in Paint Making	5646*	8590	15665*			18512	16690	17360

* known.

The increase in employment in paint making between 1901, 1907 and 1921 is apparently linear with time. On this basis, paint making employment has been estimated at 10,700 in 1911.

Estimate of Numbers of Paint Workers in Contact with White Lead

The number of paint workers in contact with lead is known for 1911-4 (F.I. Figures), but must have fallen in subsequent years as the relative consumption of white lead (as a proportion of total white pigment consumption) has decreased. A linear relationship is assumed to exist between relative consumption of white lead, and the proportion of operatives in contact with white lead.

Relative consumption of white lead in paint is known for 1907, 1924, 1948 and 1951 (0.69, 0.425, 0.182 and 0.13 respectively) and has been estimated as 0.08 in 1911.

This yields the following estimates for the numbers of paint and colour workers in contact with white lead. (It may well be an underestimate of the number of paint workers exposed to lead since consumption of red lead remained high, and since this estimate is based on the assumption that workers either used lead or non-lead pigments, whereas in practice, many would be working with both, however, it is a reasonable index of the intensity of exposure to the most hazardous lead pigment - white lead).

Estimated Proportion of Paint and Colour Workers in Contact with White Lead

Year	1901	1907	1911	1921	1948	1951
Numbers employed in Paint and Colour Making	5646	8590	10700	15665	16690	17360
White lead as a proportion of total white pigment consumption in paint		.69	.60	.425	.182	0.13
Estimated number of Paint and Colour workers in contact with white lead.		1427	1550*	1607	733	553

* known.

Housepainters

1901 Census of Employment

160,201 housepainters including glaziers

Using the ratio of housepainters to glaziers from 1911 Census of Employment gives an estimate of 2561 glaziers leaving 157,641 housepainters. Estimated 12% were employers i.e. 138724 operative painters and 18,917 employers.[42]

1911 Census of Employment

181,768 housepainters. Estimated 12% employers (see above) yielding 159,956 operative painters and 21,812 employers.

1921 Census of Employment

Occupational tables give 156,406 House, Ship and General operative painters. (i.e. 207,674 total painters, including 11,001 employers and managers, 2341 foremen, 15943 Vehicle Painters and 14,458 other workers, signwriters.
Industrial tables give 123,625 painters in the construction industry of these 112,454 were operatives and 11,171 were employers, managers and foremen (E,M,F.s).

1931 Census of Employment

Occupational tables give 206,323 House, Ship, Vehicle and General operative painters with 16,893 (E.M.F.s).
Industrial tables give 144,092 Operative painters and 14,354 E.M.F.s in the construction industry (Total 158,446).

1951 Census of Employment

Occupational tables give 253,470 House, Ship, Vehicle and General operative painters with 9,735 E.M.Fs.
Industrial tables give 173,195 operative painters in the construction (+ 483 paint sprayers) Total Operatives 173,678 and 5240 foremen.
Total 178,918

Ship-Painting

1901 Census of Employment

Does not give a separate figure for painters, who are classified along with 'others in shipbuilding' (31587 out of a total of 86542 in the industry)

The 1911 Census of Employment shows 5002 ship-painters, out of 34523 'others in shipbuilding' and 104508 total employed in the industry. Assuming that the ratio between ship-painters and 'others in shipbuilding' was constant between 1901 and 1911 yields an estimate of 4577 ship-painters in 1901. Assuming that the ratio between ship-painters and total shipbuilding workers was constant between 1901 and 1911 yields an estimate of 4141 ship-painters in 1901.

The average has been taken as most representative - i.e. 4359 ship-painters in 1901. (This may be an underestimate since the 1901 F.I. survey reports 145786 ship and boat builders in 606 sites).

1911 Census of Employment

Operative ship and boat painters 5002.

1921 Census of Employment

Operative ship and boat painters 5833 with 161 foremen i.e. 5995 total.

1931 Census of Employment

Operative ship and boat painters 3819 and 458 paint sprayers total operatives 4277 plus 143 foremen - totalling 4420.

1951 Census of Employment

Includes shipbuilding with other heavy engineering and a separate figure for ship painters cannot be estimated.

It must be remembered that ship painters are not the only workers in ship building to be exposed to lead paint hazards, since lead paint was encountered by other workers involved in fitting the hull and more seriously in scrapping ship painted with lead paint. This will be dealt with later.

Vehicle Painters

1901 Census of Employment

No separate category for painters, who are included in 4561 "others in vehicle making" out of 118400 total employed in vehicle building.

1901 F.I. Returns

174756 workers in vehicle building (2907 returns i.e. sites) (in 1904 F.I.Report p.52 [CD.2569] 1905).

1903 F.I. Survey

Covered 603 most important coach building works found 9608 workers using lead paint. If the same relationship between total employees and painters was found in the rest of the vehicle industry and the average size were the same, an estimate can be made (from 1901 F.I.) of 46319 vehicle painters. However this method of scaling up almost certainly involves a gross over-estimate since the F.I. Survey covered sites selected presumably because they were large, employed a high proportion of painters or had given rise to many cases of poisoning.

1911 Census of Employment

No separate figures for painters who are included in 5938 "others in vehicle making" out of 182300 total single employees.

If it is assumed that the relationship between total employed and number of painters is the same in 1901 and 1911 as in 1921 (when 15,331 out of 356500 workers were painters) it can be estimated that the number of vehicle painters was 5092 (1901) and 7840 (1911).

However the industry had changed in structure and grown largely to the increase of motor vehicle production (accounting for the majority of vehicle production in 1921) which was becoming mechanised and there is therefore some uncertainty as to the validity of this estimate, which is much lower than the 1903 and 1912 F.I. Surveys would indicate.

1912 F.I. Survey

A complete return of the number of workers in the "Coach Painting" Industry was obtained in 1912 by the Factory Inspectorate.
This showed that out of 219889 in the Industry, 29308 were involved in contact with lead, but of these 10442 were involved in bedding and jointing (use of white lead in paste form with oil or size to seal cracks between panels etc.). 18866 workers were involved full and part time in mixing paints and painting. (14895 painters).
(8.6% of total are painters - full and part time)
(6.8% excluding paint mixers)

The 1912 F.I. Survey must be considered a more accurate measure of numbers exposed to lead, however it may be less comparable with other census data by including workers exposed to lead paints on a part time basis whose job title would not necessarily be that of painter (and who would appear in a different census category).

1921 Census of Employment

Industrial Tables -

Of 356500 workers employed in the building and repair of vehicles, 15331 were classed as painters including 367 foremen. 2641 were classed as painters and decorators (who by implication were involved in painting of buildings rather than vehicle production) leaving a figure of 12323 operative production painters.

Occupational tables give the number of vehicle painters (excluding foremen) as slightly higher - 15709 (possibly because the industrial tables do not give separate figures for numbers of painters employed in the smaller sectors of vehicle production and repair).

The proportion of total employees in sectors of vehicle production classed as painters (figures in brackets exclude painters and decorators where they are distinguished from painters) are as follows:

Railways 6.5% (4.8%), Motor Vehicles 2.1%(1.8%), Carriages and Coach Bodies 21.4%(19.2%), Lorries 3.5%(2.5%), others 2.6% (2.0%) - Total 4.3% (3.5%).

1931 Census of Employment

Industrial Tables give 14816 painters (and decorators) and 1155 paint sprayers (total 15971) in the vehicle industry employing 462376 workers (3.5% of total are painters and sprayers).

1951 Census of Employment

Industrial tables give 16209 painters (and decorators) and 6921 paint sprayers (total 23130) (also 1030 foremen) in the vehicle industry employing 931347 workers (2.5% of total are painters sprayers).

Numbers employed in Vehicle production nearly quadrupled between 1901 1921 and increased nearly 3-fold between 1921 and 1951.

In this latter period the number of painters (including decorators and sprayers) only increased by 50% - half as fast. This reflects the increase in productivity achieved through fast drying paints applied by spray guns.

To get a series of figures that are comparable, Table B-14 shows numbers of operative painters (including decorators and sprayers).

The 1912 F.I. Survey data will be used, but because the figure for painters includes part-time workers, half of the paint mixers are excluded from the total (in the hope that part-time painters will more or less balance out the number of part-time mixers that were occasionally occupied in painting). In this way a figure is reached that can provide a better basis for long term comparisons of 16880. The ratio of paint mixers included in the total is the same as the number of painting labourers in the 1921 survey. It must be remembered that in all, 29308 people came into contact with white lead and the estimate used for comparison with other industries/years only amounts to half of these. However most cases of poisoning arise from painting, and the use of white lead stopping and bedding compound declined rapidly with the introduction of metal panels in vehicles (and the introduction of lead (see stopping materials).

A very rough estimate of the numbers involved in painting vehicles in 1901 can be obtained by scaling down the 1912 F.I. survey to the numbers in the 1901 F.I. returns (it is presumed that both were made on the same industrial classification - which presumption cannot be made about the census data) which gives a figure of 13415 painters (1901).

The percentage of vehicle builders estimated to be involved full-time in painting is as follows :

1901	1911	1921	1931	1952
(7.7)	7.7	4.3	3.5	2.5

It is known that output of vehicles has increased substantially. Painting technology has clearly become very much more productive as a result of the introduction of spray painting (and also fast-drying and stoving paints). Since spray painters would probably not use lead paints, the incidence of poisoning has also been calculated amongst the manual painting workers only (i.e. excluding the numbers of spray painters for 1931 and 1951 and assuming that all lead poisoning occurred amongst manual painting workers.).

Other Industrial Painters

It is difficult to estimate the size of this group of workers since they are spread over all the industries outside vehicles, shipbuilding and construction. They will comprise factory based painting and decorating teams as well as production painters but it is not possible to distinguish between these groups except i) in the case of spray painters who are all by implication production painters and ii) in non-manufacturing industries (breakdown of painters in each sector of industry available for 1951 only).* As already noted, the historical classification of japanners as separate from painters (1901) and subsequent inclusion of stovers and enamellers in this group (1921) (even of vitreous enamellers 1951) confuses the situation. However japanners would not be exposed to lead pigments, and stoving paints and enamels were usually lead free (based on Zinc Oxide pigment).

*A rough figure for industrial painters (production and factory decorators) can be obtained by subtracting from the total number of operative painters, the number of painters in shipbuilding, vehicles, and construction industries as follows:

1901 Census of Employment

Industrial tables, 2,596 Japanners.

1911 Census of Employment

Industrial tables, 14,411 Furniture painters.

1921 Census of Employment

Industrial tables, 6,897 Metal painters (Japanners, Enamellers and Stovers.

Occupational tables give 156,406 House, General and Ship Painters (not including vehicles)
Subtracting 112,454 Housepainters (Industrial tables) and
5,833 Ship Painters (Industrial tables)
Leaving an estimated 38,119 Other Industrial Painters.

1931 Census of Employment

Industrial tables, 8,729 Metal painters (Japanners, Enamellers [including cycles]).

Occupational tables give 206,323 House, Ship, Vehicle and General Painters and 4,895 Spray Painters
Subtracting 144,092 Construction industry painters, and
14,816 Vehicle industry painters with 1,115 Spray painters and
3,891 Shipbuilding industry with 458 Spray painters
Leaving an estimated 43,596 operative painters in 'other industries' and 3,322 spray painters.
(Total Painters and Sprayers = 46,918).

1951 Census of Employment

5,937 Metal Finishers (Japanners and Enamellers - including Vitreous Enamellers).

Occupational tables give a total of 216,200 painters and 19,800 decorators.
The total numbers of painters and decorators were 216,200 and there were 19,800 Sprayers.
Subtracting 16,209 vehicle building painters and 6,021 Sprayers and

173,195 construction industry painters and 488 Sprayers. Leaving an estimated 26,796 painters and 12,391 Sprayers employed in shipbuilding and all other industries.

There are no separate figures for shipbuilding, which is included in the Minimum List Heading for Engineering and Electrical Engineering (12,733 painters and decorators, 4,457 Sprayers).

If it is assumed that one third of these painters were from the shipbuilding industry (i.e. 4,243 painters and 1,486 sprayers) the estimated number of other industrial painters would be 22,553 painters and decorators and 10,905 spray painters (Total 33,458).

The number of painters and decorators and of spray painters in the various industry groupings is as follows:

	Painters and Decorators	Spray Painters
Agriculture	216	-
Mining	957	-
Ceramic/Glass	598	130
Chemicals	2250	248
Metal Manufacture	1505	653
Other Metal Goods	1236	2749
Precision goods, jewellery	286	460
Textiles	1380	87
Leather	106	62
Clothing	224	33
Food Tobacco etc.	2808	42
Wood Manufacturers	2379	1803
Paper Manufacturers	926	210
Other Manufacturers	1299	1056
Gas	2051	103
Transport	4686	151
Distribution	2000	184
Finance	1263	1

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54. - G.Rhodes, Inspectorates in British Government, Law Enforcement and Standards of Efficiency, Allen and Unwin, London, 1981, especially Chapter 6, pp.61-95.
- P.W.J.Bartrip, 'British Government Inspection 1832-75 some observations', The Historical Journal, 25 (3), 1982. pp.605-26.
- P.W.J.Bartrip and P.T.Fenn, 'The Administration of Safety : The enforcement policy of the early factory inspectorate 1844-64', Public Administration, 58, 1980, pp.82-102.

55. One example of this was the failure of the Factory Inspectorate to prosecute breaches of the 1968 Asbestos Regulations at Acre Mill asbestos factory where asbestos exposure had led to massive levels of disease and death amongst the workforce.
A.J.P.Dalton, Asbestos Killer Dust, British Society for Social Responsibility in Science, London 1979.
See also, J.Grayson and C.Goddard, 'Industrial Safety and the Trade Union Movement', Studies for Trade Unionists, 1 (4), Workers Education Association, London, December. 1975 (2nd revised edition September 1976).

56. K.Marx, 1976, op.cit.,
Thus at pp.625-6, Marx notes, regarding the 1867 Factories Act, "the necessity imposed on the Parliament of the ruling classes of adopting, in principle such extraordinary and extensive measures against the excesses of capitalist exploitation and on the other hand the hesitation, unwillingness and the bad faith with which it actually puts these measures into practice". However, see also Ibid., p.390 and p.612.

57. W.G.Carson, 1979, op.cit.,
Carson, following Foucault is concerned to establish the origin and nature of differences in acceptance of 'customary illegalities' on class lines. As such, he makes no assessment of the extent of compliance or the effects of legislation. See reference 60.

58. This approach is traced back to M.Bernstein, Regulating Business by Independent Commission, Princeton University Press, 1955.
Robert J.Williams, 'Politics and the Ecology of Regulation', Public Administration, 54, 1976. pp.319-3311

59. P.W.J.Bartrip and P.T.Fenn, 'The Conventionalisation of Factory Crime, a reassessment'. International Journal of the Sociology of Law, 8, 1980, pp.175-186.
See also :
- R.J.Williams, 1976, op.cit.
- B.F.Gillespie, 1977, op.cit.

60. Thus Bartrip and Fenn ('The Conventionalisation of Factory Crime - A Reassessment', 1980 op.cit.) argue that it is possible to see a consensual enforcement policy as an attempt by enforcement agencies to use their limited resources most efficiently. Bartrip and Fenn make a range of criticisms of deterministic assumptions apparent within this 'critical' school. Unfortunately they (mis)interpret both Marx's and Carson's theories, for example as involving a 'bourgeoise conspiracy'. Their criticisms are thus more pertinent to elite theory and related brands of 'vulgar' Marxism than to a developed Marxist approach.

61. G.Rhodes, 1981, op.cit., p.65.
Rhodes found it "impossible to put even an approximate figure on how large a part" of the 70% reduction in fatal accident frequency rates in British mines between 1853-1893 was "due to the [Mines and Quarries] inspectors".

62 Bartrip and Fenn, 'The Administration of Safety : The Enforcement Policy of the Early Factory Inspectorate", 1980, op.cit. In particular the rate of reporting of non-fatal accidents varies inter alia according to the prosecution rates by Factory Inspectors.

63. Ibid.

64. P.W.J.Bartrip, 1980, op.cit.

65. H.A.Scarrow, 'The Impact of British Domestic Air Pollution Legislation', British Journal of Political Science, 2, 1971. pp.261-282.

66. K.Marx, 1976, op.cit.
References in the text are to page numbers in this edition.

67. Marx notes in particular the tendency of employers to legitimate their opposition to regulation in the 'natural' (or technical) impossibility of introducing the changes proposed, thereby obscuring the economic/political basis of their resistance. These technical barriers frequently evaporate once regulation is adopted (pp.605-7).

68. The economic benefits of factory legislation in promoting industrial development have been noted elsewhere; see particularly, S.Webb, 1911, op.cit., and Harrison and Hutchins, 1911, op.cit., Chapter 4.

69. Bartrip and Fenn, 'The Conventionalisation of Factory Crime - A Reassessment', 1980, op.cit.
Bartrip and Fenn suggest that regulation, and the emergence of the Factory Inspectorate, played an "important role in the emergence of a viable class society".

70. For example the (temporary) support by the "spokesmen of the manufacturing classes" for the '10-Hours Bill' in order to win the workers support for the repeal of the Corn Laws. Subsequently capital 'sought' the support of its employees to oppose this Bill. K.Marx, 1976, op.cit. pp.393-396.

71. Thus initial factory legislation covered child labour and subsequently female labour, in conformity to existing social mores, but not adult male labour.

72. Although there have been very different interpretations of Marx's analysis of the Factory Inspectorate cf. Carson, 1979, op.cit., and Bartrip and Fenn, 'The Conventionalisation of Factory Crime - A Reassessment', 1980, op.cit.

73. This conflict between the judiciary and the enforcement agencies and legislature illustrates that the state is not monolithic but can exhibit internal differences and divisions. Such divisions are rooted, inter alia in the differing functions and relationships between sectors of the state and the various parties involved in the question of regulation.

74. Hirsch, 1978, op.cit.
Offe, 1975, op.cit.

75. The position adopted broadly follows that advanced by Bob Jessop, 1977, op.cit.

76. - K.Marx, 1976, op.cit. p.611.
- B.Commoner, 'Workplace Burden', Environment, July/August 1973, pp.15-20.

77. See for example :
- U.S.President's Scientific Advisory Committee, Chemicals and Health : Report of a Panel, Science and Technology Policy Office, U.S.National Science Foundation, Washington, September 1973.
- W.T.Singleton, Health and Safety in Agriculture, A.P.Note 24, Applied Psychology Department, University of Aston in Birmingham, 1970.
- Jan Kronlund, 'Organising for Safety', New Scientist, 82 (1189), 14 June 1979, pp.899-901.

78. For example a major area of current concern is with the possible health hazards of the large number of new chemicals used industrially.
- R.A.Williams, 'Chemical Hazards', Science Bulletin, (21), Spring 1979, pp.3-6.
- L.Doyal, 1983, op.cit.

79. Part of a viable class society; see reference 69.

80. It is of note that reductions in working time subsequent to the '10 Hours Act' were achieved primarily through trade union bargaining with employers rather than legislation.

81. For contrasting analyses of the changing role of the Factory Inspectorate see :
- Carson 1979, op.cit., Grayson and Goddard, 1975, op.cit., Owen, 1978, op.cit., Rhodes, 1981, op.cit.
- P.W.J.Bartrip, 'British Government Inspection 1832-75', The Historical Journal, 25 (3), 1982. pp.605-626.

82. For a discussion of the changing role of experts in the history of regulation of industrial hazards in Britain see; H.F.Steward, 'Scientific Expertise, Workers Interest and Public Involvement : industrial risks as an example', paper presented at Risk and Participation Conference, Leusden, Holland, 17-20 August 1982.

83. An example of this 'ideological' role of knowledge is the development of standards for workplace exposure to chemicals which incorporate a 'balance' between risk and the cost of control, but which are presented as scientifically determined 'safe' standards. See : R.A.Williams, 1979, op.cit., L.McGinty and G.Atherley, 1977, op.cit.

84. A.Gramsci, 1971, op.cit.

85. B.Gillespie, 1977, op.cit.
Gillespie discusses the effects of conflict between the state's role as regulator and promoter of the use of agricultural pesticides and their potential hazards to workers, consumers and the environment.

86. For example, see :
- Rowland Livock, 'Science and the Law in Compensation and Industrial Disease', paper presented to British Sociological Association Annual Conference, (mimeo), University of Hull, April 1979.
- R.A.Williams, 'Trade Union Activity Around Health and Safety at Work : The Foundry Workers' Union 1939-1954, unpublished M.Sc. thesis, Department of Safety and Hygiene, University of Aston in Birmingham, 1977.

87. For example by legislation - in particular recent laws for the testing of toxic hazards of chemicals. A more characteristic response to this problem over the past century has been the attempt by regulatory agencies to develop policy in close cooperation with the regulated industry. Such a strategy is not without problems; the state still needs expertise to assess 'industry' information, moreover the adequacy of 'industry' information as a basis for policy formation may be challenged politically.

88. P.Bartrip, 1982, op.cit.

89. i.e. to produce such knowledge, in Offe's sense of the word. Offe, 1975, op.cit.

90. L.Doyal et al, 1983, op.cit.

91. H.F.Steward, 1982, op.cit.

92. J.Hallerbach 1978, quoted in V.Ronge, 1980, op.cit.

93. The significance of such 'voluntary compliance' as a political factor stimulating the adoption of regulation can be observed in this case-study in both the example of white lead production and paint manufacture (see Section 4.2). Voluntary compliance appears to be significant outside the sphere of factory legislation; for example in air pollution legislation H.A.Scarrow, 1971, op.cit.

94. R.A.Williams, 1977, op.cit.

95. See for example the duty of compliance embodied in the clause 'so far as is reasonably practicable' which qualifies much of the 1974 Health and Safety at Work Act, and the judicial interpretation of the phrase 'practicable means' which qualifies sections 10-15 of the 1961 Factories Act. I.Fife and E.A. Machin, Redgrave's Health and Safety at Work Act, Butterworth, London, 1976.

96. Ashford and Heaton, op.cit., in, C.T.Hill (Ed.), 1979, op.cit. Informal stimuli such as political movements towards regulation were found to be more important than formal regulation in promoting changes to avoid hazards in the U.S. chemical industry in recent years.

97. J.Kronlund, 1979, op.cit.

98. Such a phenomenom is by definition hard to identify. The present case-study provides an example whereby posing the prohibition of white lead pigments depended on the development of effective and economic lead-free pigments. L.Teleky, A History of Factory and Mine Hygiene, Columbia University Press, New York, 1948.

99. For example, the greater resources available to industrial interests gives them increased opportunities to influence inter alia the body of expertise on industrial hygiene than popular interests (e.g. unions, consumer groups). However, Offe suggests that selectivity is located within the state as well as civil society - see previous discussion, C.Offe, 1974, op.cit.

100. Although unions may have fewer opportunities for influence than employer groups - see discussion of the Vehicle Painting Regulations in Chapter 5.

101. For a discussion of differential access by 'industrial and popular interests' to regulatory decision making see : B.F.Gillespie, 1977, op.cit., H.F.Steward, 1982, op.cit., L.Doyal et al, 1983, op.cit.

102. This is explicitly the case in the legal duty qualified by the term 'so far as is reasonably practicable', Fife and Machin, 1976, op.cit.

103. S.Webb, 1911, op.cit.,
M.Thomas, 1948, op.cit., p.289.
K.Marx, 1976, op.cit., p.626

104. Sir.E.Troup, The Home Office, 2nd Edition, Putnams, London, 1926, pp.166-7.

105. E.L.Collis and Major Greenwood, The Health of the Industrial Worker, Churchill, London, 1921, p.35.
Harrison and Hutchins, 1911, op.cit. p.202.

106. H.A.Mess, Factory Legislation and its Administration 1891-1924, King, London, 1926, Chapter III.

107. Troupe, 1926, op.cit.

108. Employers had considerable opportunity to argue for the dilution of Regulations or the exemption of their class of production from specific clauses. The consensual approach to drafting Regulations was matched by a consensual approach to enforcement, in which Factory Inspectors had considerable discretion as to whether to prosecute. See Grayson and Goddard, 1976, op.cit.

109. Another example of such selectivity is the situation where the state sets up mechanisms to compensate the victims of industrial hazards without regulating them. Thus the political pressures for regulation can be partly dissipated (by compensating victims) while leaving the hazardous process untouched. Thus in Britain and elsewhere the state provided compensation for victime of certain economically important carcinogens without regulating their use in a manner consistent with their carcinogenicity. R.Montesano and L.Tomatis, 'Considerations on Legislation concerning Chemical Carcinogens in Several Industrial Countries', Cancer Research, 37, 1977, p.310.

110. Thus between the initial diagnosis of an occupational hazard and its regulation, delays of between fifteen and forty years have been noted.
- A.J.P.Dalton, Oil : a workers' guide to the health hazards, British Society for Social Responsibility in Science, London, 1975.
- A.J.P.Dalton, 1979, op.cit.
- S.M.Wolfe, 'Standards for Carcinogens', IN, H.H.Hiatt et al (Eds), Origins of Human Cancer, Book C, Cold Spring Harbor Conference on Cell Proliferation, Cold Spring Harbor Laboratory, New York, U.S.A., 1977, pp.1735-1747.
- R.A.Williams, 1977, op.cit.

111. Thus Regulations prohibiting the use of certain highly carcinogenic chemicals were introduced in Britain only after their use had practically ceased. These were shale oil used to lubricate spinning equipment (1953 Mule Spinning Regulations) and certain aromatic amines used in the rubber and dyestuffs industry. (1967 Carcinogenic Substances Regulations).
- A.J.P.Dalton, 1975, op.cit.
- P.Kinnersley, Hazards of Work, Pluto Press, London, 1972.

112. An example of this is the Woodworking Machines Regulations 1974, which had very little impact on accidents at woodworking machines. The technology for guarding these machines was rudimentary and the Regulations focused on safe methods of working with a dangerous and inadequately guarded machine. In contrast, the Power Press Regulations 1972 were based on an effective guarding technology and had a dramatic effect on accidents at power presses. The Woodworking Machines Regulations can thus be seen as having a primarily ideological effect - in particular they served to transfer legal and moral responsibility for injuries from the employer and 'his' dangerous process to the worker.
- R.T.Booth, 'Dangers at Work' IN, Proceedings of a Conference on Safety and Health at Work, Institute of Local Government Studies, Birmingham University, April 1975.

113. S.Edw.VII C.42. Now sections 67, 77 of the 1961 Factories Act. File and Machin, 1976, op.cit.

114. This industry had long been the subject of concern and had been covered by Factory legislation since 1864, though this had not successfully controlled the hazard. Hutchins and Harrison, 1911, op.cit. pp.156, 271.

115. Statutory Instrument 1953 No.1545.

116. S.R. and O. 1919, No.1775. A.J.P.Dalton, 1976, op.cit.

117. A.J.P.Dalton, 1976, op.cit.

118. Statutory Instrument 1953 No.1545.

119. P.Kinnersley, 1972, op.cit.

120. (U.S.) National Institute for Occupational Safety and Health, 'Benzidine Derived Dyes', N.I.O.S.H. Current Intelligence Bulletin, 17 April 1978.
- R.A.Williams, 1977, op.cit.

121. - The first industrial hygiene standard was produced from Legge and Goadby's estimation of the daily lead intake that would produce frank lead poisoning. T.S.Legge and K.W.Goadby, Lead Poisoning and Lead Absorbtion, Arnold, London, 1912, p.207. The systematic establishment of workplace hygiene standards for airborne chemicals began in the U.S.A. at the end of the Second World War. A.Cook, 'Maximum Acceptable Concentrations of Industrial Atmospheric Contaminants', Industrial Medicine, November 1945, pp.936-46.

122. G.B.Health and Safety Executive, Threshold Limit Values for 1976, H.S.E. Guidance Note EH15/76, HMSO, London, 1977. American Conference of Governmental Industrial Hygienists, Documentation of the Threshold Limit Values for Substances in Workroom Air, ACGIH, Cincinnatti, Ohio, 1976, (3rd printing).

123. The only Regulations tied to a specific standard were the 1968 Asbestos Regulations. Fife and Machin, 1976, op.cit.

124. G.B.Health and Safety at Work etc. Act, 1974. Elizabeth II, 1974. Chapter 37. HMSO, London, 1974.

125. For example less than 100 chemicals were covered by Regulations (compared to the estimated 10,000 in industrial use). Fife and Machin, 1976, op.cit.

126. At the early stages of regulatory development fragmentation of the regulatory apparatus between different modes of hazard (e.g. environment, consumer, different groups of workers) can be seen as beneficial for capital as it protects the production process itself by treating separately the different phases of hazard (e.g. this is visible in the history of regulation of white lead preparation and use) and obstructing a wholesale regulatory solution (e.g. prohibition). However, it is suggested that, as regulation becomes more generalised, the inconsistency and duplication between different regulatory provisions become increasingly onerous for the enterprise, generating in turn pressures for the reform of the regulatory apparatus by capital as well as (for different reasons) popular groups and the state.

127. A.Pittom, 1978, op.cit.

128. C.Clutterbuck, 'Death in the Plastics Industry', Radical Science Journal, (4), 1976, pp.61-80.

129. Fife and Machin, 1976, op.cit.

130. Great Britain, Committee on Health and Safety at Work, Report of the Committee 1970-2, Chairman Lord Robens, [Cmnd.5034], HMSO, London, 1972.
It is clear that Lord Roben's consensual view of health and safety is not fully reflected in the legislation adopted.
For a critique of this approach see :
Grayson and Goddard, 1975, op.cit.

131. Presidents Scientific Advisory Panel, 1973, op.cit. Chapter 12.

1. F.Armitage, The British Paint Industry, Pergamon, Oxford, 1967.
A survey by the U.K. Factory Inspectorate for 1903 found 351 paint and colour, 43 lead colour and 133 varnish factories.
G.B.Home Department, Annual Report of the Chief Inspector of Factories 1904 [Cd.2569], HMSO, London, 1905. p.52.

2. J.H.Goodier, 'Craftsmen who defied official logic' (Futures). The Guardian, 3 June 1982, p.19.
G.B.Home Department, Report of a Departmental Committee Appointed to Investigate the Dangers Attendant on the Use of Paints Containing Lead in the Painting of Buildings [Cd.7882], HMSO, London, 1915.
A.Rivet, a witness for the 'Independent Paint Grinders' stated that the proportion of paints supplied 'ready mixed' by his firm had increased from 10% to 2-% between 1910 and 1912.

3. G.B.Home Office, Report of the (1921 Departmental) Committee on Industrial Paints, HMSO, London, 1923.
D.C.Blewes, Scottish Master Painters' Federation, welcomed the introduction of paste and readymade paints or "saving labour and requiring fewer skilled men", leading to a claimed 40% increase in productivity (as a result of which it was opposed by the painters' union). Ibid.,(minutes.

4. J.J.Mattiello, Protective and Decorative Coatings, Vol.III, Chapman and Hall, London,1943, p.271.

5. G.B.Government Statistical Service, Business Statistics Office, Historical Record of the Census of Production 1907-1970, HMSO, London, 1978.

6. F.Armitage, 1967, op.cit.
Figures for Research and Development Expenditure by the U.K. paint industry are given in Table 2.3. Though no figures for distribution of this expenditure across the industry are available for Britain, in the U.S.A. the top 50 companies were held to conduct the overwhelming bulk of R&D.
American Chemical Society, Chemicals in the Economy, A.C.S., Washington, 1973, pp.150-170.

7. G.B.Government Statistical Service, 1978, op.cit., Tables 1 and 4.

8. G.B.Price Commission, Decorative Paint, Price Commission Report No.33, HMSO, London, 1978.

9. Even by 1921, industrial painters (60,000) accounted for less than half the number of house painters (123,000), despite a 21% increase in numbers of ship and vehicle painters since 1901. Since the technology of paint application was then substantially similar for house and industrial painters, it is estimated that the volume of paint consumed was proportional to numbers employed. Although the industrial painters might have had higher productivity (in terms of volume of paint used per head) for primarily organisational reasons, this would be offset by the numbers of industrial painters employed in decorating factory buildings.
For basis of estimates, see Chapter 6.

10. G.B.Price Commission, 1978, op.cit.
D.Pickering, 'Paintmakers Look for Silver Linings', Financial Times, 25 November 1980, p.16.
The proportion of paint used in 'Do It Yourself' home decoration must be rapidly approaching 50% of decorative paints, compared to estimates of 15%. (F.Armitage, 1967, op.cit.) for 1967 and 30% by 1970.
D.Thomas, 'Paint Makers' Problems', Marketing, November 1970, pp.42-5.

11. G.B.Government Statistical Service, 1978, op.cit.
B.G.Reuben and M.L.Burstall, The Chemical Economy, Longman, London, 1973.

12. F.Armitage, 1967, op.cit.
Exports have fallen from 24% of output 1907 to 12% in 1967.

13. Ibid.
T.Such, 'Future trends in Material and Energy Sources', Finishing Industries, May 1979, pp.44-52.

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18. J.Bharier (International Paint Co.), 'The Hazards of Paint', Information Sheet No.1., Coventry Health and Safety Movement, Coventry, 1977.

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American Chemical Society, 1973, op.cit.

21. Reuben and Burstall, 1973, op.cit.

22. Ibid.
American Chemical Society, 1973, op.cit.

23. Unless specifically referred otherwise, this account derives from the following sources:
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- American Chemical Society, 1963, op.cit.,
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24. British Resin Manufacturers Association, _Surface Coatings Resin 1965_, BRMA, London, 1965.

25. Reuben and Burstall, 1973, _op.cit._

26. F.Armitage, 1967, _op.cit._

27. W.von Fischer (ed.), _Paint and Varnish Technology_, Reinhold, New York, 1948, Chapter 1.

28. Oil and Colour Chemists Association, 1948, _op.cit._

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30. D.J.T.Howe, "Problems of toxicity in the Paint Industry", _Journal of the Oil and Colour Chemists Association_, 1973, _56_ (7), pp.232-4.

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CHAPTER 3.

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141. A.S.Jennings, 1914, op.cit.

142. Since the labour costs of applying paint were double the material costs, a 10% reduction in paint durability/longevity would have an effect on total painting costs equivalent to a 30% increase in the materials cost of painting an area. If the pigment accounted for half the material costs, the price per unit hiding power would have to rise by 60% to have the same effect.

143. N.A.R. Falla, 1980, op.cit.

144. G.Stas, 1885, cited in,
G.Petit, 1907, op.cit., pp.85-6.

145. Thus Petit (Ibid. 1907) points out that Stas 'is not absolutely exact' since genuine linseed oil does not contain margaric acid.
Remington and Frances (1954, op.cit. p.12) point out that the formation of lead soaps in fact make the paint less opaque.

146. See for example :
Kirk and Othmer, 1968, op.cit.

147. See for example :
Stas and Petit, in,
Petit, 1907, op.cit. p.85-7.

148. Oil and Colour Chemists Association, 1949, op.cit. p.42.
Kirk and Othmer, 1968, op.cit.

149. G.B.Home Department [Cd.7882], 1915, op.cit. (various witnesses - see Table 4.10).

150. J.J.Mattiello, 1942, op.cit. p.373-4.

151. D.J.W. Orr, 1921, op.cit..

152. J.J.Mattiello, 1942, op.cit., pp.379-80.

153. T.H.Zappert, 1927, op.cit.
N.F.Budgen, 1926, op.cit.

154. Remington and Frances, 1954, op.cit. pp.40-9.

155. J.T.Richmond, 1957, op.cit.

156. M.A.Claridge, 1982, op.cit.
Kirk and Othmer, 1968, op.cit.

157. I.D.Hagar, 1927, op.cit.

158. G.Stas, cited by Mr. M.Miller (witness for the white lead corroders at the 1911 Departmental Committees), in,
G.B.Home Department [Cd.7882]. 1915, op.cit. p.67.

159. G.Petit, 1907, op.cit.

160. Indeed appeals to natural barriers have been a frequent tactic of campaigns against factory legislation,
K.Marx, Capital : Volume 1, Penguin Books, Harmondsworth, 1976, p.605.

161. Kirk and Othmer, 1968, op.cit. British Resin Manufacturers' Association, Surface Coatings Resin Index, B.R.M.A., London, 1974.

162. Links between paint manufacturers and suppliers of pigments and other raw materials were noted as playing an important role in the successful formulation of paints based on new pigments. See for example :
T.H.Zappert, 1927, op.cit., and
W.H.Madson, 1948, op.cit.

163. M.Petit, 1907, op.cit. p.7.

164. Ibid., p.53.

165. C.A.Line, evidence to 1911 Departmental Committee in,
G.B.Home Department [Cd.632], 1920, op.cit. para.9903-.

166. T.Oliver, 1911, op.cit. p.26.

167. W.G.Sutherland, Memorandum, in,
G.B.Home Department [cd.7882], 1915, op.cit., p.104-.

168. G.Despierres attributed failures with zinc oxide paints to the lack of technical knowledge amongst housepainters.
Ibid. p.32.

169. G.Petit, 1907, op.cit., p.89.

170. See for example the evidence of the following witnesses to the 1911 Departmental Committee :
Patterson (Office of Works) p.41.,
Mumby and Wonnacott (Royal Institute of British Architects), p.44.,
Vickers, Despierres, Cunnew and Chancellor (Paint Manufacturers), pp.29-31,
J.C.Smith and Line (Paint Consultants) p.36, in,
G.B.Home Department [Cd.7882], 1915, op.cit.

171. M.Toch, 'Paint Vehicles as Protective Agents against Corrosion', Journal of the Society of the Chemical Industry, 34 (11), 1915, pp.592-5.
M.Pisart simultaneously called for a research programme into vehicle systems for use with zinc oxide paint,
M.Pisart, 1907, op.cit., p.90.

172. C.A.Klein, 1922, op.cit.
C.A.Klein, evidence to 1921 Departmental Committee, in,
G.B.Home Office, 1923, op.cit. Minutes of Evidence, p.16.

173. R.L.Ziegfield, 1964, op.cit.

174. N.A.R.Falla, 1980, op.cit.

175. G.B.Price Commission, Decorative Paint, Price Commission Report No.33, HMSO, London, 1978.

176. G.B.Central Statistical Office, Input/Output Tables for the United Kingdom 1963, Studies in Official Statistics No.16, HMSO, London, 1974. Table B.

177. Categorising the different types of paints listed in the 1963 Census figures for sales by the paint industry (see Figure 2-3) yielded a significantly lower estimate of 34.2% of paints for industrial use. However this is probably an under-estimate since it assumes that all air drying, emulsion and distemper paints were for buildings. This estimate does not fit with the other estimates produced and has therefore been rejected.

178. H.Brenner, 1978, op.cit.

179. T.M.Legge, Industrial Maladies, Oxford Universal Press, London, 1934, p.52.

180. N.A.R.Falla, 1980, op.cit.

181. G.B.Department of Health and Social Security, Lead and Health, HMSO, London, 1980, p.34.

182. White lead production (which exceeded consumption for all years up to 1974, after which data are not available) was 750 tons in 1978 and is estimated as 500 tons in 1980.
See Table A-1.

183. J.D.W.Orr, in,
G.B.Home Department, 1923, op.cit.

184. N.A.R.Falla, 1980, op.cit.

185. Oil and Colour Chemists Association, 1949, op.cit. p.42.

186. G.B.Department of Health and Social Security, 1980, op.cit.

187. M.A.Claridge, 1982, op.cit.
N.A.R.Falla, 1980, op.cit.

188. Paint Makers Association of G.B., Proprietary Lead Primers for Wood, Circular to members and Associates, P.M.A. London, 10 April 1978.

189. Ibid.,
N.A.R.Falla, 1980, op.cit.

1. A.Redgrave, Report by Alexander Redgrave, H.M.Chief Inspector of Factories, on the Precautions which can be enforced under the Factory Act, and as to the need of further powers, for the Protection of persons employed in White Lead Works [C.4362], HMSO, London, 29 April 1882.
G.B.Home Office, Communication to the Home Office on the Subject of White Lead Poisoning with a report by A.Redgrave [C.4363], HMSO, London 1883. Reproduced in,
British Parliamentary Papers, Reproduced in, Industrial Revolution, Factories, Volume 28, Irish University Press, Dublin, Ireland, 1971, p.81-.

2. E.L.Collis and Major Greenwood, The Health of the Industrial Worker, J.Churchill, London, 1921. p.35.

3. See Chapter 1 for a discussion of Regulations and Special Rules.

4. G.B. Home Department, Report of the Departmental Committee Appointed to Investigate the Danger Attendant on the Use of Paints Containing Lead in the Painting of Buildings [Cd.7882], HMSO, London, 1915.

5. I.Fife and E.A.Machin, Redgraves Factories Acts, 21st Edition, Butterworth, London, 1966.

6. G.B.Home Department, Report from the Departmental Committee on the Various Lead Industries 1893/4 [C.7239]. HMSO, London, 1894. (Subtitled : Report of departmental committee on conditions of labour in lead industries and dangers to work people and remedies proposed).

7. H.A.Mess, Factory Legislation and the Administration 1891-1924, P.S.King, London, 1926. p.38.

8. - G.B. Factory Department, Annual Report of the Chief Inspector of Factories for 1901 [Cd.1112], HMSO, London, 1902. p.207.
- G.B.Home Department [Cd.7882], 1915. op.cit., pp75-9.

9. - G.B.Home Department [Cd.7882], 1915. loc.cit.

10. In particular see the writings of T.M.Legge, the Chief Medical Inspector of Factories from 1900 until 1926.
T.M.Legge, Industrial Maladies, Oxford University Press, London, 1934. p.52.

11. The distinction between these two strategies is still a matter of concern today. It conforms broadly to the distinction between safe process and safe worker strategies made by Atherley (who argues that the former is most effective at reducing hazards).
G.R.C.Atherley, Occupational health and safety concepts : chemical and processing hazards, Applied Science Publishers, London, 1978.

12. - A.Redgrave [C.4362], 1882, op.cit.
- G.B.Home Office [C.4363], 1882, op.cit.

13. - Collis and Greenwood, 1921, op.cit.
- A.Harris and B.L.Hutchins, A History of Factory Legislation, 2nd edition, King, London, 1911, p.202.

14. Sir Thomas Oliver, 'Industrial Lead Poisoning, with descriptions of lead processes in Great Britain and the Western States of Europe', Bulletin of the Bureau of Labour (95). July 1911. p.1
N.B. The question of women's alleged propensity to lead poisoning was subject to much debate. Exclusion of women from lead processes became a common feature of legislation. The adoption of this particular strategy involved more than simple medical issues and deserves further analysis. There is not space here to do justice to this question.

15. G.B.Home Department [C.7239], 1894, op.cit. para.10.

16. Ibid.

17. H.Mess, 1926, op.cit., p.51.

18. G.B.Home Department [C.7239], 1894, op.cit., Report paras.8-10.

19. Ibid., para.14.

20. Ibid., para.29.

21. Who Was Who, Vol.IV 1914-50, Black, London, 1951.

22. G.B.Home Department [C.7239], 1894, op.cit.

23. Ibid., Minutes, line 6864 -

24. Ibid., Report, para.28.

25. Ibid., Report, para. 29. This conclusion was reached even though the report acknowledged that "several compounds have been mentioned to the committee as being equal to the committee as being equal to white lead and capable of taking its place if only the prejudice of the middlemen were removed".

26. H.Mess, 1926, op.cit., p.51.

27. For detailed figures see Chapter 6.

28. - G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1904,[Cd.2569] HMSO, London,1905, p.52.
- G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1912,[Cd.6852], HMSO, London,1913, p.205.
- G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1913,[Cd.7491], HMSO, London,1914, p.132.
- G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1914,[Cd.8051], HMSO, London,1915, p.240.
- G.B.Department of Trade and Industry, Census of Production for the year(s) 1948, 1951, 1963, HMSO, London.

29. G.B.Home Department [C.7239], 1894, op.cit., Report, paras.1-10.

30. G.B.Factory Department, [Cd.1112], 1902, op.cit., p.208.
See Table 4.3 for figures.

31. Dr. T.M.Legge, Report of the Medical Inspector of Factories, IN G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1905 [Cd.3036], HMSO, London, 1906, p.351.

32. Ibid., see also T.Oliver, 1911, op.cit. p.20.

33. G.B.Factory Department, Report on the Manufacture of Paints and Colours containing lead as affecting the health of operatives employed, (with a circular by Henry Cunynghame, Chief Inspector of Factories), 15 June 1905, HMSO, London, 1905.

34. Home Office Memorandum, 10 November 1905 IN Home Office File 102578, Item 9. Available in Public Records Office, File LAB 14/176.

35. Ibid., Item 30.

36. S.R. and O., 1907, No.17.

37. G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1907, [Cd.4166], HMSO, London, 1908.

38. S.R. and O., 1911, No.752.

39. Sir Thomas Oliver, Lead Poisoning, From the Industrial, Medical and Social Point of View, H.K.Lewis, London, 1914, p.27.

40. Oliver, 1914, op.cit., p.20.

41. The 1930 Census of Production shows sales of white lead with 15 thousand tons in dry form and 11.9 thousand tons in paste form. (See Chapter 4).

42. T.M.Legge, 1934, op.cit., p.52.

43. A.Rivet, evidence to 1911 Departmental Committee IN G.B.Home Office, [Cd.7882], 1915, op.cit., p.28.

44. D.C.Blewes, witness for the Scottish Master Painters Federation to the 1921 Committee on Industrial Paints. IN. G.B.Home Office, 1921 (Departmental) Committee on Industrial Paints, HMSO, London, 1923.

The fact that use of lead paste/paint "eliminates the dustiest job" of mixing paints on site was only seen as a secondary advantage.

45. T.Legge, Medical Inspector of Factories, noted that "the considerable diminution [in the number of lead poisoning cases since 1900] is limited to industries, especially white lead, earthenware and china and paints and colours, in which under

45 (contd)

Regulations or Special Rules, locally applied exhaust ventilation for the removal of dust and periodical medical examination of the workers have been required .... Where, owing to the nature of the processes carried on, it has been found impracticable in the present state of knowledge to apply local exhaust ventilation, especially in industries using paint, the position is almost a stationary one". G.B.Factory Department, [Cd.4166], 1908, op.cit., p.230.

46. Medical Inspector's Report, IN, G.B.Factory Department, [Cd.3036], 1906, op.cit., p.366.

47. Medical Inspector's Report, IN G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1906, [Cd.3586], HMSO, London, 1907, p.281.

48. Medical Inspector's Report IN, G.B.Factory Department [Cd.4166], 1908, op.cit., p.230.

This remarked that "One important Coventry motor firm, on the occurrence of cases of lead poisoning, discorded the use of lead paint".

49. G.B.Factory Department, [Cd.2569], 1905, op.cit., p.52. G.B.Factory Department, [Cd.3036], 1906, op.cit., p.366

50. The legal duties of the Factory and Workshop Acts, for historical reasons, rested not on 'employers' but on 'occupiers' of 'factories and workshops' (places where goods were made for gain). The use of the definition by location, rather than the more obvious employment relation, an aftermath of the intermediate forms of organisation of production between domestic production and 'the factory system', was one of the consequences of the struggle over the extension of factory legislation. It had the effect of excluding productive activities, such as housepainting and plumbing, which took place outside factory premises from the provisions of the Factories Act (unless a specific Act of Parliament was introduced to alter this situation), For the current legal definition of a factory, under Factory Law, See Fife and Machin, 1966, op.cit., pp.409-429.

51. Arthur Whitelegge, M.D., Chief Inspector of Factories, Industrial Lead Poisoning, Home Office Memorandum, March 19380, IN, G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1900, [Cd.668], HMSO, London, 1901, pp.208-9.

52. G.B.Factory Department, [Cd.1112], 1902, op.cit., p.208.

53. G.B.Factory Department [Cd.3036], 1906, op.cit.

54. Medical Inspector's Report, IN, G.B.Factory Department, [Cd.4166], 1908, op.cit., p.208 .

55. Ibid.

56. International Labour Office, White Lead : Data Collected by the International Labour Office in regard to the Use of White Lead in the Painting Industries, Studies and Reports, Series F (Industrial Hygiene) No.11, I.L.O., Geneva, 1927. Published in Britain by : King, London, 1927, pp.11-53. This 415 page report is an updated and corrected version of the report drawn up by the I.L.O. for the 3rd Session of the International Labour Convention, Geneva, 1921 (discussed below).

57. Sir Thomas Oliver, 1911, op.cit., p.29-34

58. The International Association for Labour Legislation, the forerunner of the International Labour Organisation, was a 'voluntary', 'tripartite' body with union, employer and government representatives. Its aim was to extend protective legislation for workers on an international basis, in order to avoid industries in non-regulated countries having a competitive advantage over those in regulated countries. The I.A.L.L. was set up in Geneva in 1900, with support from the Swiss government, after unsuccessful attempts for more than a decade. The organisation changed from being primarily technical investigative role, (with an initial focus on women and night work, health hazards from lead pigments and phosphorous) comprising mainly self-selected professionals, to a representative body after 1905. It had some success in encouraging bilateral agreements with countries around 'consensual issues' (notably emigration and social insurance). A.Alcock, The History of the International Labour Organisation, Macmillan, London, 1971. Chapter 1.

59. International Labour Office, 1927, op.cit., p.13.

60. International Association for Labour Legislation (I.A.L.L.), Report of the Third General Assembly of the Committee of the I.A.L.L., Berger-Lerrault and Cie, Paris, 1905.

61. I.A.L.L., Report of the 5th General Assembly of the I.A.L.L., Berger-Lerrault and Cie, Paris, 1909.

62. I.A.L.L., Petition Made by the Executive and Sections of the I.A.L.L. relative to the campaign against lead poisoning among workers occupied in painting and varnishing, Basle, 15 December 1909, IN, International Labour Organisation, 1927, op.cit., Appendix 1, p.307.

63. Ibid.

64. International Labour Office, 1927, op.cit., p.15.

65. Ibid., p.18-22.

66. Ibid., p.22-25.

67. Public Records Office, LAB 14/211 :
J.Hugh Smith M.P., letter to Home Secretary, 27 April 1923, (Home Office File 428004, Item 27.).

68. However, it is revealing to note that, although the 1911 Departmental Committees examined the continental experience of regulating lead paints in some detail, the strength of the conflict and controversy surrounding prohibition of white lead is not reflected in the government reports of the day.

69. G.B.Home Department, Report of the Departmental Committee appointed to investigate the Dangers Attendant on the Use of Lead Compounds in the Painting, Enamelling and Varnishing of Coaches and Carriages [Cmd.630], Volume II, HMSO, London, 1920.

70. G.B.Home Department, Reports of the Departmental Committees appointed to investigate the Danges Attendant on the Use of Paints Containing Lead in the Painting of Buildings and of the Use of Lead Compounds in the Painting, Enamelling and Varnishing of Coaches and Carriages : Volume III Appendices to Both Reports [Cmd. 631], and Volume IV Minutes of Evidence taken by both Committees [Cmd. 632], HMSO, London 1920.

71. These are respectively :
- G.B.Home Department [Cd.7882], 1915, op.cit.
- G.B.Home Department [Cmd. 630], 1920, op.cit.
- G.B.Home Department [Cmd. 631], 1920, op.cit.
- G.B.Home Department [Cmd. 632], 1920, op.cit.

72. G.B.Home Department [Cd. 7882], 1915, op.cit.
The report notes that the White Lead Manufacturers' witnesses "might well have been regarded as irrelevant to .... the terms of reference" but they were accepted because "the interests which they represented were from an indirect point of view, most liable to be affected", and that they "greatly extended the period of the enquiry".

73. Measured as a percentage of paint solid, by weight, that dissolves in dilute hydrochloric acid. This criterion for lead content was borrowed from Regulations applied to the potteries. It's main effect was to exempt from prohibition of direct zinc oxide, lead chromate and the use of paints with up to 20% of lead sulphate.
Ibid., p.102.

74. Ibid.,p.104-124.

75. They were the most extensively reported item in the International Labour Office's review of the literature.
International Labour Office 1927, op.cit.

76. See in particular :
- T.M.Legge and K.W.Goadby, Lead Poisong and Lead Absorbtion, Arnold, London, 1912.
- T.Oliver, Lead Poisoning, H.K.Lewis, London, 1914.

Apart from the Factory Inspectorate, the major source of expertise on lead poisoning was the Certifying Surgeons appointed to conduct medical examinations of lead workers under the Regulations dealing with lead processes.

77. G.B.Home Department [Cd.7882], 1915, op.cit., p.82.

78. Ibid., p.59-62.

79. Ibid., p.36.

80. Ibid., Appendix 31.

81. Ibid., Appendix 21.

82. G.B.Home Department [Cd.7882], 1915, op.cit., p.60.

83. Ibid., p.105,118.

84. G.B.Home Office, Report of the Departmental Committee appointed to re-examine the Danger of Lead Paints to Workers in the Painting Trades and the Comparative Efficiency, Cost and Effects on the Health of Workers of Lead and Leadless Paints., HMSO, London, 1923.

85. - Legge and Goadby, 1912, op.cit.
- G.B.Home Department [Cd.7882], 1915, op.cit., p.84, 84ff. (Figures based on estimated daily lead intake in inhalation of 10 cubic metres of air. 0.5 milligrams of lead per cubic metre of air was found to lead to colic rarely and would not cause more severe symptoms of paralysis and encophalopathy).

86. G.B.Home Department [Cd.631], 1920, op.cit., Appendix XIII. Table 1 p.16, Table 2 p.17.
Figures for airborne lead dust levels in sanding lead paint in the interior of houses, provided by an Austrian witness (Dr.I.Kamp), were comparable at 1.25mg/m^3. G.B.Home Department [Cd.7882], 1915, op.cit., p.84.

87. G.B. Home Department [Cd.7882], 1915, op.cit., p.4.

88. Ibid., pp.77-8.

89. This estimate received some confirmation from the evidence of the certifying surgeon for North Birmingham who noted that only three out of 11 cases of lead poisoning in housepainters that came to his attention were notified to the Home Office. Ibid., p.46.

90. G.B.Home Department [Cd.631], 1920, op.cit., Appendices XI and XII.

91. Ibid.
These figures appear to be comparable to the current measure of Proportional Mortality Rate.
The method of calculation of Mortality Rates in these figures are not given, but appear to be based on total mortality not standardised for age at death. The baseline is deaths amongst all males in England and Wales 1900-2, calculated from the Supplement to the Sixty Fifth Annual Report of the Registrar General for Births, Deaths and Marriages. Whilst the mortality rate calculated from the Registrar General's figures for house-painters operate for the same period (1900-2) the union figures are for a different period : (1904-10 National Society, 1901-10 Scottish Society).

92. Ibid., Appendix 34. Schooling argued that housepainting was overall a relatively healthy occupation.
G.B.Home Department [Cd. 7882], 1915, op.cit., pp.71-2.

93. Ibid., pp.77-9.

94. Ibid., p.104.
Sutherland argued that :
i) many cases of poisoning in housepainters were due to organic vapours, not to lead.
ii) that the incidence of poisoning in housepainters was any way low
iii) that lead poisoning was low in Scotland - which was taken to indicate that other environmental factors predisposed painters to lead poisoning
iv) that diagnosis of lead poisoning was poor and erred in favour of the victim.

The rest of the committee refuted Sutherland's third point on the evidence of the Scottish Painting Union. Ibid., p.125.

95. Even Goadby, when describing his thesis that a proportion of cases of poisoning (including some of the fatalities from kidney failure) in housepainters were due to turpentine, not lead, was forced to agree that the number of deaths from lead poisoning represented 'a very serious state of affairs'. Ibid., p.60.

96. See for example the evidence of A.G.White, representing the National Federation of Building Trades Employers. Ibid., pp.6-7.

97. Ibid., p.79

98. Both Sutherland (Ibid., p.104) and Schooling (Ibid., pp.71-72) noted the low relative risk of housepainting. Despite Schooling's statement that lead poisoning accounted for only 1/54th of the deaths amongst housepainters and plumbers and was 'relatively trivial', he admitted on cross-examination that this one in 54 should be saved if possible, and that the absolute number of deaths amongst housepainters (48 in 1911) "was deplorable in itself".

99. These costs were a central theme of the evidence of the White Lead Corroders' witnesses in Ibid. See for example Miller (p.66), Humphreys (p.67), Lancaster (p.68) and Sutherland (p.104).

100. Ibid., p.79

101. T.Oliver, 1911, op.cit., pp.21, 24.

102. International Labour Office, 1927, op.cit., pp.114-5.
Doctors Turner and Gibson had sought 'to prove that lead poisoning among children is much more frequent than is generally admitted.'

103. G.B.Departmental Committee [Cd. 7882], 1915, op.cit. p.iv.

104. A parallel can be drawn here with the exclusion of painters' hazards from the deliberations from the 1893 Departmental Committees. See the earlier remarks about the political process of establishing a framework of regulation.

105. G.B.Departmental Committee [Cd.7882], 1915, op.cit., pp.81-2. To avoid confusion the terms Prohibition and Regulation will be used throughout this account to describe these two regulatory strategies. (In the reports of these Departmental Committess, and the subsequent regulatory debate these terms were used less consistently - for example, proponents of Regulation ~~were~~ called for prohibition of the use of dry sand-papering). In contrast the term Regulations refers to Statutory Instruments, and regulation to state control over industrial activities (particularly regarding hazards).

106. Ibid., pp.82-84
This and the following references are the summary and conclusions of the 1911 Painting of Buildings Report. The views of the individual witnesses are stated in brief in the first part of this report, and verbatim in the 1911 Committees Minutes.

107. Ibid., pp.84-7.

108. Ibid., p.89.

109. Ibid., pp.84-7, pp.4-19.

110. Ibid., pp.89-8.

111. Ibid., p.90.

112. Ibid., p.89.

113. Ibid., p.90.
It is interesting to note that the Belgian Master Painters' Federation passed on similar resolution in 1905 when the Belgian legislative was considering Regulations for house-painting. See M.Ricker-Devroede, Ibid., p.56.

114. Ibid., pp.9-15, and in particular the evidence of Puttrell (p.10), Holliday (p.12), Higgs (p.12), c.f. Sutherland (p.115).

115. Ibid., see in particular, Higgs (p.12) and Milton (p.15).

116. See in particular Anderson, Ibid., p.15.

117. Ibid., pp.19-25.

118. Ibid., p.89.

119. Ibid., p.91.

120. Ibid., p.84.

121. Ibid., pp.96-9.

122. Ibid., pp.4-74. See also Minutes of both Committees.

123. Cdr. Coysh said that Great Eastern Railway Shipyards had already gone over to zinc paint for commercial reasons. Ibid., p.47

124. See for example the evidence of Patterson [Office of Works] (p.41), and Appendix XXV, Munby and Wannacott [Royal Institute of British Architects], Vickers, Despierres, Cunney and Chancellor (pp.29-31).
Ibid.

125. C.A.Line Ibid., p.36.
G.Petit, The Manufacture and Comparative Merits of White Lead and Zinc White Paints, Scott Greenwood, London, 1907.
Petit also gave evidence to the 1911 Painting of Buildings Committee.

126. G.B.Home Department [Cd. 7882], 1915, op.cit., pp.126-134.

127. R.L.Hallet, 'Hiding Power of Pigments', Proceedings of the American Society for Testing Materials, 1926, 26, Part II, pp.538-545.

128. See Chapter 3.

129. See Table 4.10.

130. G.B.Home Department [Cd. 7882], 1915, op.cit., p.44.

131. J.S.Remington and W.Francis, Pigments, their Manufacture Properties and Use, L.Hill, London, 1954, pp.10-13, 23-5.

132. It is interesting to note that Master Painters were 'over-represented' amongst those believing zinc paints to cover less well then white lead, whilst Paint Makers tended towards the reverse opinion. It could be suggested that the former would be more likely to evaluate covering power on the basis of colume of paint whilst the latter would be more concerned with the overall weight of paint to do a painting job.

133. See particularly the evidence of paint manufacturers' witnesses Garson, Smyth and Despierres in, G.B.Home Department [Cd.7882], 1915, op.cit., pp.27-32.

134. - J.H.Goodier, 'Future', Guardian 3 June 1932, p.19
- A.S.Jennings, Commercial Paints and Painting, Constable, London, 1914.

135. G.B.Home Department [Cd. 7882], 1915, op.cit., p.27.

136. J.Milton. Ibid., p.15.

137. $\chi^2=9.46$. The strength of the relationship between these two variables is indicated by the Contingency Coefficient of 0.3 (C=0 - no relationship, C=1 complete dependance).
S.Siegel, Nonparametric Statistics for the Behavioural Sciences, McGraw Hill, New York, 1956, p.110.

138. $\chi^2 = 3{\cdot}65$ (1 degree of freedom).

139. G.B.Home Department [Cd.7882], 1915, op.cit., pp.91-99.

140. Ibid., pp.56-7.

141. Thus 111 out of 125 painters felt that there was no substitute for white lead for exterior work (although only 78 had used zinc pigments for such paint!).

142. Thus a survey conducted by Sir Thomas Oliver in 1913 found that 43 out of 45 master painters favoured white lead paints for the outside of buildings.
T.Oliver, 1914, op.cit., p.39.

143. G.B.Home Department [Cd.7882], 1915, op.cit., pp.104-124. 3½ out of 18 pages of argument in Sutherland's Memorandum were in criticism of the evidence of the Office of Works. See pp.108-111.

144. Ibid., p.111.

145. Ibid., pp.66-7.

146. These are the White Lead Corroders figures. J.Merton, of the Metal Exchange cites a lower figure of 45 thousand tons (with another 12 thousand tons of red lead).

147. Ibid., pp.66-68, 99-101, 110, 117.

148. Ibid., p.68.

149. Ibid., pp.99-100.

150. G.B.Home Department [Cd.630], 1920, op.cit.

151. Ibid., p.27.

152. Ibid., p.30. See also Appendix XIII.

153. Ibid., pp.33-4.

154. Ibid., pp.3-5, 18-19, 22, 37.

155. Ibid., pp.41-3.

156. International Labour Office, 1927, op.cit.

157. L.Teleky, A History of Factory and Mine Hygiene, Columbia University Press, New York, 1948. p.87 et seq.

158. International Labour Office, Prohibition of the Use of White Lead in Painting, Report VI, prepared by the I.L.O. for the 1921 Geneva Convention, I.L.O. Geneva, 1921.

[The wording of this questionnaire was subsequently criticised by those states opposing prohibition of white lead paint because of its 'bias' and its failure to distinguish different types of painting activity (e.g.house and insutrial painting). Though

158. Contd.
the International Labour Office rejected charges of bias, its handling of this and other matters does indicate that it either 'preferred' Prohibition or was out of touch with the extent of opposition to this strategy.]

159. I.L.O., 1927, op.cit., p.381.

160. Whilst this list of states with reservations about Prohibition certainly includes some of the industrialised countries in which White Lead was most used, it also contains major lead producing countries (India, South Africa, Spain). The economic impact of Prohibition on national industries (pigment production and paint use) would thus appear to have been a significant factor behind the policies of the different governments. However it cannot be seen as a direct determinant of policy, since these are notable exceptions (e.g. Canada, a major lead producer, supported Prohibition, whilst Sweden, which was only a minor user of white lead, had reservations).

This question is discussed further in Chapter 7, regarding the implementation of the Convention on White Lead.
Figures for production and consumption of White Lead are presented in Table 7-2 and 7-3.

161. I.L.O., 1927, op.cit., p.385.

162. J.A.Gibson, White Lead and its suppression for interior painting National Amalgamated Society of Operative House and Ship Painters and Decorators, Trade Papers Publishing Co., London, 1924.

163. This account of the activities of the International Labour Conference is derived from the Provisional Record of the Conference, summarised IN,
International Labour Organisation, 1927, op.cit., pp.383-405.

164. In contrast the French employers delegate opposed Prohibition even though this had already been introduced in France. However it had only covered larger firms : small master painters had continued to use white lead.

165. League of Nations, International Labour Conference, Draft Convention and Recommendations Adopted by the Conference at its Third Session 25 October 1921 - 19 November 1921. [Cmd. 1612], HMSO, London, 1922.

166. - C.A.Klein, Oil and Colour Trade Journal, 6/13 December 1913, p.1973-.
- H.E.Armstrong, Journal of the Society of the Chemical Industry, 1915, 34, pp.765-9.
- Klein and Armstrong, paper at Royal Society of Arts meeting 14 July 1921, reviews IN, J.Soc.Chem.Ind.Review, 30 July 1921, 11 (14), p.273.
- Klein and Armstrong, J.Soc.Chem.Ind.Rev. 1921, 11 (19), p.320.
- Klein, J.Soc.Chem.Ind., 1922, 12.

167. C.A.Klein, 'Presidential Address', Journal of the Oil and Colour Chemists Association, 1926, (9), p.270.

168. Medical Inspector's Report, IN, G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1918, [Cmd.340], HMSO, London, 1918.

169. G.B.Home Department [Cmd.630], 1920, op.cit., p.42.

170. G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1920, [Cmd.1403], HMSO, London, 1921. pp.8-9. Public Records Office, LAB14/226 : Home Office Memorandum, 21 July 1922, (Home Office File 428004, Item 5).

172. International Labour Office, 1927, op.cit., p.394.

173. J.Lawrence, 'Craft Principles and Modern Conditions', Journal of Decorative Art, June 1921.

174. H.E.Armstrong, 'The Development and Control of Industry by Public Influences', Journal of the Society of the Chemical Industry, 1915, 34, pp.765-9.

175. G.B.Home Office, 1923, op.cit. Reflecting this concern, one of the objectives of the 1921 committee on Industrial Paints was to advise the government on painting its own buildings.

176. - H.E.Armstrong and C.A.Klein, 'Paints, Painting and Painters', Journal of the Society of the Chemical Industry : Review, 30 July 1921, 11 (14), p.273.

The work of K.Goadby (a medical consultant who appeared as a witness for the White Lead Corroders at the 1911 Departmental Committees) is cited in support of this statement. See:
- K.Goadby, 'Immunity and Industrial Disease', Journal of the Royal Society of Arts, 1 July 1921, 69, p.8580.

177. Medical Inspector's Report, IN, G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1915, [Cd. 8276], HMSO, London, 1916.

178. Captain Bowyer, 'Written Answers', Parliamentary Debates : House of Commons, 20 July 1921. Cols.2220-2.

179. Captain Bowyer and Mr. Shortt, 'Written Answers', Parliamentary Debates : House of Commons, 21 July 1921. Cols.2448-9.

180. J.A.Gibson, 1924, op.cit., p.13.

181. G.B.Home Office, 1923, op.cit.

182. J.A.Gibson, 1924, op.cit.
This was a pamphlet, produced by J.A.Gibson, the General Secretary of the National Association of Ship and House Painting Operatives, to support its campaign for prohibition of white lead paint. Gibson, (p.13) complained that "the enquiry of the Norman Committee cannot be compared with the extensive enquiry of the 1911 Committee and it is amazing how lightly it seeks to reverse the decision of the 1911 enquiry".

183. G.B.Home Office, 1923, op.cit., Minutes of evidence and appendices, p.17.

184. C.Cookson (p.89), and C.A.Klein (Minutes p.16), IN, Ibid.

185. Dr. R.S.Morrell (pp.57-8) IN, Ibid.

186. C.A.Klein (p.23) IN, Ibid.

187. In particular they received contradictory evidence on the liability of lead paints to chalk (oxidative decomposition of the vehicle promoted by ultra-violet light) and on the relative price of painting with lead and 'lead free' paints.

188. Ibid., p.31.

189. Ibid., pp.36-7.

190. T.Oliver, 1914, op.cit., p.67.

191. Public Records Office, LAB 14/311 : Notes on a Home Office Conference with the Painters and Decorators Joint Industrial Council, 4 April 1922.

192. G.B.Home Office, Memorandum and Draft Regulations for the Use of White Lead Paint, June 1922. (Copy in Public Records Office, LAB 14/211.)

1. G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1922 [Cmd.1920], HMSO, London, 1923. p.8.

2. In addition much public debate was aroused in Britain by newspaper coverage of demonstrations organised in Brussels and Paris (on 3rd March and 26th April 1923) by the International Red Cross Societies calling for the adoption of the International Labour Convention.

3. J.A.Gibson, White Lead and its suppression for Interior Painting, Trade Papers Publishing Co., London, 1924.

4. E.Johns, "White Lead", Journal of Decorative Art, June 1923, pp.181-2.

5. J.Gibson, 1924, op.cit.

6. International Labour Office, White Lead, Studies and Reports Series F. No.11,I.L.O., Geneva, 1927, p.46.

7. G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1925 [Cmd.2715], HMSO, London, 1926.

8. A.J.P.Taylor, English History 1914-1945, Clarendon Press, Oxford, 1965. Chapter 6, particularly pp.192,196, 208.

9. Ibid., p.210.

10. Ibid., p.237.

11. Henry Pelling, A History of British Trade Unionism, MacMillan, London, 3rd edition, 1976.

12. Allen Hutt, British Trade Unionism, Lawrence and Wishart, London, 6th Edition, 1975.

13. D.McEachern, A Class Against Itself, Cambridge University Press, Cambridge, 1980.

14. Public Records Office (P.R.O.), LAB 14/211: Home Office Memorandum, June 1922.

15. P.R.O., LAB.14/211: Home Office Notes on a Delegation received from the Scottish and English Painting Operatives, 16 May 1923.

16. P.R.O., LAB.14/211: Statement by Painting Trade Materials Committee at a Deputation to the Home Office, 30 April 1923.

17. Ibid.,

18. P.R.O., LAB.14/211: Home Office Notes on a Deputation received from the Master Painters Federations (Painting Trade Materials Committee), 30 April 1923.

19. P.R.O., LAB.14/211: Memorandum from the White Lead Makers, submitted to the Home Office at a Deputation by the National Confederation of Employers' Organisations, 27 April 1923.

20. P.R.O., LAB.14/211: Letter from Sir M.Delevingne (Deputy Permanent Under-Secretary of State at Home Office) to Home Secretary, with attached documentation (Home Office File 428004 Item 27a), 6 September 1923.

21. P.R.O., LAB.14/211: Home Office Notes on a Deputation from the National Confederation of Employers' Organisations, received by Mr. Locker-Lampson, M.P., (Lord Privy Seal), in the presence of Home Office and Factory Department officials, 27 April 1923.

22. Sir Andrew Duncan. Ibid.

23. In contrast, the Home Office concluded, on the basis of discussions with the Master Painters, that the Building Employers employed only around 2000 painters. Ibid.

24. P.R.O., LAB.14/211: Memorandum from the White Lead Makers, 27 April 1923, op.cit.

25. P.R.O., LAB.14/211: Letter from L.Butler, International Labour Office, to Home Office, received 30 April 1923.
This letter refutes the accounts of a speech by M. Thomas, Director of the I.L.O., that were being circulated "by the White Lead People". They had claimed that M. Thomas, in a speech at a demonstration organised in Paris by the International Red Cross to support the implementation of the 1921 Geneva Convention, had called for Internal Prohibition as "a jumping off point for a further attack" (i.e. total Prohibition) and had described wet sanding as "a lie".

26. P.R.O., LAB.14/211: Memorandum from the White Lead Makers, 27 April 1923, op.cit.

27. P.R.O., LAB.14/211: Home Office Notes on a Deputation received from the Painters and Decorators Joint Industrial Council, 13 May 1924.

28. Estimates presented in Chapter 3 indicate that industrial painting amounted to one third of all painting work (estimated on the basis of numbers employed in painting activity) in 1924. A 'realistic guestimate' suggests that some 22% of white lead was used in internal painting of all kinds (c.f. Master Painters estimate of 25%). See Tables 3.10 and 3.11.

Similarly the figures cited for Vienna by Oliver indicate that about 25% of white lead used in painting buildings was for internal decoration.

Sir Thomas Oliver, Lead Poisoning from the Industrial, Medical and and Social Point of View, H.K.Lewis, London, 1914, p.67.

29. A minor exception to this was the approach by the Painters Union to the National Union of General Workers, representing White Lead workers after they had lobbied the Home Office to oppose Prohibition on 15 May 1924. The N.U.G.W. agreed to rescind its opposition on the basis of an agreement that the date of implementing Prohibition would be deferred at least six years.
P.R.O., LAB.14/211: Home Office Notes on a Deputation from the National Union of General Workers, 16 May 1924.
J.Gibson, 1924, op.cit.

30. J.Gibson, 1924, op.cit.

31. International Labour Office, 1927, op.cit., p.46.

32. P.R.O., LAB.14/211: Home Office Notes on a Deputation from the National Confederation of Employers' Organisations, op.cit., 27 April 1923.

33. A handwritten note attached to the record of this meeting disputed the claim by the National Federation of Building Trades Employers that "they spoke with more weight than the Master Painters' Federations", noting that the N.F.B.T.E employed only a small proportion of painters (see reference 23 above), and argued that their representative, Loasby, had "no technical knowledge of paints". Ibid.

A subsequent Memorandum to the Home Secretary suggested that the Master Painters were the most legitimate interest to take into account since they were "the employers organisation mainly concerned".

P.R.O., LAB.14/211: Memorandum by Sir M.Delevingne (Home Office) to Home Secretary, 6 September 1923.

34. P.R.O., LAB.14/211: Home Office Notes on a Deputation received from the Master Painters Federations, 30 April 1923, op.cit.

As a result of a Home Office request the Master Painters Federations undertook a survey of the proportion of lead used by their members in interior painting. (Reported at reference 28).

35. P.R.O., LAB.14/211: Home Office Notes on a Delegation received from the Scottish and English Painting Operatives, 16 May 1923, op.cit.

The painting workers claimed that waterproof sandpaper was not available. Moreover, since it would increase the cost and effort for employers and workers, and might affect the quality of the product, they believed that it would not be adopted.

36. P.R.O., LAB.14/211 : Home Office Letter to Butterworth, Painters and Decorators Joint Industrial Council, 18 March 1924.

37. P.R.O., LAB.14/218: Banantyne, Home Office, Letters to Butterworth, Master Painters' Federations, and Gibson, Painting Operatives' Unions (Home Office File 428004, Item 99), 1 May 1924.

38. P.R.O., LAB.14/211: Home Office Memorandum on a visit by Butterworth, Master Painters Federations, 6 May 1924.

The Master Painters noted the small and slowly increasing usage of wet sanding; and attributed it to the "slightly increased painting costs" and the "conservatism on the part of the painting trade" - particularly in the North of the country where the painting craft is more highly organised.

39. P.R.O., LAB.41/218: Letter from Gibson (Painting Operatives Union) to Home Office, 24 May 1924.
The Painters Union even addressed a questionnaire to its branches on the subject which found that waterproof sandpaper was being used in only 43 firms.

40. P.R.O., LAB.14/211: Letter from National Union of General Workers (Northern District) to Home Office received 25 April 1924.

41. The delegation was only accepted after several written requests by the N.U.G.W. (including the intervention by the union National General Council). The Home Office maintained that it preferred representations in writing.
P.R.O., LAB.14/211: Letter from National Union of General Workers (General Council) to Home Office, 28 April 1924.
P.R.O., LAB.14/211: Home Office, Letter to N.U.G.W., 2 May 1924.

42. P.R.O., LAB.14/211; Delevingne, Memorandum to Home Secretary, 6 September 1923, op.cit.

This argued that "neither of the White Lead Corroders' arguments can be accepted" (regarding the availability of waterproof sandpaper and the proportion of white lead used in internal painting).

43. In contrast to the White Lead makers' claims,
The Home Office estimated that the reduction in total lead consumption due to Internal Prohibition would be 0.85% (based on the fact that 20% of lead was used in making white lead, 85% of which is used in paints, and an estimate that 5% of lead paint consumption would cease if all states implemented the Geneva Convention). Ibid.
The Home Office estimate is based on a conservative interpretation of the estimates on lead paint consumption produced by the Master Painters. A more realistic interpretation - that the Geneva Convention would reduce lead paint consumption by 15% - would give an estimate for the reduction in total lead consumption of 2½%.

44. The Home Office had a continuous involvement with the International Labour Organisation, indeed "the first draft of the scheme of of the International Labour Organisation .... was actually prepared in the Home Office".
Sir E.Troup, The Home Office, G.P.Putnams, London, 2nd edition. 1926, p.168.

45. P.R.O., LAB.14/211: Home Office Memorandum, Third International Labour Conference, 1921, White Lead Convention, 2 March 1923. This noted that Estonia had ratified the convention and 14 other states had taken some steps in this direction. Only South Africa had decided not to ratify.

46. Ibid.,
Repudiation of the compromise accepted at the Geneva Convention was described as "relieving the [White Lead] manufacturers only of their sacrifice".

47. P.R.O., LAB.14/211: Home Office Note to Home Secretary, 14 August 1923.

48. C.f. the estimates produced by the Home Office - reference 43. A somewhat less credible argument was advanced that since the Australian mines produced both lead and zinc ores, reduction in demand for lead would reduce the output and thus increase the price of zinc. This invocation of 'natural barriers' has been a frequent characteristic of opposition to regulation since Marx's time - see Chapter 1.

49. P.R.O., LAB.14/211: Home Office Memorandum to Home Secretary, 28 January 1924.
The Board of Trade argued that the decision should be postponed "until it was seen whether the new (wet glasspaper) process was succeeded or not".

50. P.R.O., LAB.14/218: Memorandum by J.Hugh Smity, on behalf of the White Lead Makers Section of the London Chamber of Commerce to the Board of Trade. (Home Office file 428004 Item 120), 7 May 1924.
In addition Smith noted that the incidence of lead poisoning amongst housepainters was low, and was less than half the pre-war levels.

51. P.R.O., LAB.14/218: P.Ashley, Board of Trade, to Under Secretary of State for the Home Office. (Home Office file 428004 Item 120), 30 May 1924.

52. P.R.O., LAB.14/218: R.Davies M.P., Under Secretary for the Home Office, Note in response to Board of Trade letter, 4 June 1924.

53. P.R.O., LAB.14/218: Home Office Note attached to letter from P. Ashley, Board of Trade, (op.cit., 30 May 1924), undated.

54. P.R.O., LAB.14/218: Home Office Memorandum by R.R.Banantyne (Asst.Under Secretary of State for Home Office), 3 June 1924.

55. P.R.O., LAB.14/218: R.Davies M.P. Note, 4 June 1924, op.cit.

56. P.R.O., LAB.14/218: Home Office letter to Board of Trade, 6 June 1924.

57. P.R.O., LAB.14/218: Letter from Under Secretary of State for Home Office to the Office of Works, enclosing copy of Lead Paint Bill (Home Office file 428004 Item 72), 15 April 1924.

58. P.R.O., LAB.14/218: H.Bird, Office of Works, Letter to Under Secretary of State, Home Office (Home Office file 428004 Item 70b), 13 May 1924.

59. P.R.O., LAB.14/218: Home Office Memorandum, 14 May 1928.

60. Note appended to Ibid.

61. P.R.O., LAB.14/218: Letters from Secretary of State for Home Office to Post Office, Air Ministry, Admiralty, War Office, 20 May 1924.
This move was originally suggested by the Office of Works.

62. P.R.O., LAB.14/218: War Office, Letter to Sir M.Delevingne, Home Office (Home Office file 428004 Item 122), 22 May 1924.
P.R.O., LAB.14/218: C.Price, Chief Inspector of Factories to Home Office, 27 May 1924.

The War Office initially suggested prohibition of all lead pigments, but were advised against this by the Factory Department which argued that it was best to focus attention on white lead which posed the greatest danger and the clearest case for Prohibition.

63. International Labour Office, 1927, op.cit., p.46.

64. Ibid.

65. P.R.O., LAB.14/218: Letters from Secretary of State for Home Office, 20 May 1924, op.cit.

66. P.R.O., LAB.14/218: Home Office Memorandum, 4 June 1924.
This noted that Rhys Davies had approached A.V.Alexander M.P., (the junior minister from the Board of Trade who had attended the deputation from the white lead lobby) "to point out the situation to him".

67. P.R.O., LAB.14/211: Sir Montague Barlow (Minister of Labour) Letter to W.C.Bridgeman (Home Secretary), 3 May 1923.

68. P.R.O., LAB.14/211: Sir M.Delevingne (Home Office), Letter to Home Secretary, May 1923.

69. Sir M. Barlow, Minister of Labour, in,
G.B.Parliamentary Debates, House of Commons, Official Report (H.C.Debs.), 163 (55), 9 May 1923. Col.2426 -.

70. P.R.O., LAB.14/211: Sir M.Barlow, 3 May 1923, op.cit.

71. Bellerton, Parliamentary Secretary to the Minister of Labour, in,
G.B.Parliamentary Debates, House of Commons, Official Report (H.C.Debs), 163 (55), 9 May 1923. Cols.2480-1.

72. P.R.O., LAB.14/211: Home Office Memorandum, Third International Labour Conference, 2 August 1923, op.cit.
P.R.O., LAB.14/211: Locker Lampton, Home Office, Note to Home Secretary, 14 August 1923, op.cit.
P.R.O., LAB.14/211: Home Office Memorandum to the Home Affairs Committee (with attached Memoranda from Home Secretary and Minister of Labour) 27 August 1923.

73. P.R.O., LAB.14/211: Sir M.Delevingne, Home Office, Memorandum to Home Secretary, with attached documents, 6 September 1923, op.cit.

74. A last minute amendment at the Geneva Convention, called for exclusion of women and young people from employment in painting of 'an industrial character'. It had been suggested that might apply to all painting activities not just the painting of buildings. The International Labour Office had circulated member states suggesting that they ratify on the basis of the interpretation that had been understood at that time.
International Labour Organisation, 1927, op.cit., pp.406-7.

75. P.R.O., LAB.14/218: W.Joynson-Hicks, Home Secretary, Memorandum to Cabinet Home Affairs Committee, not dated (probably early 1925), attached to:
Home Office Memorandum to Parliamentary Council (Home Office file 428004 Item 167), 3 April 1925.

76. P.R.O., LAB.14/211: Home Office Memorandum to the Home Secretary, 28 January 1924.

77. P.R.O., LAB.14/211: Home Secretary, Memorandum to Home Affairs Committee, undated Cabinet Paper No.53, 1924.

78. P.R.O., LAB.14/211: Home Office Memorandum, 28 January 1924, op.cit.

79. P.R.O., LAB.14/211: Home Secretary, Memorandum, Cabinet Paper No.53, 1924, op.cit.

80. P.R.O., LAB.14/211: Draft of a Bill; the Lead Paint Bill, 20 February 1924, with subsequent amendments, 23 and 26 February 1924.

81. P.R.O., LAB.14/218: W.Joynson-Hicks, Memorandum, and Home Office, Memorandum, 3 April 1925, op.cit.

82. It might have been technically feasible to introduce enabling legislation to extend the powers of the Factory Acts, to housepainting, but to leave the form of regulation to the discretion of the Home Secretary to be implemented by a set of Regulations developed in the normal manner. It could be argued that such an approach would have been most appropriate for the Conservative government to introduce Regulation on an experimental basis. The fact that this solution was not suggested indicates the extent of the political controversy about Prohibition which appears to have demanded its resolution in Parliament.

83. Who Was Who, 1951-60, 5, A.& C.Black, London, 1961.

84. P.R.O., LAB.14/211: R.Davies, M.P., Letter to Home Secretary, 29 February 1924.

85. P.R.O., LAB.14/211: A.Henderson, Home Secretary, letter to Spoor, Minister of Labour. 28 March 1924.

This letter was in response to Spoor's suggestion that introduction of the Lead Paint Bill be delayed, since shortage of Parliamentary time would lead to a long delay between the First and Second Reading (at which the major debate occurs). Spoor was concerned that such a delay might attract opposition to the measure.

86. P.R.O., LAB.14/211: Home Office Notes on a Deputation received from the Painters and Decorators Joint Industrial Council, 22 May 1924, op.cit.

87. G.B. Parliamentary Debates, House of Commons, Official Report (H.C.Debs), 20 June 1924. Cols.2503-2576.
See also:
Daily Telegraph, 21 June 1924.
P.R.O., LAB.14/211: Joynson-Hicks and Home Office Memoranda, 3 April 1925, op.cit.

88. P.R.O., LAB.14/218: Report on Standing Committee D, Amendments proposed for consideration in Committee (Home Office file 428004, Item 144), 21 July 1924.

89. Two of the three M.Ps, proposing the deletion of Prohibition from the 1924 Lead Paint Bill in the Committee stage were Liberals (who had also spoken against Internal Prohibition in the Second Reading of the Bill), Major J.Burnie and E.A.St.A.Harney. Ibid.
Harney had spent several years as a barrister in Australia and had served as a Senator in the Commonwealth Parliament.
Who Was Who 1929-1940, 3, A.& C.Black, London, 1947.
This background might have inclined Harney to give particular weight to the views of the Imperial Lead mining interests. Harney's speech, in support of the 1926 Lead Paint Bill (i.e. Regulation) was a straightforward reiteration of the position of the White Lead Corroders.
G.B.Parliamentary Debates, House of Commons, Official Report (H.C.Debs.), 168, 4 June 1926. Col.1063.

90. This surprising mis-representation drew a sharp response from the Painters' Union stressing that there was "no agreement between the painting trade and the manufacturers of white lead on this vexed question." The painting trade continued to support the Geneva Convention, and the Painters and Decorators Joint Industrial Council had passed a resolution confirming this on 23 January 1925. The code of Regulations agreed between the Master Painters and the Painting Unions in 1922 had been "entirely contingent on the [Geneva] Convention being ratified". The Painters' Union expressed "surprise that the Home Secretary was not better informed".
P.R.O., LAB.14/218: W.Joynson-Hicks, Home Secretary, statement to House of Commons, 9 April 1925.
P.R.O., LAB.14/218: J.A.Gibson, Operative Painters Union, Letter to Home Secretary (Home Office file 428004 Item 170), 17 April 1925.

91. Fisher (Labour M.P.), quoted IN, International Labour Office, 1927, op.cit., p.46.

92. G.B.Parliamentary Debates, House of Commons, Official Report (H.C.Debs.), 168, 4 June 1926. Col.1053 et.seq. (Second Reading of the 1926 Lead Paint (Protection Against Poisoning) Bill).

93. The only non-government speaker (Harney, Liberal; see reference 89) to speak in favour of the Bill at the Second Reading reiterated the White Lead Lobby's incorrect assertion that Internal Prohibition would eliminate 40% of lead paint consumption. Ibid.

94. Ibid.

95. Joynson-Hicks and Harney, op.cit., IN, Ibid.
Joynson-Hicks' argument followed a letter in The Times of that day by J.Obed-Smith, supporting Regulation and opposing Prohibition. Obed-Smith was a Canadian Government delegate to the International Labour Convention (and apparently considered that he was neutral although Canada was a large producer of lead and white lead whilst the French and Belgian government delegates had 'vested interests' by virtue of the zinc pigment industries of those countries).
J.Obed-Smith, The Times, 4 June 1926, p.10.

96. Joynson-Hicks, Ibid.

97. Captain Harking, Under Secretary of State for the Home Department, Ibid.

98. Ibid.

99. S.A.Henry, 'Preface' to:
T.M.Legge, Industrial Maladies, Oxford University Press, London, 1934. p.XI.

100. K.Marx, Capital Volume 1, Penguin, Harmondsworth, 1976. p.626.

101. This was cited by both the White Lead Makers and the Conservative government.
P.R.O., LAB.14/211: J.Hugh Smith, Memorandum, 27 April 1923, op.cit.
G.B.Parliamentary Debates, H.C.Debs., W.Joynson-Hicks, 9 April 1925, op.cit.

102. P.R.O., LAB.14/28: Home Office Memorandum, 'Research into Paint Technology' (Home Office file 496133 Item 1), 21 July 1926.

103. P.R.O., LAB.14/28: Factory Inspectorate Report to Chief Inspector of Factories (Factory Inspectorate file F.I.5503/2AY9) 19 July 1926. The Factory Inspectorate was not represented on the Paint Research Association. The Department of Scientific Industrial Research was represented however and liaised with the Factory Department.

104. P.R.O., LAB.14/28: Factory Inspectorate Report to Chief Inspector of Factories, 13 May 1929.

105. See also:
G.B.Department of Scientific Industrial Research, D.S.I.R. Report for the year 1929/30 [Cmd.3789], HMSO, London 1931 p.140. and subsequent reports for 1930/31 [Cmd.3989], 1931, for 1931/32 [Cmd.4254], 1933; for 1932/33 [Cmd.4483], 1934.

106. P.R.O., LAB.14/28: R.R.Banantyne, Home Office, Note, 10 February 1930.

107. P.R.O., LAB.14/28: Factory Inspectorate, Report, 13 May 1929, op.cit.

108. P.R.O., LAB.14/28: Factory Inspectorate, Note, 15 October 1930.

109. P.R.O., LAB.14/28: Factory Inspectorate, Note, 18 December 1933.

110. P.R.O., LAB.14/28: Price, Factory Inspector, Letter to Senior Engineering Inspector, 7 February 1936.

111. Thus in 1929, the Home Office representative on the British Engineering Standards Association Subcommittee on Paint and Varnish was withdrawn, noting that involvement in its activities "needs special expertise".
P.R.O., LAB.14/28: Factory Inspectorate, Report, 13 May 1929, op.cit.

112. Thus proposals by the Office of Works to carry out tests of paint performance in conjunction with the government chemist were dropped.
Ibid.

113. P.R.O., LAB.14/211: Home Office Notes on a Deputation from the National Confederation of Employers' Organisations, 27 April 1923, op.cit.

114. P.R.O., LAB.14/215: Home Office Memorandum (Home Office file 428004 Item 43, Home Office file 481945, Item 1), 14 August 1923.

115. P.R.O., LAB.14/215: Home Office Memorandum, 9 March 1925.

116. G.B.Factory Department, Annual Report of the Chief Inspector of Factories for 1925 [Cmd.2715], HMSO, London, 1926.

117. P.R.O., LAB.14/215: Home Office Notes on a Conference with Trade Representatives on the Draft Regulations for the Painting of Vehicle, Copy of Draft Regulations attached, 20 July 1925.

118. P.R.O., LAB.14/215: Ballantyne, Factory Department, Letter to Sir John Anderson (Vehicle Building employers) 24 July 1925.

119. P.R.O., LAB.14/215: Home Office Circular with (revised) draft Regulations on Vehicle Painting, 25 August 1925.

120. P.R.O., LAB.14/215: Home Office, Notes on a Second Conference with Trade Representatives, 2 December 1925.

This involved the E.& A.E.F., S.N.V.B.A., N.E.A.V.B. and the N.A.P.M. (For full titles see subsequent text).

121. P.R.O., LAB.14/215: Home Office Memorandum on Objections to Draft Regulations (Home Office file 481945 Item 20), 30 September 1925.
P.R.O., LAB.14/215: N.E.A.V.B. Letter to Home Office (file 481945, Item 19), undated, 1925.
P.R.O., LAB.14/215: S.N.V.B.A. Letter to Home Office (file 418945, Item 20), 23 September 1925.

122. P.R.O., LAB.14/215: E.A.E.F., Letter to Home Office (file 481945, Item 20), 23 September 1925.
P.R.O., LAB.14/215: Home Office Memorandum, 30 September 1925, op.cit.

123. P.R.O., LAB.14/215: E.A.Harney, M.P., Letter to Locker Lampson M.P., Parliamentary Under Secretary to Home Office (Home Office file 481945 Item 2), 17 July 1925.
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124. P.R.O., LAB.14/215: London Chamber of Commerce, White Lead Makers Section, Letter to Home Office (Home Office file 481945 Item 22), 24 September 1925. (With appended manuscript note by Home Office undated).

125. P.R.O., LAB.14/215: Notes of Chief Inspectors Conference with Representatives of the N.U.V.B. (Factory Inspectorate file 403/3 Hd), 26 October 1925.

126. P.R.O., LAB.14/215: Home Office Circular, 16 February 1926.
P.R.O., LAB.14/215: Home Office Memorandum, 12 March 1926.

127. S.R. and O. No.299. 1926. Issued 12 March 1926.

128. P.R.O., LAB.14/226: Memorandum to Home Office from Secretary of Committee on Industrial Paints (Home Office file 428004 Item 5), 21 July 1922.

129. P.R.O., LAB.14/211: Home Office Notes on a meeting with the P.& D.J.I.C., 4 April 1922, op.cit.

130. P.R.O., LAB.14/226: Statement by Sir Gerald Bellhouse to be given before the Referee (W.W.MacKenzie) on 22 June 1927.

131. G.B.Home Office, Report to H.M.Secretary of State for the Department on the Draft Regulations for Preventing Danger from Lead Paint to Persons Employed on or in connection with the Painting of Buildings, Referee: Sir W.W.MacKenzie, HMSO, London, 1927. 34-9999.

132. P.R.O., LAB.14/226: Report by McNair and Price, Factory Inspectorate, and Home Office Memorandum on Wire brushing Metal Structures, 29 July 1927.

133. P.R.O., LAB.14/226: Statement by Bellhouse, 22 June 1926, op.cit.

134. S.R.& O., No.847., 1927.

135. P.R.O., LAB.14/211: Home Office Notes on a Deputation from the National Confederation of Employers Organisations, 27 April 1923, op.cit.

136. S.R.& O. No. 1931.

137. International Labour Office, 1927, op.cit. p.46.

138. K.Marx, 1976, op.cit., p.621.

139. See also, Ibid., p.635.

140. P.R.O., LAB.14/215: Notes of Chief Inspectors Conference, 4 September 1925, op.cit.
T.M.Legge at this meeting noted that the use of lead vehicle paints had been greatly reduced because of the introduction of spray paints, where lead was not used.

141. P.R.O., LAB.14/215: Home Office, Notes on a conference, 20 July 1925, op.cit.

142. T.M.Legge, 1934, op.cit., p.52.

143. P.R.O., LAB.14/176 : Home Office Memorandum (Home Office file 102578 Item 9), 9 November 1905.

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1903	[Cd. 2139]	1904;
1904	[Cd. 2569]	1905;
1905	[Cd. 3036]	1906;
1906	[Cd. 3586]	1907;
1907	[Cd. 4166]	1908;
1908	[Cd. 4664]	1909;
1909	[Cd. 5191]	1910;
1910	[Cd. 5693]	1911;
1911	[Cd. 6239]	1912;
1912	[Cd. 6852]	1913;
1913	[Cd. 7491]	1914;
1914	[Cd. 8051]	1915;
1915	[Cd. 8276]	1916;
1916	[Cd. 8570]	1917;
1917	[Cd. 9108]	1918;
1918	[Cmd. 340]	1919;
1919	[Cmd. 941]	1920;
1920	[Cmd.1403]	1921;
1921	[Cmd.1705]	1922;
1922	[Cmd.1920]	1923;
1923	[Cmd.2165]	1924;
1924	[Cmd.2437]	1925;
1925	[Cmd.2715]	1926;
1926	[Cmd.2903]	1927;
1927	[Cmd.3144]	1928;
1928	[Cmd.3360]	1929;
1929	[Cmd.3633]	1930;
1930	[Cmd.3927]	1931;
1931	[Cmd.4078]	1932;
1932	[Cmd.4377]	1933;
1933	[Cmd.4657]	1934;
1934	[Cmd.4931]	1935;
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1941	[Cmd. 6397]	1942;
1942	[Cmd. 6471]	1943;
1943	[Cmd. 6563]	1944;
1944	[Cmd. 6698]	1945;
1945	[Cmd. 6992]	1946;
1946	[Cmd. 7299]	1948;
1947	[Cmd. 7621]	1949;
1948	[Cmd. 7839]	1949;
1949	[Cmd. 8155]	1951;
1950	[Cmd. 8455]	1952;
1951	[Cmd. 8772]	1953;
1952	[Cmd. 9154]	1954;
1953	[Cmd. 9630]	1954;
1954	[Cmd. 9605]	1955;
1955	[Cmnd. 8]	1956;
1956	[Cmnd. 329]	1958;
1957	[Cmnd. 521]	1958;
1958	[Cmnd. 810]	1959;
1959	[Cmnd.1107]	1960;
1960	[Cmnd.1479]	1961;
1961	[Cmnd.1816]	1962;
1962	[Cmnd.2128]	1963;
1963	[Cmnd.2454]	1964;
1964	[Cmnd.2724]	1965;
1965	[Cmnd.3080]	1966;
1966	[Cmnd.3358]	1967;
1967	[Cmnd.3745]	1968;
1968	[Cmnd.4146]	1969;
1969	[Cmnd.4461]	1970;
1970	[Cmnd.4758]	1971;
1971	[Cmnd.5098]	1972;
1972	[Cmnd.5398]	1973;
1973	[Cmnd.5709]	1974;
1974	[Cmnd.6322]	1975;

G.B.Factory Inspectorate, Annual Report of the Chief Inspector of Factories on Industrial Health for the Year 1961 [Cmd.1815], HMSO, London, 1962.

1962	[Cmnd.2129]	1963;
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1964	[Cmnd.2723]	1965;
1965	[Cmnd.3081]	1966;
1966	[Cmnd.3359]	1967;

2. G.B.Home Department, Report of the Departmental Committee Appointed to Investigate the Danger Attendant on the Use of Paints Containing Lead in the Painting of Buildings, [Cd.7882], HMSO, London, 1915. p.78. (evidence of T.M.Legge, Medical Inspector of Factories).

3. T.M.Legge, Industrial Maladies, Oxford University Press, London, 1934. Table 11.
International Labour Office, White Lead, I.L.O., Geneva, 1927.

4. G.B.Home Department [Cd.7882], 1915, op.cit., pp.75-8.

5. G.B.Factory Department; [Cd.668], 1901, op.cit., pp.119-20; [Cd.1112], 1902, op.cit., p.208; [Cd.3036], 1906, op.cit., See Chapter 3.

6. G.B.Home Department [Cd.7882], 1915, op.cit., p.78.

7. G.B.Factory Department [Cmnd.5398], 1973, op.cit.

8. An additional source of variation in voluntary notification of lead poisoning in housepainters stems from regional differences in reporting rates. Evidence was presented to the 1921 Committee on Industrial Paints which showed that the voluntarily notified cases of lead poisoning in housepainters between 1910-4 had the following regional distribution : Scotland and Ireland, 32, England and Wales 1027 - of which, North West 171, North East 89, Midlands 166, South West 144, South East 477.
G.B. Home Department, Report of the Departmental Committee (on Industrial Paints), HMSO, London, 1923.
It has not been possible to investigate this aspect further. The rate of notification in Ireland and Scotland is so low that mortality and employment statistics for England and Wales only have been used in calculations and comparison with cases of occupational lead poisoning for Britain as a whole, without making a correction.

9. G.B.Factory Department [Cd.7491], 1914, op.cit. p.126.

10. G.B.Registrar General, 74th Annual Report of the Registrar General for England and Wales [Cd.7578], HMSO, London, 1914 p.88.

11. G.B.Factory Department [Cmd.3144], 1929, op.cit.

12. G.B.Factory Department [Cd.6239], 1912, op.cit., p.209.

13. G.B.Factory Department [Cd.7491], 1914, op.cit., p.126.

14. Sir Thomas Oliver, Lead Poisoning, H.K.Lewis, London, 1914, p.205.

15. R.E.Lane, 'Health Control in Inorganic Lead Industries', Archives of Environmental Health, 8, February 1964, pp.243-50.

16. G.B.Health and Safety Executive, Health and Safety Statistics 1975, HMSO , London, 1977.

17. R.E.Lane, 1964, op.cit.,

18. A.Goldberg, 'Haem derivatives in the early diagnosis of Lead Poisoning' in H.Holden and G.Kazantzis (eds.), Early Detection of Occupational Health Hazards, Proceedings of a symposium, Newcastle 1970, Society of Occupational Medicine, London, 1971.

19. H.Holden, 'Criteria for Notification of Industrial Disease', and R.Goulding, 'What is Poisoning?', in, H.Holden and G.Kazantzis (eds.), 1971, op.cit.

20. The Lead Processes (Medical Examinations) Regulations 1964, Statutory Instrument No.1728, HMSO., London, 1964.

21. The Control of Lead at Work Regulations 1980, Statutory Instrument No.1248, HMSO, London, 1980.
G.B.Health and Safety Commission, Control of Lead at Work : Approved Code of Practice, HMSO., London, 1980.
In addition, the Employment Protection (Consolidation) Act 1978 gave workers the right to remuneration if suspended from work for medical grounds (i.e. lead absorbtion).

22. G.B.Factory Department [Cmd.1705], 1922, op.cit.,p.69
See also T.M.Legge, 1934, op.cit., p.58.

23. G.B.Factory Department [Cd.6239], 1912, op.cit., p.209

24. The figures for cases of lead poisoning classed as severe in 1920-4. (factory occupations and [partially estimated] housepainters) are derived from :
T.M.Legge, 1934, op.cit., p.53
G.B.Home Department, Report of the Committee (on Industrial Paint), 1923, op.cit.

25. Sir Arnold Wilson and Herman Levy, Workmen's Compensation : Volume 1, Social and Political Development, Oxford University Press, London, 1939, p.100-.

26. G.B.Home Office, Statistics of Compensation and of Proceedings under the Workmen's Compensation and the Employers' Liability Acts : Annual Report for 1908, HMSO, London, 1910, p.12.

27. The Holman-Gregory Committee, appointed 13th May 1919, "to enquire into the working of the present system of the payment of compensation to workmen ..." cited in, Wilson and Levy, 1939, op.cit., pp.177-8.

28. G.B.Home Office, Annual Report(s) of Statistics of Compensation and Proceedings under the Workmen's Compensation and the Employers' Liability Acts for the Year(s) 1908-1938, HMSO, London, 1910-1940.

29. Wilson and Levy, 1939, op.cit., p.308.

30. G.B.Home Office, 1910, op.cit., p.12.

31. Ibid.,

32. The complete list of Prescribed Industrial Diseases currently in force under the Industrial Injuries Acts is available from the Department of Health and Social Security (D.H.S.S.)
G.B. D.H.S.S., Prescribed Industrial Diseases, Leaflet N.I.2., D.H.S.S., June 1976.

33. G.B. D.H.S.S. Table P.D.2, 1980. This has been provided by the D.H.S.S. Research and Statistics Section (HQ.SR.8C) whose help is gratefully acknowledged.

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G.B. Health and Safety Commission, 1980, op.cit., p.4.

36. G.B.Factory Department [Cmd.5398], 1973, op.cit.

37. G.B.Office of Population Censuses and Surveys, Decennial Census(es) of the Population of England and Wales, O.P.C.S., London :
for 1901, Summary Tables, 1903. Table 35 - Occupations;
for 1911, Part I Volume 10, Occupations Tables 1913-14;
for 1921, Volume 2, Occupations Tables, 1924, and Volume 3, Industries Tables, 1925;
for 1931, Occupations Tables, 1934, and Industries Tables, 1934;
for 1951, Occupations Tables, 1956, and Industries Tables, 1951.

38. G.B.Factory Department: [Cd.2569], 1905, op.cit., p.52; [Cd.3036], 1906, op.cit., p.366; [Cd.6239], 1912, op.cit.; [Cd.6852], 1913, op.cit., p.204; [Cd.7491], 1914, op.cit. p.132; [Cd.8051], 1915, op.cit.

39. G.B.Census of Production; Final Report on the first Census of Production of the United Kingdom (1907), [Cmd.6320], HMSO, London, 1912.
G.B.Census of Production, Final Report on the third Census of Production of the United Kingdom (1924) (5 volumes), HMSO, London, 1930-2. (in particular, volume 3, 1931 and 5, 1932 - these include some results of the second [1912] Census of Production).
G.B.Census of Production, Final Report on the fourth Census of Production (1930), (5 volumes), HMSO, London, 1933-5. (Part III, 1934 and Part IV, 1935).
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G.B.Census of Production, The Report on the Census of Production for 1951, (13 volumes), HMSO., London, 1954-6. (Volume 2, 1954).

40. G.B. Business Statistics Office, Historical Record of the Census of Production 1907-70, HMSO., London, 1978. Table 8. pp.294-341.

41. G.B.Home Department [Cd.7882], 1915, op.cit., p.66. (evidence of Muller, White Lead Corroders section of London Chamber of Commerce).

42. Ibid., p.78.

43. More than 90% of U.K. employment in pigment and paint manufacture, and vehicle painting was in England and Wales in this period. A smaller proportion of housepainters were employed in England and Wales, but this does not affect the incidence of lead poisoning, since notified poisoning was largely confined to these countries. The calculation of incidence of poisoning from U.K. poisoning and English and Welsh employment produces a significant error only in the case of ship painting which probably overestimates the 'true' incidence by between 20% (1951) and 29% (1927).

44. The increase in incidence in observed cases of poisoning in housepainters over the 1900-14 period is probably a result of the increasing rate of voluntary notification, and is not matched by an increase in the estimated incidence of poisoning adjusted for under-reporting in housepainters (derived from the proportion of cases of poisoning in house and industrial painters that were fatal - (see Table 6.12). The incidence of fatal lead poisoning amongst painters is also static in this period (with the exception of the somewhat anomalously high figures in ship builders prior to World War 1.).

45. H.E.Ayer, 'Proposed OSHA Health Hazard Monitoring Requirements', National Safety News, May 1976, pp.57-66.

46. G.R.C.Atherley, Occupational Health and Safety Concepts, Applied Science Publishers, 1978.

47. H.A.Waldron, Lecture Notes on Occupational Medicine, (2nd edition), Blackwell Scientific, Oxford, 1929.

48. G.B.Factory Department, [Cmd.340], 1919, op.cit., p.66.

49. Sir Thomas Oliver, 1914, op.cit., p.67.

50. G.B.Census of Production, various years, op.cit., For a detailed description of sources, see Reference 39 and Appendix A-1.

51. T.M.Legge, 1934, op.cit., p.58.

52. Between 1945-9 and 1950-4, the reduction in white lead consumption can account for virtually all of the reduction in lead poisoning amongst house and industrial painters. As a result, a very low estimate is obtained for these years of the rate of reduction of lead poisoning due to changes in paint technology and working methods of 1½% p.a. amongst housepainters and 3% amongst industrial painters. (Compared to 10% and 7% over the preceding 25 years and 14% and 10% in the following decade). This is probably an underestimate.

53. The limited data available on number of firms and workers involved in white lead manufacture are shown in Table 4.7 (with additional estimated data in Appendix B-6). These show the increasing concentration of white lead manufacture after 1904. Such a concentrated industry was amenable to detailed Factory Inspection. Only 18 white lead factories were recorded by the Factory Inspectorate in 1901 (of these, a single works in Newcastle on Tyne accounted for about one third of all lead poisoning from white

53. continued
lead manufacture between 1900 and 1903).
G.B.Factory Department : [Cd.668] 1901, op.cit.; [Cd.1112] 1902, op.cit.; [Cd.1610], op.cit., and [Cd.2139] 1904, op.cit.

54. The introduction of medical examination in one factory brought the proportion of the workforce showing signs of plumbism down from 88% in 1902 to 53% in 1903.
This factor, combined with a change in the design of the 'pots' which supported the 'white lead corrosions' that reduced the exposure to white lead dust when emptying the 'stacks' led to a further reduction in lead poisoning to 9.4% by 1905.
Medical Inspectors Report, in, G.B.Factory Department [Cd.3036], 1906, op.cit., p.352.

55. W.D.Buchanan,'Toxic Hazards in the Paint Industry', Journal of the Oil and Colour Chemists Association, 40 (5), May 1957, pp.337-349.

56. F.Armitage, The British Paint Industry, Pergamon, Oxford, 1967. pp.96-100.
H.Brunner, 'Paint', Chapter 23 in, T.I.Williams (ed), A History of Technology : The 20th Century c.1900-1950, Volume VI Part 1, Clarendon Press, Oxford, 1978.

57. S.J.Douglas, Comparison of Strategies for Lowering the Exposure of Children to Lead, forthcoming Ph.D.thesis, Technology Policy Unit, University of Aston.

58. D.Hunter, The Diseases of Occupations, 1978, Hodder and Stoughton, London, 1978, pp.284-7.

59. G.B.Health and Safety Executive, Prevention of Lead Poisoning in Painters, Leaflet SHW 394 (reprint), HMSO , London, 1978.

60. See for example :
- W.D.Buchanan, 1957, op.cit.
- R.Piper, 'Paint Hazards', Chemistry and Industry, 17 February 1968, pp.201-6.
- D.J.T.Howe, 'Problems of Toxicity in the Paint Industry', Journal of the Oil and Colour Chemists Association, 56 (7), 1973, pp.323-4.

Buchanan for example described the total number of cases of lead poisoning in paint making between 1945 and 1954 (32 including one death) as 'satisfactory'.

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W.Allen, 'Forced Sterilisation in U.S.', Morning Star, 6 February 1979, p.4.
British Society for Social Responsibility in Science, Lead : Benefit or Curse to civilisation?, (Mimeo), B.S.S.R.S., London, 29 November 1979.

78. Anon,
1973, p.32.
L.A.O'Neil, 1981, op.cit.
U.S.Federal Register, 42(170), 1977, p.44194.

79. See for example:
L.A.O'Neil, 1981, op.cit., p.84.
Paintmakers' Association of G.B. Proprietory Lead Primers for Wood, P.A. Circular MD/7/72, P.A., London, 10 April 1972.

80. Paintmakers' Association of G.B., Children and Paints Containing Lead and other toxic Compounds, Circular G/30/63, P.A., London, 15 July 1963.
Paint Manufacturer's Joint Executive Council, Circular, P.M.J.E.C., London, 5 November 1962.
(N.B. the Paint Manufacturers J.E.C. changed its name to the Paintmakers' Association between the making of the agreement in 1962 and its implementation in 1963).

81. L.A.O'Neil, 1981, op.cit.

82. R.Piper, 1968, op.cit. See also :
N.A.R.Falla, 'Lead in Paint', Environmental Health, October 1980, pp.226-7, 232.

83. Personal Communication with A.J.Whitney, Paintmakers' Association of G.B., 1 September 1980.
Paintmakers' Association of G.B., 1972, op.cit.

84. L.A.O'Neil, 1981, op.cit., p.33.

85. Toys (Safety) Regulations 1967, Statutory Instrument No.1157, HMSO., London, 1967.

86. Toys (Safety) Regulations 1974, Statutory Instrument No.1367, HMSO., London, 1974.

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88. Council of the European Communities, 'Council Directive Relating to the Classification, Packaging and Labelling of Paints, Varnishes, Adhesives and Similar Products: 7 November 1977', Official Journal of the European Community, 20(L303), 1977.
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L.A.O'Neil, 1981, op.cit., pp.18-9

89. R.Russell-Jones, 'How to Poison the World without even trying', The Guardian, 25 March 1983, p.21.

90. G.B.Department of Health and Social Security, 1980, op.cit., p.34.

91. N.A.R.Falla, 1980, op.cit.
Paintmakers' Association of G.B. Notes on the Use of Lead in Paints, P.A., London, May 1980.

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63. G.B.Health and Safety Commission, 1980, op.cit.

64. D.Hunter, 1978, op.cit., p.291.

65. J.J.Chisholm and H.E.Harrison, Pediatrics, 18, 1956. p.943.
and D.Barttrop, D.Burman and S.Tucker, Archives of Diseases in Childhood 51, 1976. p.809. cited in,
G.B.Department of Health and Social Security, Lead and Health, Report of a D.H.S.S. Working Party on Lead in the Environment (Lowther Report), HMSO., London, 1980.

66. G.B.Department of Health and Social Security, 1980, op.cit., p.35.

67. Personal Communication with Dr. M.S.Cuthbert, Department of Health and Social Security, 28 February 1980.

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70. P.R.Jones, 'Paint Work', The Guardian, 13 May 1982, p.16.

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76. D.Robbins and R.Johnson,, 1976, op.cit.
L.A.O'Neil, 1981, op.cit. p.85.

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Judging for example by recent legislation in the U.S.A. and other countries.

R.Russell-Jones, 'How to poison the World without even trying', The Guardian, 25 March 1982, p.21.
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The picture if further complicated by shifts in the location of metal ore refinement and processing. See Chapter 3.

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