# TECHNOLOGICAL INNOVATION : AN INTER-INDUSTRY PERSPECTIVE

A Study of Technical Change in the UK Tinplate and Can-making Industries

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This research aims to contribute to the understanding of the nature of technical change and its role in industrial development. It is intended that the study will form part of the burgeoning literature which seeks to construct a distinct 'theory of innovation'. This objective reflects dissatisfaction with the way traditional economics has treated technical change. The emerging theory is based on case study material, which has tended to restrict itself to radical innovations in the newer industries. This research examines the view that innovation is essentially a process, a stream of minor and incremental changes; to understand this process it must be examined by detailed historical enquiry. The predilection for the study of exciting innovations in "glamorous" industries has led to neglect of innovation in traditional industries and, consequently, a lack of awareness of the important role of these staple industries in industrial development and economic progress. The study argues that technical change is a complex and diverse phenomenon which is best understood within a broad analytical framework. To achieve this an inter-industry, or "systems", perspective is necessary. This study examines technical change in can-making since 1810, it focuses particularly on the nature of innovation and its role in the industry's development since 1945. The analysis is extended to include tinplate, food processing, alternative packaging, complementary production, socio-economic and marketing factors. It has been found that the humble tin-can industry has been a hot-bed of innovation, albeit for the most part minor and incremental. It is shown that this innovation has made a consistently significant contribution to human welfare. In the case of tinplate it is argued that although the industry appears to be characterized by major innovation, these are but the accumulation of on-going advances in engineering in general. It has been found that a broad analytical framework is required in order to understand can-making innovation at both the technical and the commercial level; technical advances are made only after reference to the likely impact on inter-dependent processes, often across industrial boundaries. On the commercial plane, it has been shown that the principal stimulus to innovation is competition - in its widest sense. The immediate industrial structure is of significance in that it may be an additional source of competitive pressure. The study has found that diffusion is a valuable indicator of the importance of both major and minor innovations, but it must be applied with due regard to the prevailing industrial framework and the purpose for which each technical change is introduced. The research has suggested that physical measures, rather than monetary, are best suited to assess the significance of technical change.

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PREFACE:

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The general theoretical perspective, and the particular hypotheses, which have been chosen for examination have evolved out of a review of the way in which technical change has been treated in traditional economic theory, and by a review of recent research into technological change in its own right. Specific sources of information are as indicated in the References to Chapter I.

The historical examination of the innovative records of the tinplate and can-making industries has been compiled from a review of the month by month editions of the commercial and technical literature of the tin, sheet metal, packaging, and food processing industries covering a thirty year period. This review has taken place in the Commercial and Technical Libraries of the City of Liverpool.

The post-war record of the innovative performance of the UK tinplate and can-making industries is based on a postal questionaire data collection exercise undertaken as part of this research project. The results of the exercise are included as an Appendix.

Primary research has been the source of a significant amount of technical background to Chapter three and to Chapter four; Chapter five is derived virtually exclusively from primary research. The Companies which have actively co-operated by allowing field research within their organizations are as follows:

International Tin Research Institute

British Steel Corporation (Tinplate Division)

H J Heinz Ltd

Reads Ltd

United Glass

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# CHAPTER I

## INTRODUCTION AND LITERATURE REVIEW

## 1. The Importance of Technological Innovation

Definitions of 'technology' and of 'innovation' vary, even when the chosen definition is accepted problems are often encountered in deciding which changes constitute innovations. One method of defining technology and innovation is to differentiate between science and technology on the one hand and invention and innovation on the other. Science is considered to be concerned with 'knowing why' whereas technology is concerned with 'know how', with the distinction being that the latter implies the application of knowledge. Pre-occupation with the dichotomy between invention and innovation stems from the work of Schumpeter (1) who argued that innovation need not embody invention at all. This has led to the abandonment of the definition of innovation as the 'application of an invention'. Schumpeter's own definition, and regarded as amongst the widest, is that an innovation is the commercial exploitation of a 'new thing' or a new way of doing something. This is the definition adopted in this study. The main problem in applying such a general interpretation to empirical analysis is in determining whether minor changes in fact contain the necessary element of novelty to be regarded as innovations.

Technological innovation is about 'getting more for less' or, to put it differently, improving the ratio of outputs to inputs. The key to maximizing economic performance is by making optimum use of scarce resources. Technological innovation is important because it offers an industrial strategy by which one "can improve the productivity of resources and generate new products, or improvements to existing products". (2)

There is no alternative method of wealth creation to technological innovation without the discovery and exploitation of additional scarce natural resources. Modern industrial society is consuming its natural resources faster than it is discovering them. Technological innovation therefore offers the only plausible long term strategy for maintaining or improving human welfare in industrial societies.

## 2. The Need for Study of Technological Innovation

Despite a widespread consensus on the significance of technological change to industrial development, study of the former is, as Johnston and Gibbons (3) have noted, still very much in the impressionistic stage. Academic study of the area is still relatively neglected, despite an upsurge of interest in the last decade. Attempts to evolve a distinct theory of technological innovation is a comparatively recent phenomenon. There is, consequently, a need for more understanding of the nature of innovation. The priority at present would appear to be for the formulating of hypotheses on the nature of innovation, and the testing of those hypothesis by empirical study. In this way one might hope to contribute to the construction of a theoretical corpus regarding technical change, and thereby provide a framework for subsequent research.

## 3. The Theoretical Perspective

This study postulates three central hypotheses regarding the nature of technological innovation, from which a number of further related hypotheses follow.

### i. The Innovation System is Complex and Diverse

The innovation system - the boundaries within which the principal causes and effects of technical change may be found - is a complicated matrix of interactions which cut across traditional ideas of industrial groupings. To examine the nature of innovation - the factors which give rise to it and the industrial impact which it has - one must adopt an analytical framework which is sufficiently inclusive to reflect the major causes and consequences of innovation.

ii. Technological Change is Essentially Evolutionary

It is postulated that technical change is predominantly a continuous evolutionary process rather than a series of irregular and discontinuous interruptions to on-going industrial development. It is held that because the vast majority of innovations are evolutionary, in aggregate they contribute more to human welfare than the radical but infrequent innovation.

iii. Innovation Owes its Industrial Significance to Diffusion

It is argued that an innovation owes its relevance to the rate and extent to which it is diffused throughout an industry, rather than to its first application.

From the above three hypotheses the following may reasonably be postulated.

a. Because innovation cuts across traditional industrial classifications, and because a number of individual industries are at any one time engaged in complementary or competitive activity of one kind or another, innovations will tend to generate a chain reaction of supportive or defensive developments. A major stimulus to innovation, it is argued is, therefore, innovation itself.

b. Most evolutionary innovation, but not necessarily all, must be minor or otherwise it would disrupt continuity. Because the majority of innovation is both minor and on-going it may safely be said to be "routinised"; being minor, such innovation must largely represent incremental improvements to the state of the art. It would seem reasonable to expect, therefore, that at least some 'radical innovations' are in reality merely the harnessing of a number of piecemeal developments, possibly drawn from diverse areas.

Because innovation is typically minor it should not be associated principally with the emergence of new firms and new industries. It is argued that because innovation is part of the process of widespread industrial evolution and adaptation to change, the most common and typical source of innovation is the traditional industrial base.

c. It follows from the hypothesis that innovation is generated from the interplay of a complicated array of commercial forces that the propensity to innovate should not be primarily determined, as it is often argued to be, by one factor alone - market structure. Given hypotheses 1, it is postulated that market structure determines the propensity to innovate only inasmuch that market structure controls the operation of these complex commercial pressures. It is argued that as these pressures are held to cut across traditional ideas of industrial groupings, alternative industrial structures should not of themselves produce different patterns of innovative behaviour. It is, however, considered that firm size, irrespective of market structure, may be an important variable in innovative behaviour.

d. From the hypotheses concerning diffusion, it is further argued that the rate of dissemination of an innovation is determined primarily by the attractiveness of that innovation to potential imitators and, secondly, by the extent of the capital outlay required to adopt it.

e. It is also argued that the process of diffusion will tend to generate defensive technical change in the product or process being displaced which, if successful, will delay, perhaps indefinitely, the rate of adoption.

f. From the observation that innovation owes its significance to diffusion follows a more general hypotheses that physical measures in general are the most meaningful indicators of the impact of an innovation. Monetary measures are fraught with comparability problems both nationally and internationally and, more importantly, over time. Industrial innovation initially manifests itself as physical changes to the process or product; these physical changes are the intended outcome of the innovation. These physical changes are only a means to an end - reducing costs, increasing sales etc. - the extent to which they do in fact materialize reflects the success of an innovation in a manufacturing context. This study will try to reflect the industrial impact of innovations by recourse, principally, to physical measures - the degree of diffusion, the reduction in material input, the speed of output etc. These are the real consequences of technical change in terms of optimimizing the use of resources, and they lend themselves to causal relation more readily than monetary measures such as price, profit etc. which are prey to every transient commercial breeze.

## 4. Economists' Views of Technological Innovation

Traditionally, the primary role of economics is to explain the way in which wealth is created. This process of wealth creation is more usually referred to as economic development or, more recently, economic growth. Economic development was originally considered to be the fundamental problem facing economics though, over time, its treatment has not always been considered crucial or fashionable.

i. Classical Treatments

"The Wealth of Nations" (4) by Adam Smith was, in 1776, the first successful general treatise which sought to identify the determinants of economics progress. Technical change plays a central role in Smith's explanation of the causes of economic progress because, as Kierstead (5) has observed, Smith equates it with the division of labour. Cannan (6) believes that this association relegated the importance of technical knowledge and innovation in economic change by submerging the two under the general advantages to be had from the division of labour; Robbins (7) however, ridicules this criticism. Cannan's point does however draw attention to the fact that the division of labour and technical change are not surrogate terms and Smith, indeed, does occasionally use the term 'project' when referring exclusively to innovation. When talking of the division of labour Smith is including, by his own tripartite definition, (8) an integral element of technical change. It is analytically tenable, therefore, to take Kierstead's premise and examine the role of innovation in industrial development through the division of labour.

Smith's view of the role of innovation is, then, hinged on the effects of the division of labour. These he observes to manifest themselves primarily in physical output. From his analysis that innovation - or the division of labour - increases output Smith's whole prognosis follows: Increased output per unit of input means a growth in the National Income. National Income is comprised of three elements - rent, wages and profit (which includes the rate of interest). Smith examined the problem of profit, wages and rent separately and thereby invoked technological innovation into the separate discussion of each, as well as dealing with it in his first three chapters. This piecemeal approach to technical change is not the most satisfactory approach to the problem. Moreover, Smith's treatment in detail of the repercussions of technical change are somewhat superficial; he argues that the improved output of labour caused by innovation is invariably accompanied by capital formation. As such, this observation adds little to what we know about the effects of economies of scale. Smith fails to tackle the question of completely new enterprises arising out of radical innovation, keeping his perspective within technological horizons. He assumed, further, that a process innovation would always and only manifest itself in the form of cost reductions, ignoring qualitative changes.

Smith's treatment is important, however, because of the central role of the division of labour, and thereby innovation. Moreover, in Smith's analysis innovation was the result of economic pressures i.e. he considered it to be wholly endogenous. This insight is most important from the historical perspective.

The salient criticism of the 'Wealth of Nations' applied equally well to most of the other classical writers, and also to Marx, the criticism being the failure to discuss technological change in its own right.

Ricardo (9) is perhaps even a more lucid example of this tendency. Richardo discusses technical change intermittently in all the traditional theories; thus, we find it surfacing in the theory of rent, of value and of wages; he broaches it again in his theory of comparative advantage and, finally, in his chapter on machinery wherein his celebrated 'change of mind' on the effect of new machines on employment is discussed.

Richardo's'change of mind' was the major stimulus to that part of the subsequent classical work which dealt with innovation. The focal question now became, in this debate, what was the effect of new machines on the demand for labour? Malthus (10) devoted ten pages to the question while Sismondi (11), J. S. Mill (12), Cairnes (13), Bentham (14) and McCulloch (15) all added their own contributions.

In the case of Marx (16) the criticism of partial treatment to the subject of technical change must be abandoned. To Marx the whole of his analysis rested upon the owners of capital being engaged in an unavoidable quest for the revolutionising of the methods of production. It was this process which would, it was predicted, ultimately bring about the downfall of Capitalism. As in the post-Richardian Classical analysis, Marx concentrated on the question of whether there was a labour saving bias in the process of technical change. His conclusion in the affirmative has been well substantiated by Blaug as the fundamental error in Marx' analysis.

Despite the limitations of the classical economists' treatments of technology, they do contain important insights into the process of innovation. Richardo, for example, whose treatment of technical change is characterized by a particularly inadequate perspective, did contribute, as Schumpeter (18) has noted, the insight that there accrued to management a temporary 'abnormal' profit when innovating. Schumpeter observes that what Richardo, and subsequently Marx, had observed as a peculiarity was in fact the most typical of all, the return on risk-taking.

In this overview of the classical treatment only the major names have been mentioned and only an indication of their contribution given. A detailed discussion would reveal further specific criticisms such as the above by Ricardo; the classical economists neglect of a theory of substitution, particularly important for the labour-capital saving nature of innovation argument has not, for example, been mentioned. Moreover, in considering only the leading figures lesser known writers, now often virtually forgotten and who did in fact contribute pertinent observations on the subject of technical change, are overlooked. Lauderdale and John Rae are two particular examples and, to a lesser extent, Knight and also Babbage (19).

ii. Neo-classical

The neo-classical era is both a far less productive and far less interesting one as regards discussion of technical change. This is primarily because it was considered that problems which had pre-occupied the later classical writers had been overtaken by events. It was considered that the Marxian prognosis of collapse, if not disproved, was certainly postponed for the forseeable future. The continuing productive achievements of capitalism made the labour displacing argument temporarily unfashionable and created a confidence in the ability of long term development to look after itself. Given that the productive powers of the Western economies appeared to be self generating, economic analysis turned to a consideration of the detailed short term problems, in particular that of distribution and the theory of the firm. The tools of analysis also changed; as Musson (20) observes, the neo-classical economists discarded the empirical socio-historical techniques in favour of the more rigorous theoretical and mathematical techniques which had proved so successful in the physical sciences.

This sterility regarding the treatment of technology was not universal. Musson [(21)] cites the example of the German Historical School as evidence of some continued interest in long term questions of change and development. Marshall,[(22)] too, still gave some attention to technical change but took the analysis no further than had already been achieved by classical scholars. An important exception is that of John Bates Clark [(23)] who represents the early American variation in neo-classical thought. Clark, however, was similar to the classical economists in that he had no theory of technical change per se, but dealt with the problem where he met it; in Clark's case in the theory of Distribution. Clark is particularly interesting because he attempted to temper the neo-classical 'static' (or 'natural' in classical terminology) analysis by introducing dynamic considerations. He used this technique in an attempt to show that a natural law of distributive justice existed whereby each productive agent received its just rewards. He introduced technical change as the dynamic factor which disturbed static, or 'natural', distribution patterns but in doing so re-allocated new wealth along lines predicated by static analysis.

Clark was, then, interested in the effects of technical change rather than technical change itself. His analysis, however, is rather too abstract to be of practical use in an empirical analysis. He does, though, make some concrete observations on the nature of innovation. He notes, for example, that the dramatic flow of inventions taking place at the time were only serving to alter the industrial structure and not to create unemployment. Clark's work, however, reinforced the neo-classical faith in long term development and, as such, militated against a re-appraisal of the role of technological innovation.

There was renewed interest in the long term problem of economic development in the inter-war years. Musson has probably correctly identified the cause as unemployment, which must have shaken faith in the idea of self generating progress and of distributive justice. The focus of attention regarding innovation was cyclical fluctuations. The leading exponent of a causal relationship between technological innovation and fluctuations in business profits was Schumpeter. Schumpeter was a product of the Austrian Subjectivist School led by Menger and Bohm-Bawerk. The subjectivist tradition had historically tended to ignore technical change, as in the case of Gossen and of Walras. (24) Bohm Bawerk (25) broke this tradition with his 'temporal' theory of capital which argued that production methods differed in the extent of their 'roundaboutness'. Bohm Bawerk argued that inventions could lead to more or less roundabout production methods but usually the former.

Schumpeter believed, like Wicksell, that the business cycle was generated by innovation. He used the three cycles identified by Kondratieff (sixty year), Juglar (nine and a half year) and Kitchin (thirty eight months) to illustrate his argument. "Business Cycles" (26), his most profound work, is the most important general treatise on economic development inasmuch that it contains detailed theoretical argument on the nature and role of technical change.

Ironically, the appearance in 1938 of "Business Cycles" did not make a major impact on the direction of economic thought because of academic pre-occupation with Keynes' "General Theory", which had appeared two years earlier. 'Keynesianism' took such a hold on fashionable intellectual opinion that the inter-war work on cyclical fluctuations was all but abandoned at what should have been its finest hour. The ideas which Schumpeter generated in the first half of the twentieth century including, in particular, one of his last works - "Capitalism, Socialism and Democracy" - still have a major influence upon thought on the nature and process of innovation, despite the demise of cyclical analysis. On the subject of technical change and long term economic development his influence can best be seen in the post-war writings of Kuznets (27).

iii. The Production Function

The work of Schumpeter was outside the mainstream of both micro-economic and macro-economic thought in that it did not conform to the increasingly widespread trend of examining economic problems by means of mathematical techniques. Mathematical approaches to the theory and problems of production found expression in the concept of the production function. The very earliest attempts to develop this type of analysis - those of Walras, Wickstead and Barone (28) - tended to ignore the changes caused by technology.

Theoretical production functions describe the connection between production and factor inputs. In its simplest form, the micro-economic production function describes the technical possibilities open to the firm from the particular combination of factors of production embodied in the production function. Because technical change causes an adjustment in the relationship between production and its combination of factors, technical change which is gradual and continuous therefore causes a 'shift' in the production function - the equilibrium between factors of production and output. Major technical change leads to the creation of wholly new production functions. The micro-economic production function is commonly used as a statement of the existing or 'given' technical possibilities and as the starting point of economic analysis, this is reconciled by saying that the state of technology is a non-economic factor and outside the control of the firm. This perspective is inadequate and militates against serious consideration of technology by economists. Technology cannot be treated as a non-economic factor because it is dependent on economic processes [29].

The existence of a macro-economic production function rests on the premise that it is analytically tenable to aggregate micro-production functions. A central problem which this raises is whether it is realistic to assume that heterogenous units of a factor of production, say capital, can find mathematical expression as if they could be reduced to some common denominator. Because a micro-economic production function represents an optimum equilibrium between the factors of production and output, it does not follow that aggregating the production functions for all the firms in an industry, or in an economy, will give an efficient allocation of resources for the industry or economy as a whole. Consideration of the fact that the resources of individual firms are typically allocated so as to oppose or frustrate the allocation of resources by other firms would seem to bear this criticism out. Attempts to come to terms with technical change and to represent its effects through the macro-economic production function have met with great difficulties. It has been pointed out that in the micro-sense technical change is such a diverse process it can be described more or less adequately by assuming that new production functions are arising all the time. This cannot be reconciled by macro-economic theory which assumes that aggregate production functions not only exist, but are shifting all the time (30). Macro-economics has tried to overcome the constraints on its analysis created by technical change by assuming that all innovation is 'neutral' i.e. it does not re-allocate the factors of production. Such a limiting assumption amounts to disregard of technical change because, by definition, technical change re-allocates resources.

The production function is such a central part of most University curricula that its proponents are amongst the widest known in economics. The theory has been developed very much as an academic debate in the leading economic journals with the principal figures being Cobb and Douglas, Hicks, Robinson, Kaldor, Salter, Solow and Samuelson.

iv. Growth Theory

Inter-war unemployment encouraged a return to the traditional problem in economics of long term development. Economists became concerned to explain the process of economic development and prescribe how it could be generated, principally by central government direction. This branch of economics became known as Growth Theory, and the term 'growth' itself is now, erroneously, used interchangeably with 'development' and 'progress' to describe the central or overall problem facing economics.

Growth theory is in fact very much an extension of macro-economic production function theory, the analytical tools and techniques of the two being very similar. Not surprisingly, therefore, many of the leading exponents of the production function are to be found in growth theory.

The principal analytical framework of growth theory has been the growth model. Growth models are based on measureable variables, any variable which cannot be measured therefore poses problems. This predilection for measurability has meant that growth theory has concentrated primarily on one factor, the rate of investment. Only a small band of economists, principally out of the Austrian Subjectivist tradition, have consistently denied the value of growth theory throughout the post-war period. The foremost of these, Hayek, restated in his Nobel prize - winning lecture [31], that the application of the techniques of the physical sciences to the study of economics had done the latter a great disservice.

The definitive study of the theory of economic growth is that by Hahn and Mathews [32]. Hahn and Mathews identify three categories of post-war growth theory, 1. Growth without technical progress - in these theories growth is due solely to population increases and/or capital accumulation. 2. Growth with technical progress and 3. The linear models such as those of Neumann and Leontief.

In the models of growth with technical progress much of the empirical work in the 1950s conceptually separated the effects of technical progress and capital accumulation eg. Kendrick (1961), Abramovitz (1956), Solow (1957) and Reddaway and Smith (1960). Hahn and Mathews note:

"The basic procedure is to estimate the contributions made to the

growth in output by increases in inputs to labour and capital over a period by multiplying the observed increases in inputs by observed factor prices (taken as a measure of marginal product) and deducting the result from the overall growth in output; the 'residual' is attributed to technical progress".
This approach was subsequently considered inadequate and a second branch of theory argued that the 'residual' was unsound because the effects of capital accumulation cannot be separated from those of technical progress. Because technical progress cannot be implemented without new kinds of machines it is not possible to speak of capital as a homogeneous entity. In this approach capital accumulation is regarded as the vehicle of technical progress i.e. technical progress is embodied in new machines.

'Endogenous', 'exogenous', 'neutral', 'non-neutral', 'embodied', 'disembodied', are examples of qualifications which growth theorists introduced to make their models either realistic or workable; the two however represented opposing poles and the legacy of the 'residual' is a testament to an inability to provide a satisfactory treatment of technical change.

It is the quandry in which conceptual approaches to technological innovation find themselves and, in particular, the lack of any fundamental agreement on the nature and process of technological innovation, which makes empirical work to formulate a basic understanding of what technical progress is all about so important. Until technological innovation is better defined by rigorous empirical work, the advance in theoretical conceptualisation is restricted. Only when an understanding of the real nature of technological innovation is arrived at will the very foundation of further conceptual model building exist. Not until this bridge has been crossed is it likely to be possible to then formulate theories which are open to empirical application and verification. In the words of Hahn and Mathews "We want theories that can be used as plumbers use a spanner - not simply abstract systems". Growth theories have not treated technological change in a manner that is either empirically applicable or verifiable. What is needed is industrial studies so as to come to grips with the real life realities of industrial innovation. When this is achieved it will then be possible to formulate theories which are likely to have both empirical applicability and verifiability.

It is the unsatisfactory treatment of technological innovation as a residual factor that has spawned the exclusive treatment of the subject in its own right in the last ten years or so.

v. <u>The Theory of Technological Innovation</u>

The burgeoning literature on technological innovation in its own right which has been emerging from British and American Universities in recent years represents an attempt to construct a "theory of innovation". The work is based on the concept of a 'process of innovation' which begins with discovery and development, is followed by the transition from pilot plant to full scale production, culminates in commercial exploitation, is then diffused throughout the economy until it is relegated to the status of routine, or is itself replaced. (This is closely akin to the idea of a new product life cycle). In examining the nature of innovation the literature asks such questions as 'what are the factors which give rise to innovation' and how can it be promoted and, similarly, what factors affect its rapid dissemination and how can these be promoted. The students of innovation in constructing a theoretical framework, therefore see a practical application for their observations in encouraging innovative behaviour by exposition of the factors which facilitate it.

The formulation of abstract principles regarding technological innovation has to date been based largely on the evidence of case studies, these studies characterise the early, tentative investigations. Case studies can vary in their approach but have tended to be historical narrative, while attempting to identify factors of importance. Johston and Gibbons [33] have noted that such an approach is appropriate in the early development of a field because of the scarcity of supportive theory and the general uncertainty about the nature of the phenomenon involved. Postgraduate theses on innovation surfacing from British and American Universities on an individual basis have tended to be of the case study type. These studies are generally limited in that they are unstructured and, also, lack a common methodology - which often prevents the collation and comparison of data. The case study approach has, however, become more refined and there are now examples of studies which employ a common methodology, cover a number of cases, and are therefore able to offer abstract ideas on the nature of innovation, an example is that by Langrish et al [34]. The Langrish study examined eighty-four industrial innovations which had won the "Queens Award for Industry". Although individual case studies may be of limited value because they often lack a theoretical nucleus, in aggregate they perform a useful role in helping to structure a field as similarities between different cases, perhaps fortuitously, present themselves.

A development from the case study approach, and an extension of the Langrish methodology, are the more sophisticated attempts to identify similarities in the case histories of a large number of innovations. The study by Myers and Marquis [35], project Sappho [36] and project Hindsight [37] are three examples. Myers and Marquis studied 567 innovations, project Sappho analysed twenty two paired innovations in chemical processing and twenty one in scientific instruments, whilst Hindsight was a study of thirty major weapons projects involving several hundred new technical developments. All three studies attempted to identify the factors which characterized successful innovations. These studies differed from earlier case histories also in that they employed quantitative measures to support their arguments.

A review of the dissertation index [38] of British and American Universities reveals that the majority of theses dealing with technological innovation do so within the framework of a chosen industry. These industry studies employ the case study methodology to examine the role of a single innovation, as with Engler [39], on the development of an industry or, more usually, the role of technical change in general within an industry, as the case with Gidwani [40]. These studies reflect the treatment of technical change by many historians, notably Nef [41] and Usher [42], who interpret economic history in terms of technical and mechanical developments.

Many of these industry studies relate technical change to a single other variable such as unemployment [43], production [44] or organization [45]. Such analyses may be 'causal' studies or simply 'association' studies, either way they represent a move away from the purely case study approach towards the more analytical hypothesis - based perspective.

From the unstructured case study material and from the testing of specific hypothesis about the nature of innovation have emerged a number of central themes which will ultimately be among the cornerstones of a theory of innovation. Two of these themes are the way in which innovations arise and, secondly, the way in which they are diffused. The question of the way in which innovations arise has primarily been approached by hypothesising that innovation is the result of 'technology push' or, alternatively, 'demand pull'. According to Schumpeter (46), change is inherent in the capitalist process and technological innovation is the vehicle of that change. Schumpeter has been criticized on the grounds that his analysis fails to show how innovations arise. Schumpeter would no doubt reject this criticism and cite the role of the entrepreneur who, driven by the profit motive, harnesses technical possibilities and carries them through to commercial exploitation. This act generates abnormal profits - the return on risk taking - which is the stimulus to imitators. However, it is true that Schumpeter does not detail the constituent elements of innovation as is meant by the contemporary idea of a 'process of innovation', and his definition of innovation as the act of commercial introduction has largely given way to the idea that innovation encompasses the whole process from discovery to end use. The argument that innovation is 'technology push' generated is based on the idea that the work of scientists, inventors and professional research and development departments generates its own output and technical possibilities without, often, any clear recognition of market needs. Work such as that of Jewkes (47) tend to support this theory. The belief that innovation was in fact generated by 'demand pull' was greatly strengthened by the aforementioned studies of success and failure such as that of Myers and Marquis. The most influential study supporting the demand theory was probably that of Schmookler [48], he observed that:

"The fact that inventions are usually made because men want to solve economic problems or capitalise on economic opportunities is of overwhelming importance for economic theory".

In assessing the state of the debate Freeman [49] argues that whilst there is still controversy the available evidence has tended to favour the demand pull theory. The essential weakness of the technology push argument is its implication that invention and innovation is exogenous to the economic process, which goes against recent work which argues for more serious and systematic treatment of innovation by economists. It also questions the whole rationale of the need for a theory of innovation.

The diffusion study is typically a further extension of the basic case study methodology. It was Schumpeter [50], again, who first drew attention to the importance of diffusion in his analysis of the role of the imitator. In the Schumpeterian scheme, imitators competed away abnormal profit and by their actions, in aggregate, created a depression. A depression in Schumpeterian terminology does not have the contemporary overtones of gloom, it was primarily a depression of business profits. Imitators reduced the market price of an innovatory product or process by increasing its supply. This downward price trend increased the numbers able to benefit by purchasing the innovation. Ultimately price creates an equilibrium between supply and demand at which point further production is unviable. In the Schumpeterian analysis, therefore, diffusion was the process by which the masses of people benefited in terms of real welfare from innovation. The effect of the diffusion process in reducing the real prices of goods and the factors of production which produce them ultimately creates conditions favourable to the exploitation of further technical advances.

This view of diffusion as the central agent in the innovation process is reflected in contemporary work. Nasbeth and Ray (51), for example, state:

"... even if a new process was used only by its innovator in his home country it might still be of great economic importance. But it is mostly through its diffusion to other companies, both nationally and internationally, that a new process becomes really significant."

The principal perspective in diffusion study is the rate of adoption and the factors which affect it. There are two alternative methods of measuring the extent of diffusion; Gold (52) has chosen the percentage of output of an industry accounted for by an innovation whereas Mansfield (53) uses the criterion of the number of firms adopting the process. Output measures would seem to be a better measure for total diffusion whereas the number of firms adopting may be more appropriate for, say, information flows. Each can be used to measure different things but, in general, output is probably the more useful. The number of firms adopting a process would, for example, have serious limitations in a Monopolistic situation.

An advantage of the diffusion study approach vis-à-vis many earlier case histories is that while they focus on a particular innovation, or group of innovations, they take the analysis beyond the framework of the innovating firm. In their study of the US Iron and Steel Industry Gold et al (54) found that a complex interplay of factors affected the adoption decision including technological uncertainties, cost and output projections, effect on undepreciated assets, and a whole host of external factors. The authors found a great diversity of diffusion patterns, suggesting that firms appraising newly available major technological innovations usually emerge with widely differing estimates of the desireability of immediate adoption.

A variation on the usual diffusion study is that of Pierce (55); Pierce studies a major innovation at the blast furnace stage of the American Iron and Steel Industry - the 'tachonite process'. This process involved the use of a 'synthetic iron ore', derived from tachonite rock in pelletized form as the input to a blast furnace as an alternative to the use of conventional foreign iron ore. He examines the viability of the tachonite process by breaking down the separate stages of production and distribution of tachonite. His analysis demonstrates that if the attractiveness of the process is assessed in terms of the alternative cost of tachonite compared to 'natural' iron ore then the pelletizing innovation would appear uneconomic, mainly because the pellets cost 25% more than the conventional ore. When the viability study of tachonite is extended beyond the iron ore industry, however, to include the blast furnace, transportation and ancillary stages of production and distribution the overall cost factors change decidedly in favour of the new process. This explains the success of the tachonite innovation. By exploring succesive 'ripples' caused by pelletizing Pierce draws attention to the interdependent and competitive nature of innovations in different industries:

"There is good reason to believe that the ripples still spreading out from pelletizing will interact with the complex pattern of ripples from other innovations, cancelling and reinforcing each other at numerous obscure points".

The evidence of Pierce's approach would seem to suggest that the only way to adequately explore the process of innovation is not through a case study or a diffusion or industry study, but through a systems approach.

In measuring the output attributable to an innovation, the diffusion study is in effect trying to apply an indicator of the impact of an innovation in an industrial context. The evidence from diffusion studies of wide disparaties in adoption rates suggests that individual assessments by firms of the likely repercussions of an innovation and the magnitude of its effects vary widely, indicating that either the knowledge of those likely effects or the means of measuring them is inadequate. Because of its close connection with diffusion studies this has been an area to which Gold has given considerable thought [(56)].

Gold found that management and engineering literature seemed to support the belief that innovations generate a distinctive pattern of cost effects, with particular types of innovations associated with particular cost reducing effects. However, in the six industries studies by Gold and his colleagues, actual cost adjustments over a forty year period did not conform with these expectations. Gold emphasised that innovation affected industry by producing physical effects: 1. Changes in physical inputs - quantity and quality, skills etc. 2. Changes in physical outputs - aggregate quantities, product variety, range of sizes/ grades, product characteristics. 3. Changes in physical aspects of production flows - techniques and characteristics of production flow eg. degree of integration. What is therefore needed is to "either assess the effects of past innovations or select which alternatives to promote in the future ... by penetrating beneath measures of aggregative effects to identify the distinctive outcomes likely to be associated with each (innovation)".

vi. Priorities in the Study of Innovation

There is a consensus that technological innovation has been such a neglected area that there is a general need for further research in all areas to gain a better understanding of what technical change is all about. In the words of Thirwell and Kennedy (57): "... the process of technical change is of vital interest. The reader of this survey may well have been struck by the apparent thinness of studies in this field as compared to macro-economic production functions.

... most of the research on technical progress is American. In Great Britain there is obvious scope for ... micro studies which seek to examine the process of technical change in a disaggregated way. At present the evidence in this country and elsewhere seems to be inconclusive on such fundamental issues ... If firm judgements are to be made ... there is no substitute for more and more research both in the testing of general hypotheses and of the case study variety ... research on the process of technical change - especially ... on the determinants of the speed of diffusion of innovations - could be very fruitful".

Gold [58] considers that the most urgent needs in the study of innovation centre around 1. The development of concepts of technological change and of measures of their effects which would facilitate more effective probing of the complex relationships to be identified and appraised. 2. The development of an analytical framework that will break open the 'black box' which, in conventional analysis, covers the stages of adaptive interactions between the initial impacts of innovations on physical inputs and their eventual effects on physical outputs and costs - and that will extend the analysis to consider further effects within and beyond the plant and firm. 3. The accumulation of an expanding array of empirical findings reflecting a variety of technological innovations and industrial contexts in order to replace the prevailing oversimplifications of popular mythology and ad hoc theorising.

Regarding the pool of case study material Gold says:

"... the analytical framework which has been focused primarily on the individual firm up to this point must be placed within the larger economic context composed of: competitors constituting the industry; the labour capital and material supplied from which the firm's inputs are drawn; the buyers whose tastes and purchasing power shape shifts in demand; and even broader influences exercised by competing industries and various levels of government".

In respect of the analytical problems found in a burgeoning area of study Gold notes:

"Input - output measurements are essentially a means of summarizing the results of complex activity systems rather than the basis for understanding or managing the intricate and usually highly specialised processes involved. Indeed such measurements are likely to become useful only as a result of progressive understanding of whatever system is of concern - for only in that way can we learn which variables are important for particular control or evaluative purposes. In short ... when we do not understand the system ... we cannot devise strategically significant measures of its 'productivity' or 'efficiency' or determine its production function".

vii. Literature Review - Summary

The foregoing review has examined the ways in which economists have, or have not, treated the subject of technical change. The examination has two purposes; to indicate the diversity of approaches and, secondly, to substantiate the challenge that these treatments had been inadequate. The central flaw of classical analysis was that it treated the subject of technical change in a piecemeal fashion within the structure of several different theories instead of treating it in its own right as a separate theory. Marx, on the other hand, made technical change the lynchpin of his theory but confined his analysis largely to one erroneous premise - that technical change contained a labour saving bias. Neo-classical economists tended to ignore technical change in a general neglect of problems of long term development. Schumpeter is the exception in that from the publication of Economic Development at the turn of the century until the publication of Business Cycles in 1938 he expounded, like Marx, the theory that the capitalist process was generated by the process of technical change. Schumpeter, however, in keeping with the Austrian Subjectivist School, clung to traditional analysis at a time when academic interest was centred on the use of the tools of the physical sciences in economics. Partly for this reason and also due to its publication being preceeded by the General Theory, Schumpeter's work failed to stimulate serious treatment of technical change by economists. Micro and macro production functions, and subsequently economic growth models, tended to pay lip service to the importance of technical change, but found fundamental problems in incorporating them within their models whilst retaining any resemblence to reality. As a result, mainstream economics has tended to treat technology as 'given' or 'exogenous' which is totally inadequate. Probably because of frustation at this sidelining of technical change in economic theory proper, in the last decade or so an attempt has been made to give serious consideration to innovation. This work is still in its formative stage and the corpus of knowledge assembled has been almost wholly through a case study type methodology. Increasingly, however, treatments of technical change are based on the formulation and testing of abstract hypotheses.

## 5. The Empirical Study

The nature of the hypotheses to be tested and the evidence of the literature review suggest that the most appropriate focus of study would be a traditional British industry with an unglamorous innovatory record. The UK can-making industry, while not particularly long established, is the archetypal mundane and unexciting industry. The end product of the industry would appear so humble as not to warrant serious academic consideration. The innovative record of the industry is, to say the least, superficially unspectacular. Not surprisingly, therefore, there appears to have been no consideration of the UK can-making industry as a suitable subject for the basis of academic enquiry. Review of the British and American dissertation index, again, indicates that the can-making industry has not been used as the object of empirical academic study. The objectives of the research suggested that the co-operation of industrial organizations was essential; in this respect the chosen area seemed to pose considerable research problems because the UK packaging industry in general and the can-making industry in particular, is noted for its 'closed' outlook. A consequence of this attitude within the industry is that can-making is completely devoid of generally available statistics about its operations. Metal Box, the UK's and Europe's leading packaging company, and the second largest can-maker in the world, exemplify this outlook. The success of the empirical research therefore hinged on penetration of this cloak of secrecy. It was considered essential that, in the absence of secondary data, the UK can-making industry agreed to a detailed examination of its innovative record, and its relationships with associated industries.

## 6. Summary and Conclusions

Technological innovation is worthy of academic study principally because of its role in wealth creation, or economic welfare; technical change offers the only plausible long term strategy for improving human welfare in industrial societies.

Despite a recognition by academics of the important role of industrial innovation, mainstream economics in the post-war era has sidelined technical change to the stratus of a 'residual' or 'exogenous' factor. Recent attempts to develop a distinct 'theory of innovation' have been severely restricted because the available studies are scanty, and they tend to be piecemeal. Hypotheses on the nature of innovation have inevitably been influenced by the methodology and character of the research which has been undertaken. This has predominantly been of the case study variety and has tended to focus on specific, major innovations, usually within 'glamorous' or high technology industries. This has encouraged the belief that innovation is essentially concerned with radical change, and that the most innovative firms and industries are those with a strong science base or those which are highly capital intensive.

This study examines the view that technical change is essentially a process, a stream of incremental innovation, with only occasional radical change. It argues that this change is evolutionary rather than revolutionary. It is argued that to understand the "process of innovation" one must foresake the single innovation, case study methodology and examine the development of an industry over time; innovation cannot be studied in isolation, an inter-industry or 'systems' perspective is necessary because change in one part of an industry affects another. The perspective adopted attempts to include those competitive and complementary activities upon which innovation in the focal firm or industry is likely to impact, and possibly produce a response, which in turn may generate a further change in the innovating firm or industry. One of the most important responses to an innovation, it is held, is the diffusion process. The extent to which an innovation is adopted or imitated is held to be the best measure of its worth.

To examine the above hypotheses a detailed historical examination of industrial development within a traditional industrial classification has been undertaken. The innovative record of the tinplate and can-making industries since the turn of the eighteenth century has been examined. The innovation that has taken place is analysed from the perspective of the technological needs of the industries themselves, and from the industrial structure from which they evolved. From this analysis it is hoped to gain insight into the nature of innovation and its role in industrial development.

REFERENCES


1. Schumpeter, J. A. "Business Cycles", Vols. 1 and 2, New York, 1939.

2. Littler, D. A. "Britain and Technological Innovation in The Management of Industrial Innovation", Liverpool, 1977.

3. Johnston, R. D., Gibbons, M. "The Interaction of Science and Technology", Dept. of Liberal Studies in Science, Manchester University, 1971.

4. Smith, A. "An Inquiry into the Nature and Causes of the Wealth of Nations", London, 1776.

5. Kierstead, B. S. "The Theory of Economic Change" Macmillan, 1948.

6. Cannan, E. "A Review of Economic Theory", Cass. London, 1964.

7. Robbins, L. "The Evolution of Modern Economic Theory", London, Macmillan, 1970.

8. Smith, A. Op Cit.

9. Ricardo, D. "On The Principles of Political Economy and Taxation", London, 1895.

10. Malthus T. A. "Principles of Political Economy", London, 1820.

11. Sismondi, J. C. "Nouveaux Principes d'economie Politique", Paris, 1819.

12. Mill, J. S. "Essays on Some Unsettled Questions of Political Economy", London, 1844.

13. Cairnes, "Essays in Political Economy", Macmillan, 1873.

14. Bentham, J. "Defence of Usury", London, 1817.

15. McCulloch, J. R. "The Principles of Political Economy", Edingburgh, 1825.

16. Marx, K. "Capital - A Critical Analysis of Capitalist Production", ed. Engels, F., London, 1874.

17. Blaug M. "Economic Theory in Retrospect", Heinemann, London, 1968.

18. Schumpeter, J. A. "History of Economic Analysis", London, 1961.

19. Schumpeter, J. A. Ibid.

20. Musson, A. E. (Ed.) "Science, Technology and Economic Growth in the 18th Century", Methuen, 1972.

21. Musson, Ibid.

22. Marshall, A. "Principles of Economics", London, 1890.

23. Clark, J. B. "The Distribution of Wealth", New York, 1902.

24. See Heertje A. "Economics and Technical Change", London, 1973.

25. Bohm Bawerk, E. Von "Capital and Interest", Macmillan, New York, 1890.

26. Schumpeter, J. A. "Business Cycles", Op Cit.

27. Kuznets, S. "Six Lectures on Economic Growth", Free Press of Glencoe, 1959.

28. Heertje A. Ibid.

29. Heertje A. Ibid.

30. Heertje A. Ibid.

31. Hayek, F. A. von. "The Pretence of Knowledge", Swedish Journal of Economics, 1975.

32. Hahn, F. H., Mathews R. C. O. "The Theory of Economic Growth: A Survey:" Econ. Journal, December, 1964.

33. Johnston, R. D., Gibbons, M. Ibid.

34. Langrish, J., et al "Wealth from Knowledge", London, Macmillan, 1972.

35. Myers, S., Marquis, D. "Successful Industrial Innovation", National Science Foundation, 1960.

36. Rothwell, R. et al "Sappho Updated", Research Policy, June, 1973.

37. Isensen, R. "Factors Affecting the Growth of Technology - As Seen Through Hindsight", Washington, 1968.

38. "Aslib Index to Theses: Xerox University Microfilms Dissertation Index 1861 - 1972, (Vol. 25 and 26).

39. Engler, G. N. "The Typewriter Industry: The Impact of A Significant Technological Innovation", University of California, 1969.

40. Gidwani, S. J. "Causes and Effects of Technological Growth , A Case Study of the Petroleum Refining Industry," Minnesota University, 1964.

41. Nef, J. "The Conquest of the Material World", University of Chicago Press, 1964.

42. Usher, A.P. "A History of Mechanical Inventions", London, 1929.

43. Williams, E. J. "The Impact of Technology on Employment in the Petroleum Refining Industry in Texas", 1947 - 1966, University of Texas, 1971.

44. Nyquist, R. S. "The Effects of an Important Technological Change on Production Patterns and Prices", University of Minnesota, 1964.

45. Bailey, R. M. "The Effects of Technological Change Upon the Productivity and Organizational Structure of the Medical Industry", Indiana University, 1964.

46. Schumpeter, J. A. "Business Cycles", Op Cit.

47. Jewkes, J. et al "The Sources of Invention", Macmillan, 1969.

48. Schmookler, J. "Invention and Economic Growth", Harvard U.P., 1966.

49. Freeman, C. "The Determinants of Innovation", Futures, June 1966.

50. Schumpeter, J. A. "Business Cycles", Op Cit.

51. Nasbeth, R. "The Diffusion of New Industrial Processes".

52. Gold, B. "Explorations in Managerial Economics", Productivity, Costs, Technology and Growth", London, 1971.

53. Mansfield, E. "The Economics of Technological Change", Norton, 1968.

54. Gold, B. (Ed.) "Technological Change: Economics, Management and Enviroment", Pergamon, 1975.

55. Pierce, W. S. "The Effects of Technological Innovation: Exploring Successive Ripples", in (54).

56. Gold, B. "Explorations in Managerial Economies", Op Cit.

57. Thirwall, A. P., Kennedy, C. "Surveys in Applied Economics: Technical Progress", Economica, March, 1972.

58. Gold, B. "Technological Change: Economics, Management, and Enviroment", Op Cit.

# CHAPTER II

## HISTORICAL BACKGROUND

## Section A: The Technology of Tinplate Manufacture 1810-1939

### 1. Introduction

The established method of manufacturing tinplate in Britain at the end of the period under discussion differed little in principle from that employed at the time of the birth of the canning industry in 1810. At that time Britain had not only an indigenous tinplate industry producing 150,000 boxes (112 sheets of 20 in. x 14 in. per box) of the material each year, but was also exporting significant quantities to the continent of Europe. This was a noteworthy achievement in view of the fact that it had been found necessary to institute a protective tarrif against imports from Germany in 1706, following a number of abortive attempts to successfully manufacture the product in England and Wales.

Although the tarrif of 1706 may have facilitated the foundation of a home tinplate industry, the competitive strength of that industry was due to the technological lead taken in Britain. The original method of manufacturing tinplate for tinning was to heat the prepared iron bars in the forge, to mechanically hammer them into plates and, finally, to hand beat them to a smooth finish using a tilt hammer. This final operation required the benefit of experience, a factor which would have seriously limited the potential early growth of the domestic industry. The production of smooth, flat plates from iron was not, however, a problem peculiar to the tinplate industry. This same problem had been overcome in other branches of the iron trade by the development of the water-driven rolling mill; the application of this British innovation to the manufacture of blackplates overcame an important constraint on the British industry. This development, which took place in South Wales in 1728, represented the first mechanization of tinplate since the mechanical hammer.

The rolling of iron slabs, or 'tinplate bars' as they were known, was followed by a number of accommodating innovations. The sequence of operations which hot bar rolling instituted became known as the 'hot-pack' process. Despite the slow but reasonably continuous development of this production method into the 1950's it remained recognisably the same. It is, therefore, principally with the evolution of the hot-pack process that we are here concerned.

In view of the modifications which the process underwent it is not possible to give a detailed description of the hot-pack process. Moreover, developments proceeded throughout the industry at an alarmingly uneven rate and with critical diffusion problems. At any one time there was, consequently, an enormous variation amongst the existing practitioners. However, if one takes the 'hot-pack' process to refer to the complete sequence of operations from the forge through to the final despatch of plates, and not only to the operations undertaken to produce the required gauge of base material, then it becomes analytically tenable to consider the 1810-1939 hot-pack period in Britain as in two phases. The death knell of the first period was sounded by the introduction of steel in place of iron and by developments in the end uses of tinplate. These production and marketing factors exerted pressure for change on the technology of tinplate manufacture. The first of the two phases of the hot-pack period began its demise around 1870. Within the second epoch it is necessary to consider the United States' experience; in the first quarter of the twentieth century the Americans were more concerned with the replacement rather than the improvement of the hot-pack method. This development did not materialise in the UK until 1938, but since this was a straightforward case of international technological diffusion one must, to understand the background to post-war British developments, examine the American origins.

## 2. 1810 - Circa 1870

### 1. Hot Hand-rolling

One of the clearest differences between the manufacture of tinplate in the first half century or so of can-making and that subsequently practised was in the organization of production. In the earlier period the making of tinplate was considered to commence with the actual production of the 'tinplate bar' from wrought iron. This is as would be expected since the charcoal forge or puddling furnace in which the iron bar was produced was usually on the same site and attached to the rolling area. Similarly, the area in which the plates were fabricated was adjoined to the section in which the coating of tin was applied. The manufacture of tinplate was, therefore, a predominantly vertically integrated operation undertaken in three stages. The forge and the rolling area comprised the 'mill' and the final stage the 'tinhouse'.

Despite the apparent homogeneity of the product, commercial tinplate is not, nor has it ever been, produced to any pre-determined specification. The tinplate produced by the hot-pack process was to satisfy specific customer requirements and was not despatched from existing stocks. Consequently, the first stage in the hot-pack process was the production of iron bars of a length commensurate with the final dimensions required in the plate. From the long bar form in which the iron was forged were cut the so determined short lengths which were then passed on to the rolling mill.

The mill consisted of a number of cast iron mill-rolls arranged in sets of two. Each set of rolls operated in a fashion not unlike the early hand operated clothes wringer. The rollerman took the iron bar and passed it through the first set of rolls. This was continued until the bar was converted to a plate of the required dimensions. This concluded the first stage of the rolling operation. The iron was then re-heated to its original temperature in the furnace and re-rolled; on completion of this second working the 'pack' operation commenced. The iron plate was folded over and flattened by the use of doubling shears. The "Doubles", as this folded plate was known, was then re-heated and the process of wrestling the plate through the rolls re-commenced. This further extended the plates and reduced their gauge. A further doubling was then performed and the uneven ends cut off by the use of squaring shears. If the required gauge had by then been attained the pack was complete and ready for final working in the finishing roll. Usually, however, the process of heating, rolling, doubling and shearing was continued until 'eights' were produced. The packing stage of the hot-pack process was then complete apart from the final separation of the sheets. At this stage holes or surface imperfections would appear on the plate if there was undue difficulty in separation; indeed, the plates were sometimes all but welded together. To reduce the likelihood of this eventuality the rolled and re-rolled sheets would be separated before each bout in the furnace.

The production of good quality blackplate of the desired gauge by such mechanistic methods was not the stultifying task it might seem. The process required considerable physical strength at many points, and where this was not so women or boys were often employed. Estimating the amount of rolling required to convert the iron to blackplate with the minimum wastage or 'wasters', as below standard plates were termed, was the critical operation in the mill and one that necessitated considerable skill and experience.

The blackplate produced by hot rolling required further treatment before it was in a suitable condition to take its coating of tin. Before transfer to the tinhouse it was necessary to improve on the characteristics of the material and also to alleviate some of the undesirable effects of the hot rolling.

ii. Pickling

The last of these preparatory processes was that of 'pickling'. Even by 1810 this term, like 'blackplate', was an anachronism. In past times the separated pack had been immersed in fermented barley water to remove rust, the process thus being referred to in the trade as pickling. In the early decades of the canning industry, while the problem of a film of scale and oxide still remained after the plate had been fabricated, barley water had been dispensed with as a form of treatment. Dilute Muriatic acid was adopted as a pickling agent in the second half of the eighteenth century, whilst in 1829 a sulphuric acid pickling process was patented by one Thomas Morgan. The plates were individually placed into troughs containing this acidic solution and left to steep for about ten hours. They were then transferred to a second trough containing a mixture of sulphuric acid and water and agitated for about an hour to acquire a bright surface free from black spots. The pickled plates were then put in pure water and scoured with hemp and sand, followed by a final rinsing in clean water.

iii. Annealing

The brittle temper of the material produced in the rolling mill is illustrated by the frequency of the breaking of plates, this was always a problem during the early hot-pack period. To help impart the ductile qualities necessary for subsequent fabrication of the plate into useful articles it was necessary to 'soften' the material. The technique by which this quality is imparted is known as annealing. Annealing was an intrinsic part of the hot-pack process but its execution became increasingly elaborate over the years. The earliest method had been to heat the plates and then simply allow them to cool on the mill floor. However, as small grain size became recognized as important to good surface finish so box annealing became commonplace. This, basically, involved slowly heating batches of blackplate on iron stillages, followed by equally gradual cooling in a stationary furnace.

iv. Cold Rolling

To further produce the uniform characteristics required in the material the blackplate was subjected to its third and final preparatory treatment, cold-rolling. This process was not unlike the hot-rolling performed earlier, nor did the rolls themselves differ greatly in appearance. The aim of cold rolling was to iron out any surface irregularities. To achieve this it was essential that the rolls also be maintained to a smooth, highly polished finish. As in the previous hot-rolling several passes were necessary, though in the cold rolling process an extra, third, set of rolls was used.

v. White Annealing

The cold working, unfortunately, counteracted some of the qualities imparted in the original annealing, partially returning the plate to its previous hard condition. To reintroduce this lost ductility the plates were given a second annealing. This was largely a repetition of the earlier treatment except that the temperature and the length of time required in the furnace were both reduced.

vi. White Pickling

During the final annealing process oxide film may have re-appeared on the plate. To remove any such contamination the blackplate was given a final pickling. The reduced nature of the problem is again reflected, this time in the lower concentrate of acid used. These last two finishing processes were known as 'white' annealing and 'white' pickling to distinguish them from the earlier 'black' annealing and 'black' pickling; the nomenclature may have been intended to suggest the appearance of the blackplate at each stage or, perhaps, the intensity of the differenct treatments.

vii. Cleansing

After pickling the plates were washed with clean water and then deposited in a water bath, or trough, where they were left fully immersed until conveyed to the tinhouse.

viii. Tinning

Only one method of tinning was used in Britain throughout the 1810-1938 period - the process known as 'hot-dipping'. The subsequent innovations which led to the demise of the manufacture of tinplates in pack form did not in themselves technically necessitate the abandonment of the hot-dip process; as a result the two processes have retrospectively been regarded as distinct. In the nineteenth century, however, the two were regarded as different stages of the same operation.

In the earliest recorded manufacture of tinplate in Bohemia in the thirteenth century the material was produced by dipping the prepared plate in molten tin. In the pericd 1810 to 1870 the hot-dipping technique retained most of its earlier characteristics, despite the accumulation of minor changes. The tinning process entailed a multi-stage operation involving a number of different pots all of which contained, in the main, grease, molten tin or some mixture thereof into each of which the plates were individually dipped with the help of tongs. For the moment, one may summarise hot-dipping as the sequence of operations by which was effected the alloying of tin with iron, the annealing of the alloyed plates and, finally, the cleaning of those plates. The thickness of the tin coating deposited depended primarily on the length of time the plate was left in the pot of hot grease. The extent of the excess of tin on the plates was somewhat reduced by wiping them with a hemp brush on emerging from the tinpot. As practised this process relied wholly on hand labour; it produced a plate whose tin coating was excessive for the vast majority of purposes, if not all, for which it was required; a coating whose surface was never uniform; and a coating whose application was time consuming. The actual tin content of tinplate at this time was over ten per cent.

ix. Summary

The above description of the hot-pack process between 1810 and 1870 includes all the essential aspects. The sequence of operations described; heating rolling shearing, packing, black pickling, black annealing, cold-rolling, white annealing, white-pickling and tinning remained as constituent elements throughout the 1810-1939 era. To synthesize the art of tinplate manufacture over a sixty year period, as has been attempted, is bound to suggest a sharper break in an historical trend than was in fact the case. If one were to go further and cite one single salient feature of the art during the earlier period it would have to be its manual nature.

## 3. C.1870-1939

### i. Introduction

The British tinplate industry between 1870 and 1939 may be said to be characterized by the 'mechanization of the hot-pack process'. This description must be interpreted in the context of the definition of 'hot-packing' as the complete tinplate making sequence. From the technical point of view hot-dipping was the crux of the tinplate making operation. Even allowing for earlier comment on the tilt hammer, the actual depositing of the tin onto the finished black-plate had always been the most technologically demanding operation involved. An inability to successfully tin sheets had been a major factor in the failure to establish a British tinplate industry in the seventeenth century. If the quality of hot-dipped plate had remained at its pre-1870 level of sophistication it would have effectively barred the growth of a can-making industry using mass production methods which was also based on tinplate. There is, consequently, good reason for regarding the deposition of the tin onto its ferrous base as the kernel of the tinplate making process.

A clear account of the technical change which took place after C.1870 may be achieved by summarising the developments in their manufacturing sequence, even if somewhat at the expense of the chronological order.

### ii. The Steel Base

The break in trends in tinplate bar production that occurred around 1870 was the introduction of steel. Iron was first replaced by steel in tinplate manufacture in 1856 when the experimental Bessemer steel making process was introduced by Bessemer, Phillips and Smith of Llanelly. This, however, proved to be premature birth and the tinplate produced from this trial steel only served to create an unfavourable climate of opinion as regards the potential of steel as a base metal for tinplate. A tinplate industry based on steel had to wait until 1870 when Sir William Siemens introduced the Siemens open-hearth steel making process at his Llandore works in South Wales. This may be regarded as the first successful commercial exploitation of steel in tinplate. Siemens' steel quickly became recognized as an acceptable substitute for high quality charcoal iron in tinplate manufacture. Although Bessemer steel became available for tinplate manufacture in 1880 the tinplate manufacturers opted, by and large, to use open hearth steel. Bessemer steel was regarded as a less satisfactory product by the tinplate makers but was used to replace the lower quality puddles iron in tinplate manufacture. Siemens steel, which did not entail erecting a blast furnace, required a comparatively small capital outlay and did not necessitate large scale production, was the salient factor in the complete ousting of iron in tinplate by 1900.

In the evolution of the hot-pack process the introduction of this mild steel was most important as regards the organization of the three integrated production compartments. With the success of steel the forges and furnaces adjoining the South Wales tinplate works became obsolete. Since steel was produced at its own locations a separation in the tinplate industry was effected. By 1900 it was the norm for tinplate to be produced by units independent of steel or iron-making facilities.

iii. The Rolling Mill

As a result of the separation of steel making from tinplate making in the last decades of the nineteenth century, the rolling mill came to be regarded as the first stage in the manufacture of tinplate. This was the only major innovation concerning the rolling mill until the very end of the period. There was, as is often the case in all manufacturing processes, minor improvements in the utilisation of existing methods of production. One invention applicable in the rolling mill to be made in the late nineteenth century which was considered highly promising at the time was a mechanical device for separating the pack of blackplates. This particularly troublesome operation was also the object of further mechanical ingenuity throughout the first half of the twentieth century. However, the original Williams and White invention, nor any of those that followed it, ever gained widespread acceptance. The use of steam power in tinplate works, which was first adopted at Siemens Llandore works in 1850, was rapidly diffused in the late nineteenth century. This innovation affected the location of new tinplate works rather than the methods of production.

The method of preparing the rough blackplate for tinning, while it was not subject to any revolutionary change, was significantly improved upon. It has already been shown that these operations had been the subject of 'enhancement' type innovations ever since the establishment of tinplate making in Britain. Such developments had included, in particular, the invention of the 'Grease-pot' by Moseley in 1745. In 1850 steam heated pickling vats were first introduced to replace the heavy leaden pots hitherto used, but the innovation which heralded the mechanization of the pre-tinning department was that of the pickling machine in 1874. This machine, which replaced hand pickling and subsequent cleaning, allowed the plates to be treated quickly and in bulk. The central device of the pickling machine was the steam powered cradle, operated by a valve. This was so called because of its rocking motion which imparted movement to the vertically stacked plates thus allowing all round immersion in the acid and water baths. The machine also economised on the consumption of acid. White pickling was done in like fashion in a second machine. The pickling operation took about five minutes and used hydrochloric acid.

The annealing operation was also improved during this period by both mechanization and also by furnace design. Previously the stillages of tinplate were manhandled in and out of the furnaces. A variety of mechanical methods were invented which led to the displacement of labour from this operation. The Dressler muffle furnace was the first advance on stationary 'in and out' annealing in which the plates were deposited in the furnace and withdrawn ten or twelve hours later. The Dressler furnace was built over a railed way on which bogies of tinplate would be mechanically pushed in. By generating maximum heat in the middle of the furnace each consignment of plates, successively pushed along by the following bogie, passed through the full cycle of heating, holding and cooling and emerged annealed.

iv. The Tinhouse

The centre of the break in trends in tinplate manufacture, i.e. excluding the production of the base metal, during the 1870's was to be found inside the tinhouse. Mechanical change in the tinning department tackled all the failings of established hot-dipping mentioned earlier. The introduction of machines to apply the coating to the blackplate had profound effects upon the organization of the tinhouse operation, but its most important feature was the improvement it produced in the quality of the tin layer. The tinhouse revolution begain in 1866 when the Morewood tinning process was introduced. This innovation embodied a number of significant changes in hot-dip practices, but its outstanding feature was the coating rolls it incorporated. These rolls were placed in the grease-pot thereby controlling the crucial variable, the duration of the tinning operation. The Morewood process also aided the fusion of the base metal with the tin by using palm oil instead of grease in the first stage of its operation.

The Morewood innovation was followed by further improvements such as the Lydney duplex pot which increasingly mechanized, while never basically altering, the hot-dip process. The Lydney duplex pot was based on the Morewood principle but by employing an extra pot apparently enabled the speed of production to be doubled. Morewood's palm oil was itself subsequently replaced as a tinning flux by zinc chloride. This changeover in turn facilitated the adoption of the fully mechanical tinning pot the first of which, the Taylor and Leyshon pot, was introduced in 1882.

The final treatment given to the plate in the tinhouse is the cleaning and dusting performed on exit from the tinning machines. Here again mechanical devices were introduced to replace hand labour.

The impact of this proliferation of innovation on the tinplate industry in the last quarter of the nineteenth century is borne out by the record of the industry.

TABLE I

| Year | Production (Tons) | Value | Average Price (£) |
|---|---|---|---|
| 1867 | 78,906 | 2,060,410 | 26.11 |
| 1872 | 118,083 | 3,806,973 | 32.24 |
| 1877 | 153,226 | 3,033,126 | 19.80 |
| 1882 | 265,039 | 4,642,125 | 17.51 |
| 1887 | 353,506 | 4,792,854 | 13.56 |
| 1881* | 448,379 | 7,166,655 | 15.98 |
| 1892 | 395,449 | 5,330,216 | 13.48 |
| 1893 | 379,172 | 4,991,300 | 13.16 |
| 1894 | 353,928 | 4,338,786 | 12.26 |
| 1895 | 366,120 | 4,239,193 | 11.58 |

** American import tarrif set.

v. Consolidation

The theme of the technical activity in the later decades of the nineteenth century continued throughout the early decades of the twentieth. Outside the tinplate industry the steel base, which in itself contributed to better hot dipping, was continually improved upon. In the mill and tinhouse too the machines were upgraded and added to. The initiative in technical development, however, was taken by the burgeoning American industry and throughout the first half of the century the technological gap between Britain and the United States widened. The mechanical 'leaf' doubler was invented by L.C. Steele in 1911 and commercially exploited in America four years later. The notable Welsh invention of this time was the automatic combined feeding, pickling, swilling, tinning and cleaning machine of Thomas and Davies. In America further technical developments proceeded in rapid succession and included stoker fired coal furnaces, continuous pair and pack furnaces, mechanical catchers and pilers, and an assortment of conveying tables. Two reasons can be advanced why these developments were pioneered in the United States. The first was the intransigence of the Welsh tinplate worker toward labour saving improvements and his general liking for restrictive practices; the Welsh tinplate industry was the first and most highly inionized in Britain. The second argument concerns industrial structure. The Welsh industry was characterized by a plethora of tinplate works in marked contrast to its American counterpart. Within seven years of the establishment of the US industry most of the small independent mills were banding themselves together into large combines. It is this factor which has been cited as principally responsible for American world pre-eminence in the iron and steel industry in general and the subsequent revolutionary innovations in sheet and tinplate manufacture. This concentration had important implications for the last phase of development in the 1810-1939 period - the hot-strip mill. Before turning to this development one may summarize the break in trends which occureed around 1870 as the introduction of steel and the consequent 'shortening' of the tinplate manufacturing sequence and, also, the mechanization of many mill and tinhouse operations.

## 4. The American Tinplate Revolution

### i. Introduction

While the Welsh industry was falling behind its new competitor across the Atlantic within the parameters of traditional tinplate technology, the American manufacturers were busily exploring the possibilities of a new process which had the potential to completely shift the existing technological horizon. This process was the move to the continuous production of lengths of steel in 'hot Strip mills'. Although experiments in continuous production were being undertaken quite widely, the first tangible indicator of things to come appears to have occurred in 1902 when steel was produced in strip form in Pensylvannia. This was not a continuous process, and narrow as opposed to wide strip was involved. The operation was not a commercial success and was abandoned after two years.

The hot strip produced at a number of locations in the United States during the first quarter of the twentieth century continued to be too narrow to allow the further reduction in gauge necessary for tinplate uses. American mill-owners remained convinced however, that continuous strip was desirable for tinplate production and, more importantly, that the new process would, when perfected, be economically suited to American manufacturing and market conditions. (The confidence of the tinplate owners was not, however, the main impetus to the development, this came from the rapidly expanding motor-car industry).

Whatever the desires of tinplate makers the successful commercial exploitation of hot strip for tinplate production was reliant on further developments in a wider industrial context. General advances in the technology of mechanical and electrical engineering particularly in the areas of rolls and bearings, lubrication, control and automation would have to be made first. These developments came together in the mid-1920's to facilitate the high speed production of continuous hot rolled strip and its further reduction to tinplate gauges.

The actual culmination of this quarter century of development materialised in 1924 and 1926 when continuous wide hot strip was produced in Kentucky and Pensylvannia respectively. This was quickly followed in 1927 by the first production of hot rolled strip for tinplate manufacture on the Republic Steel Corporation's mill at Warren, Ohio. This, in turn, was followed in the same year by the first production of hot strip by a tinplate manufacturer at the works of the American Sheet and Tin Plate Company, Gary, Indiana. These units rolled steel slabs unlike unsuccessful predecessors which had continued to use tinplate bars. Despite this success these advances continued to be more pertinent to other steel using industries because hot strip was not in its present form suited to use for tinplate. The strip still had to be cut into sheets and hand rolled on the conventional hot mill to reduce it to tinplate gauges.

ii. The Hot-Strip Mill

The hot-strip mill in itself only replaced the preliminary hand rolling operations but the chain of events it either accelerated or set in motion constituted a complete revolution of both the steel base manufacturing sequence and the tinplate industry. Prior to the two installations of 1927 all tinplate was still made from the bar by hot-pack rolling in two-high hand mills, batch pickled, box annealed and coated by hot dipping. The hot strip mill signalled the beginning of the continuous production of tinplate which would give a product of lower unit cost and incomparably greated uniformity and reliability.

Exactly where the tinplate manufacturing sequence is considered to begin under the continuous method is determined to some extent by the degree of integration of the production operations and locations. Strictly speaking the sequence begins at the blast furnace stage where the pig iron and other materials are converted into steel. Since only a minority of the output of these primary units goes forward to be made into tinplate it is more realistic to consider the hot strip mill where the steel ingots first enter the rolling process as the initial operation, (this is less applicable to the UK situation).

At the entry to the rolling mill the large ingots of around five tons weight were first rolled in a reversing mill to slabs of around 5 in. x 36 in. The slabs were then heated in recuperative pusher type furnaces before being passed to the basic producing unit of the process of the hot strip mill for further reduction towards tinplate gauges. The rolls in the mill varied between installations, but always incorporated was a series of four-high rolls the number and arrangements of which was optional. Every mill, though, performed two basic operations - roughing and finishing. The roughing section may only have consisted of one mill in some of the very early plants but three - six was the norm. In the roughing mill the slab was reduced to something around 1 in. in gauge whilst its width was controlled. If a number of sets of rolls was used to accomplish this reduction then the elongated slab was held on a holding table between each successive mill stand. The strip was then passed through the finishing stands of similar design and typically six in number at which it was given its final hot reduction. Strip passed through these mills continuously i.e. there was no holding table between the rolls. The additional reduction was less at each successive mill stand, this was accomplished by reducing the duration of time spent in each stand. To achieve this necessitated a complicated synchronization system if the strip was not to buckle between stands. On exit from the final stand the strip was allowed to cool before being sheared or coiled. The final dimensions of the hot rolled band varied according to the design of the installation. The hot strip mill built at Butler, Pensylvannia in 1926 rolled a band of 36 in. wide, the following two at Gary and Warren rolled widths of 26 in. and 42 in. respectively. The thickness and lengths of the band also varied, a range of .07 to .1 in. covered the typical range, whilst the Gary Tin Mill prodcued a band 180 ft. long. These early mills aimed at a maximum throughput of 1000 ft. per minute, with a rolling capacity of 100 to 125 tons per hour.

iii. Cold Reduction

As long as it remained necessary to feed hot rolled strip through the old hand mills to reduce it to final tinplate gauges, the advantages of the new method to the tinplate producer were dubious. The substitution of the continuous cold reduction process for the hand-mill method was the most important development in the manufacture of tinplate for two hundred years, i.e. since the tilt hammer was replaced by the hand mill itself.

The successful reduction of the hot rolled band to tinplate gauges in a continuous operation was based on the back-up roll principle first patented in 1863. This patent referred to the fact that the smaller the diameter of the roll the less is the pressure required to produce any given reduction. A four-high mill is capable of exploiting this principle by employing a larger back-up roll to provide the necessary resistance to deflection. For small to medium outputs a single stand reversing mill may be used for cold reduction; to serve the outputs of the continuous hot strip mill a multi-stand tandem mill is usually favoured. The first such mill designed to manufacture tinplate was commissioned by the Wheeling Steel Corporation at their Yorkville, Ohio, plant in 1929. In 1933 the American Sheet and Tin Plate Company installed the first single stand four-high reversing mill for tinplate making.

The throughput of these mills was comparable to their hot-strip counterparts.

Cold reduction radically altered the method of manufacture but it also represented a major product innovation. Not only did it effect gauge reduction but improved the shape, flatness, surface finish and mechanical properties of the plate. It also led to greater shearing accuracy, reduction of waste and a major reduction in the frequency of 'wasters'. An important impact of the adoption of cold reduction was felt at the blast furnace stage; in the hot-pack process it had been necessary to use steel having a phosphorous content of between .07 and .10 per cent if sticking or welding of the plates was to be contained. As this was not a problem in the cold reduced product it was possible to use lower phosphorous steel. This is inherently softer, more ductile and has increased corrosion resistance.

iv. Ancillary Technical Developments

The repercussions of a fundamental change to the kernel of any major manufacturing process are likely to be considerable, this was certainly so with hot strip rolling and continuous cold reduction. Over and above the implicatons for the blast furnace stage the new rolling methods generated accommodating, complimentary and parallel innovations within the tin mills. The accommodating category refers to those additional processes which are actually necessary to exploit an innovation. An obvious necessity was the adoption of welding techniques to join the hot rolled bands into continuous coils and, similarly, improved shearing devices for cutting the coils up into plates for hot dipping, and also coiling and uncoiling devices. A further requirement was the removal of the hard and brittle oxide scale after hot strip rolling so as to avoid damage to the surface of the plate during cold reduction. This involved the pickling of the tinplate in coil form. Hot strip pickling of narrow gauge plate had been successfully undertaken as early as 1913 and by the advent of cold reduction was developed to a high degree of commercial sophistication. The introduction of cold reduction simply involved a piece of technoligcal transfer within the steel using industries.

Complimentary innovations refer to developments adopted to enhance a new process rather than as technical pre-requisites. The distinction between the two types may often be blurred, particularly when commercial criteria are included. If continuous annealing had been introduced along with continuous rolling and pickling this would perhaps have been a case in point. In 1930, however, annealing technology was somewhat behind the overall trend in the industry. The old stationary furnaces with the sealed boxes of cut sheets which were rolled in and out - or through - were only just being replaced by the portable, radiant tube furnace. In this newer annealing method coils were stacked three high on steel bases and covered with a light steel tube, 'or bell'. The bell was then sealed at the base with sand. An outer heating cover was then placed over a row of these bells and heat introduced. A controlled atmosphere was produced in the inner bell which prevented oxidisation and facilitated the production of a steel surface of good tinning quality and adequate corrosion resistance. The newer process of heating, holding and cooling could still take several days to complete its cycle, and so counteract the work hardening involved in the heavy cold reduction. The principal advantages of the newer method were in fuel and maintenance savings. It was not until 1936 that the solution to the time consuming batch method was first introduced by Crown Cork and Seal at Baltimore. This was the tower type continuous annealing furnace. This was not adopted to any extent until the post-war period.

A further complimentary development was that of 'temper rolling'. Although this was a new term which came into being with cold reduction it did not represent an additional manufacturing process. It referred, rather, to the comparable cold rolling element of the hot-pack method the purpose of which was to impart the final characteristics to the steel base. Its desirability arose because it handled coil continuously, it was not, however, an accommodating innovation like continuous pickling because the operation could have been performed by a hand mill after the coil had been cut. In temper rolling the coil was passed through two stands of four-high tandem mills. As apparently with all the process innovations introduced in the wake of the hot strip mill temper rolling had a significant product dimension; as well as the surface properties imbued in the plate temper rolling introduced for the first time the ability to control the hardness of the steel base exactly.

Just as the hot strip mill and cold reduction had their impact on the manufacturing sequence so the accommodating and complimentary innovations set up secondary ripples of effects. Hot strip pickling and temper rolling were such precise, controlled operations that they dispensed with the need for white pickling and white annealing, thus effecting a shortening of the manufacturing sequence. In the American context the cluster of innovations surrounding the hot strip revolotion reduced tinplate making to nine stages.

1. Rolling of steel ingots to slabs
2. Slab heating
3. Hot strip rolling
4. Hot strip pickling
5. Cold reduction

6. Annealing

7. Temper rolling

8. Coil preparation and shearing

9. Hot dip tinning.

v. Wider implications

Cold reduction offered tremendous advantages due to economies of scale but it was also very capital intensive and greatly increased the optimum plant size. It became desirable as a result to construct fully integrated steel works to exploit these economies. The concentration of ownership in the American Tinplate industry put it in a strong position to adopt these innovations and to construct fully integrated units. When cold reduction was introduced there were six hot strip mills in the United States, by 1939 there were twenty eight. By 1939 every major American producer had installed cold reduction mills. Cold reduction also stimulated parallel, or competitive, innovation in the hot-pack sector because initially many producers did not possess the necessary technical expertise to convert immediately to the new technology. These producers therefore set about and achieved considerable improvement in their traditional methods by embracing what were in the context of the hot-pack process radical changes. The increased efficiency they obtained was principally due to thermal and mechanical alterations. Lower metalloid steel was also given more prominence and although not comparable with the cold reduced alternative did lead to considerably improved standards in the hot-pack product. The traditional methods lingered on in the US into the post-war period but this was not due to any hopes of ultimate competitiveness.

5. British Developments

Although Britain's first strip mill was not built until 1938 the developments within hot-pack technology and a slow move toward concentration did have their impact. In 1905, for example, the number of employees in the industry was 19,800 and the tonnage of tinplate produced 664,300; in 1939 the number employed had risen to 25,000 and the tonnage produced increased to 929,000 tons. A significant but hardly dramatic increase in output per head of 10.7 per cent.

The procrastination in the development of a strip mill capacity was not out of ignorance of the technology due to American secrecy, visits across the Atlantic to see the new mills were commonplace. The major problem was a doubt as to whether the new methods were suitable for UK conditions i.e. whether the British market justified a continuous wide strip mill. Despite concentration in the steel industry and the rise of Richard Thomas and Co. as the dominant firm in the tinplate sector the Welsh industry was far too slow to reorganize to meet the changing domestic and world situation. The eventual construction of the Ebbw Vale hot strip mill with an annual capacity of 200,000 tons of tinplate still left the Welsh industry in a perilous position to meet the post-war demands of the dynamic British can-making industry.

B. <u>The Technology of Can Manufacture (1810-1939)</u>.

1. <u>Origins</u>

Although man has been only too familiar with the consequences of micro-organisms in food for thousands of years, up until comparatively recently he never understood the cause of this deterioration. It follows, therefore, that the early methods employed to control deterioration must have been discovered haphazardly. The pre-science techniques used are still familiar today - pickling in vinegar, salting, the addition of sugar and such like. The common denominator amongst all these methods is that the immediate environment in which the food is held is unsuitable for the growth of micro-organisms. The principal disadvantage of these methods, to a greater or lesser extent, is that an environment unsuitable for bacterial growth imparts a change in the palletability of the food.

The basic difference between these earlier methods and the canning process is that in the latter the food is held in conditions ideally suited to the growth of micro-organisms. The prevention of deterioration depends entirely on the elimination by thermal death of any such harmful organism capable of growing in the particular food to be packed. This heat treatment is effected on the food in an airtight ('hermetically sealed') enclosure, thus preventing the re-entry of spoiling organisms. It will be appreciated that food so prepared will keep in an unspoiled condition for as long as the container performs its function of excluding air and, also, as long as the container is of such a material that the vessel itself does not affect the food.

In view of these principles it is interesting to note that in the Elizabethan era cooks would preserve cooked meat by placing it in a dish in which it was fully immersed in hot gravy. As the gravy cooled a 'lid' of dripping was formed on the surface thus creating a type of hermetic seal.

The origin of the union between metal canisters and cooked meat is not known. It is known, however, that in 1777 a certain Captain Steadman recorded in his diary whilst in Guinea an experience strange to him. He observed how roasted beef was stored in an edible condition in a closed metal canister from which the meat was served. Though Captain Steadman was himself unacquainted with this practice the nature of his description suggests it was no novelty to his hosts.

Although the inventors of the metal food canister and of hermetic food sealing may never be discovered, the title of father of the modern canning industry belongs indisputably to the Frenchman Nicholas Appert. Appert was actively experimenting in methods of food preservation, apparently of his own volition, in the last decade or so of the eighteenth century. It can be estimated from Appert's own writings that he first used hermetically sealed food containers in 1791. It is also clear from his writings that Appert had a sound understanding of the principles of thermal food preservation long before Pasteur provided the scientific proofs. Appert continued his empirical work in the nineteenth century publishing in 1810 his book "L'Art de Conserver". Appert described his process as:

"(1) in enclosing in bottles the substances to be preserved, (2) in corking the bottles with the utmost care, for it is chiefly on this corking that the success of the process depends, (3) in submitting these enclosed substances to the action of boiling water in a water bath, for a greater or less length of time, according to their nature, and in the manner pointed out with respect to each several kinds of substance, (4) in withdrawing the bottles from the water bath at the period described".

Appert was here describing what were to always remain the essentials of the food canning industry. Although Appert experimented with metal receptacles he expressed a preference for glass as the more suitable material. In recognition of his work the French Government rewarded Appert with the sum of 12,000 francs.

In the first two years or so Donkin's business proceeded precariously but it was not long before it was on a sure footing. His best customer was probably the Admiralty. Imitators were soon inevitably in the field some of them, ironically, former employees at the Bermondsey factory. But with no agricultural surplus, allied to the high price of the canned product, the industry could not flourish in Britain. End-uses continued to be the specialist expeditionary type where fresh food was not an alternative. The first canned food did not go on sale to the general public in England until 1830, and only then at a prohibitive price. It was, moreover, very unappetizing and the public were understandably suspicious of it.

In the early decades of can making, the vessels were hand made in the winter on the packer's premises and filled in the harvesting season. There was virtually no specialisation and the dichotomy between can-making and canning did not exist. (In fact the actual term 'canning' was not itself coined until the 1860's).

## 3. Can-Making as a Craft Industry

In the early manual method of production blanks for the body and end were cut by shears from sheets of scored tinplate 14 in. x 20 in. The cut pieces were then supplied to the tinsmith who formed the rectangular body blank into a cylinder with the help of a roller, he then held the body steady whilst applying the solder to the carefully overlapped edges of the side. After this operation a plain disc which had been flanged with a hammer and anvil so as to fit neatly over the aperture of the body was soldered on using capping irons. In most cases the other end of similar shape and flange was also soldered on at this point and a vent hole an inch or less in diameter was left for the food to be inserted. In these cases a tinplate disc known as a 'stud' was soldered on immediately after filling to seal the vent. From 1833 it became the practice to also leave a very small hole in the stud and before this was sealed, or 'brogged', with a drop of solder the can was heated for a time to expel some of the remaining air. This small hole also prevented any bulging or bursting of the can during processing. In some cases a complete end was left off and soldered on after filling. This method was disfavoured because of the possibility of contamination between the soldering area and the contents. Charring of the food was also a problem with this method.

The cans first made by this hand operation could be turned out by a skilled tinsmith at the rate of five or six per hour. (One may still be lucky enough to see this craft practised by 'tinkers' in the West of Ireland). This essentially remained the method of production until the late 1840's though in between times basic foot and hand operated mechanical aids were devised. By the use of these elementary devices and also presumably by virtue of the accumulation of experience it was possible to achieve outputs approaching fifty per hour.

## 4. Mechanization of Can-Making

It is at this juncture that the tremendous divergence between British and American manufacturing methods originated. Although the market for thermally processed foods in the United States was still limited, and the majority of such produce had up to 1935 been packed in glass jars, the American can industry set about mechanization.

The first transition to machine powered operations, as opposed to mechanically assisted hand operations took place in 1847 when Allen Taylor, an American, introduced his drop press. This machine cut and flanged the end from the tinplate sheet by dropping a heavy die on them. Until this time the end had been cut with shears and flanged with a very basic die. This innovation appears to have been the stimulus to a flurry of imitative inventions for the production of the can end. Two years later another American, Henry Evans, devised a 'pendulum' press for the same purpose; within a few years the best features of these machines had been collated to produce the 'combination press'.

This machine cut out the tinplate disc, flanged it, and punched out the vent hole, i.e. produced a finished can from the flat sheet in one operation.

This cluster of innovations in the production of the end must have created an imbalance in the output of the complete can for attention was immediately diverted in the early 1850's to improving the speed of body production. The first efforts were designed to facilitate faster soldering; a mandrel was introduced around which the body blank was held by a bar of slate. This bar was itself soon replaced by a device known as 'Jones' blocks'. With a secure lap between the edges the tinsmith could quickly apply the solder. The soldering operation was further improved upon in the 1860's when solders of wire were employed. These economised on cost by allowing the minimum necessary amount of solder to be used for body, end and vent hole seams.

Improved methods of producing the can end and of soldering the body inevitably directed inventive efforts to the third production operation, joining the two together. The original capping iron method was disadvantageous in that the heating of the can which it involved sometimes re-flowed the side seam solder. A variety of techniques were tried during the 1860's to overcome this problem including the crimping of the ends of the body prior to side-seam soldering. The advance which finally cured this problem and considerably increased rates of output in the process, was the 'Howe floater' introduced in 1876. By this method the can was run along on its side at such an angle and with the end in place that the seam rolled through a bath of solder and sealed on. Howe's floater did not involve any novelty apart from its use of a machine because the same principles for soldering had been employed as early as 1858. From the mid-1860's onwards machines were being tried out for all the soldering operations.

In the second half of the nineteenth century the trend toward mechanization of can-making manifested itself in all the constituent operations until by 1885 the American food can was made entirely by machinery. In the final quarter of the century mechanization started to give way to the beginnings of automation, it was principally this development which transformed output from craft industry to process industry proportions. In the 1880's the first semi-automatic can bodymaker was developed. This was a turret type bodymaker which consisted of a series of soldering horns onto which pre-curled bodies were fed by hand, soldering of the side seam was carried out automatically as the turret revolved under the control of an operator. This innovation gave can-making a status in its own right and marks the divergence between the two processes of the making and the filling of cans.

The dividing line, if one can be drawn, between the mechanical and automatic era took place in the 1890's with the advent of a complete system to make a can automatically from a sheet of tinplate. The first such machine was introduced by the Norton Brothers, who rank amongst the founding fathers of the modern industry. This bodymaker led to the first widespread use of the 'lock and lap' side seam - as opposed to the simple overlapped seam - since its invention in Germany in 1870. With the Norton machine the terminology of can-making was changed; one no longer talked of can output in terms of so many per hour but as so many per minute, one hundred per minute in this case. With the development of the fully automatic bodymaker the technological horizon of the can-maker reached a plateau, he now concerned himself with enhancement rather than original development. The Norton bodymaker was followed by a series of others, notable among them the Troyer-Fox machine of 1910. As the equipment was improved so the output went up and speeds of over three hundred per minute were common-place in the 1930's.

5. The Development of the Can

The history of technical change in the can industry clearly demonstrates the unrealistic nature of the distinction between process and product innovation. Many of the new mechanical devices mentioned above brought with them an improved final product and, similarly, the product improvements which were instituted could not have been achieved without some change in the manufacturing processes.

It has already been mentioned that metal canisters were an established article before the birth of the canning industry and it is probable that no novelty was involved in the early can sufficient to justify a British patent, although the first US patent for a can was taken out by Kensett and Daggett in 1825. It has also been observed that the first cans were made of thickly tinned wrought iron; in fabricated form these containers were a cumbersome looking object with a ring at the top for ease of carriage. So formidable were these cans that they were annotated "Open with a hammer and chisel". It is most unlikely that the first tinplate to be used for cans was designed for the purpose, it is more probable that it was the heavy gauge type of material employed for various commercial uses, e.g. roofing. As the canning industry became established the production of lighter gauge plate became justified and the can benefited accordingly.

The major design problem facing the can maker in the early days was how to make his can more attractive to the general public. Given co-operation on the part of the tinplate makers regarding the gauge of plate available, this problem centred on methods of devising a can which once bought could be easily opened. This objective could be achieved by either modifications to the can itself or by the development of opening devices, both options were pursued.

As early as 1833 Anglibert patented a new type of can the body of which had a gutter or collar around the rim into which went the solder. A flanged lid was pressed into the solder while it was still molten; to open the can the solder was re-melted. This invention was not designed with convenience in mind, but cost. The novel method of opening was intended to replace the hammer and chisel and so prevent irreparable damage to the can. This idea to re-use the can indicates their high cost to produce. The first important development specifically with opening in mind was that made by J. Bouvet in 1862. Wire was placed in a groove around the rim of the can so that it was in contact with both body and end. By flowing solder into the groove a wire effectively held the can together. A loose end of the wire was left free which could be pulled by hand thus opening the can. This somewhat crude device will be recognised as the principle on which many modern shallow fish cans are opened. (A similar type of idea was in fact patented for opening a sardine can by Widgery in 1871). A somewhat different type of easy opening idea was the 'tagger top' can. By this method a very thin piece of tinplate was soldered on to provide the hermetic seal and was itself protected by a secondary loose cover. An assortment of 'tagger tops' were invented in the 1860's but none was applied to the food can until Howe did so in 1873. This type of closure had little scope for thermally processed foods but will be readily recognised as the forerunner to the modern foil diaphragm on dry products packed in 'lever' and 'slip' lids. As the quality and suitability of tinplate improved the more practical avenue was not cans with an integral opening facility but the development of efficient can openers. By the 1870's there were a variety of sound can openers on the American market.

The can which was used continued to be the vent hole type of the early days. The job of closing these cans after filling remained the greatest single barrier to the achievement of high speed production in the canneries. It will be remembered from another context that soldering on of the whole end at this stage was impractical owing to the danger of charring the food. Equally disadvantageous was the necessity of employing skilled cappers to effect the closure, which put the employer in a particularly disadvantageous bargaining position during the short harvesting season.

It is apparent from these disadvantages that what was required was a vessel that could be supplied to the canneries with an open end of full aperture the lid of which could be hermetically attached without the use of solder.

The advantages of such a can were not lost on the can-makers even in the early eighteen hundreds. It would take a century of can-making, however, before such a vessel was established in the food industry. One of the interesting facets of the development of this type of can is the fundamental distinction which it illustrates between an invention and an innovation. Timsmiths, it seems, had been attaching ends to canisters without soldering since before the advent of the thermally processed food can. Whatever this hand operation entailed it is clear that it cannot have been suitable for the food can. It was not long before attempts were made to perform this operation by machine. The first device for double seaming was made by Joseph Rhodes of Wakefield, England, in 1824. This machine was marketed and was a commercial success inasmuch that Rhodes' firm probably made money on it. It cannot be considered an 'innovation' in the context of the canning industry because it clearly was not adopted for the purpose it was designed - to hermatically seal cans. The continued failure of soldered cans with an open ended dimension such as Anglibert's re-emphasized the need for a practical double seaming machine. Such machines continued to be invented for performing the operation into the twentieth century without being turned into innovations. The reason why all these devices failed to make a commercial impact was because, as in Rhodes' machine, the achievement of an airtight closure was dependent upon the quality of plate and the accuracy and consistency with which the component parts were put together. Deficiency in any of these respects was likely to cause a defect in the final double seam. What was required was some form of gasket which would take up any irregularity in the plate or in the join likely to cause an air leak. Attempts were made to incorporate a gasket in the seaming operation in parallel with continued efforts at a gasketless seal. In 1861 Bouquet invented the first double seam to employ a gasket, in this case a rubberised band, but again with no commercial impact on the canning industry. Bouquet's was obviously considered a practical principle on which to work for it was followed by a number of similar inventions. Research and development on a gasket for the double seam concentrated on finding a suitable solution and the most appropriate way to apply it. The first half of the problem was finally solved in 1896 by Charles Ams who patented various kinds of sealing compounds. It took the combined efforts of a number of participants including Bogle and Scott and the Cobb Preserving Company to perfect Ams' idea between 1900 and 1910. Within this time a diverse range of methods, both hand and mechanical, were tried for applying the compound. By 1910 the ultimately successful device was being used by which the sealing compound was placed in the curled edge of the can end. The double seaming operation was performed, basically, by placing the end containing the compound over the flanged rim of the body, by hooking the parts together in one seaming operation, followed by a second seaming in which the first join is compressed, the sealing compound took up any slight imperfections in the seam and thus ensured an airtight closure.

For the first time it became commercially feasible to supply cans to the packers with one complete and completely loose end. This end could be seamed on in the cannery at half the speed at which the opposite end was attached by the can-maker using the same type of automatic machinery. The new type of containers were called 'sanitary' cans. This term referred to the fact that solder was applied only to the outside of the side seam and not to the end or inside as had previously been the case. In the UK the term 'open-top' can was preferred.

By 1920 the sanitary can had come into general use in America, mainly for fruits and vegetables. Cans with soldered ends remained in use until at least the late 1930's for foods such as corned beef in rectangular cans and condensed milk in cylindrical cans.

One final area which must be considered concerning the development of the cans is that of the coatings. This is a further area in which the distinction between a process and a product innovation cannot easily be made. Basically it may be said that internal and external can coatings are employed to protect and decorate respectively.

Inside can linings are termed 'enamels' in the United States and 'lacquers' in the UK. These prevent reaction between the inside of the can and its contents be it corrosion, discolouration or some other problem. The first use of inside can varnishing was made in Paris in 1868 by Peitier and Paillard whose specific problem was internal can corrosion. This innovation was not adopted in the United States until used by Max Ams in 1890. Thereafter a variety of linings were developed in America for canning products of different acidity etc., one notable advance being in 1924 when 'C enamel' was introduced to eliminate corn black. In the UK the application of lacquers remained experimental into the 1930's. The major development of these coatings did not take-off in the States until the 1930's when the beer can was being designed. This impetus was overtaken by war-time conditions which led to the development of the modern range of synthetic lacquers.

Cans with external coatings, (other than paper labels) have an even more recent history of application than lacquers. Again the beer can was the first real stimulus but the decorated processed food can did not appear in the UK until the 1950's. Despite this post-war aspect it is appropriate to mention at this stage the background to modern can printing practices.

The contemporary method of tin-printing is lithography (literally, 'to write by stone'). This process was actually invented with tin-printing in mind by Senefelder in Germany in 1798. (The first processed food cans were painted, but this was undertaken for protection rather than decoration). The earliest lithographic presses were hand operated until 1865 when the flat bed printing machine was introduced by Voirin in France. It was soon discovered that zinc sheets outperformed stone and so consequently they quickly replaced it. The zinc sheets were advantageous because they could be shaped around a cylindrical roller allowing higher speeds to be obtained. These developments in tin-printing were not made with the can in mind. The first application of lithography to the tin box was made in New York in 1869 and first experimentally applied to a can a few years later.

The indirect, or offset, process of lithography was patented by Barclay and Fry in the UK in 1875. The actual innovation to which modern high speed tinprinting methods can be traced back was the hand fed rotary tin printing press patented in the UK by George Mann and Co. in 1903 and known as the 'Mann Standard Tin Printer'. This innovation led to the automatic metal decorating press.

## 6. Development of Canning

In food canning the term 'processing' is preferred to sterilisation since in canning not all the micro-organisms are killed. Processing, or 'commercial sterilisation' as it is sometimes called, involves the destruction of all those harmful organisms which would proliferate in the conditions of canned food. To achieve complete sterility by eliminating heat resistant organisms which do not multiply in the conditions of canned food would cause over-cooking.

Appert himself did postulate the existence of micro-organisms even though he could not prove their presence. His own canning practices drawn on his empirical investigations provided a sound base for the commercial food processing industry. It was to some extent unfortunate therefore that Gay-Lussacs, with whom Appert disagreed, was at the same time (1810) expounding his 'free oxygen' theory of food spoillage. This diverted research from the actual cause to unsuccessful attempts at 'cold sterilisation' by canning foods in inert gasses.

In the early decades of the canning industry food was processed by simply heating it in boiling water in stoves or ovens; this method took inordinate time to achieve sterilisation. About 1837 steam was employed in processing. The first major advance on Appert's practices was the method in which chemical additives were used to allow processing temperatures beyond boiling point. In 1841 Stephen Goldner patented:

> 'A mode of heating the vessels in which animal or vegetable substances are to be preserved by driving off the atmospheric air and producing a vacuum therein which has heretofore for the most part been performed by stoves or ovens which are liable to burn the materials. I employ a chemical bath in the manner described in John Wertheiners patent.

be cooled rapidly. The first retorts were of the 'still' type which were not ideally suited to fulfilling these conditions without modification. As a result between 1874 and 1939 the canning industry advanced primarily by incremental improvements to the retort. This incremental innovation contained two main themes; the use of automatic controls to facilitate the manipulation of still retorts and, secondly, the introduction of continuous and agitating types of retort.

Shriver's retort of 1874 was the first cooker to have externally generated steam fed into it rather than to have the retort itself heated. This allowed the use of automatic controls on the heat supply. In 1895 Underwood and Prescott started their classic research on food spoillage; three years later their results re-emphasised what Appert had always maintained - but which the industry had tended to overlook - namely the importance of the heat penetration rate at the centre of the can, and also the importance of rapid cooling. This work encouraged the development of heat measuring devices in retorts. As a result in 1917 thermocouples were first used to measure heat penetration in place of glass thermometers.

The introduction of continuous pressure cookers allowed, by the use of steam valves, the cans to be loaded into and taken out of the retort without any pressure loss in the chamber. This meant that precisely the same treatment could be given to different batches of cans without any guesswork. An important addition to the pressure cooker was the principle of agitation. This feature may have been used on still retorts as early as 1855, but its first significant application appears to have been made by Meyenberg in 1885 for sterilising milk. In 1899 the spiral type continuous pressure cooker was patented, by 1939 this had received widespread acceptance. Whilst agitation of the can improved the rate of heat penetration to the centre of the can's contents, thus controlling overcooking of the contents adjacent to the side walls, it was not suitable for products which were easily damaged such as pear halves. To overcome this gap in the technology the

Anderson-Barngrover non-agitating pressure cooker was introduced in 1931.

## 7. Market Developments

Although the American market for canned food was never as limited as that in Britain the growth of the former was slow for the same reasons which prevented its burgeoning in the UK - price, the quality of the can and prejudice, not unfounded, about the dangers of poisoning. The introduction into the States in 1853 of canned condensed milk led to a significant lowering in the infant mortality rate in the areas in which it was sold. This considerably improved the acceptability of canned foods in general. It was not, however, until 1860, when it became apparent that the Civil War was not going to be quickly resolved, that canned food received its real impetus. Canned food was ideal for solving the problem of feeding the Union armies in the field.

With the conclusion of the Civil War both victors and vanquished turned to the opening up of the West, this migration re-fuelled the war-time impetus. A further socio-economic factor favouring the continued growth in the use of canned food was rapid urbanisation in the later nineteenth century. Once canned food had made these breakthroughs into the nation's diet its diffusion and proliferation was reasonably assured given the American standard of living. By the early twentieth century the can had become a symbol of the American way of life.

## 8. UK Developments

While the American market for canned goods was accelerating apace UK domestic production remained negligible. There was no separate can-making industry in existence although tin box makers did occasionally produce cans e.g. for the Boer War. At the end of the nineteenth century there were only a few firms who packed any of their food in cans, among them the now famous names of Crosse and Blackwell (Formerly Donkin Gamble and Hall) and Chivers. These firms made whatever cans they required on their own premises using the old hand methods.

This situation continued up until the 1920's when the first determined attempts were initiated to establish a UK canning industry. Improved methods of refrigeration and transportation and higher standards of living in Britain took the pressure off the domestic agricultural sector in the late nineteenth and early twentieth centuries. They allowed much greater importation of canned food and in much improved condition. As a result the country was ripe for its own canning industry to be established.

By the early 1920's the number of firms which canned food had risen to ten; with antiquated methods that produced cans of which twenty-five per cent were defective (compared with one per cent in the US) it was unlikely that a can-making industry could be soundly based on this nucleus.

What was needed in Britain in the mid-twenties was a firm commitment to the adoption of American methods of high-speed, high quality can-making from an organization with sufficient dynamism to encourage the food processors to make the necessary complimentary advances. This is in fact what happened. In 1927 the tin box maker G. E Williamson attempted to revitalise his business by diversifying into can-making. He chose to install a can-making facility on a semi-automatic basis. This home based industry might well have been nipped in the bud two years later when the American Can Company (ACC) entered the British market. ACC was at this time by far the largest can-making company in the US - and the world - having been formed in 1901 from a combination of over one hundred other enterprises. It might have been expected, particularly in view of the popularity of Frederick Lists' infant industry argument, that the firms making cans in Britain would have been overwhelmed by this competition. On the contary after a sharp bout of industrial manouverings ACC was forced to withdraw from the British market within two years. At the end of this conflict the Metal Box Company under the dynamic and ruthless leadership of Robert Barlow emerged as the dominent force, having taken over Williamson's business.

In the early 1930's the British Canning industry was in a depressed state. Price competition was of the cut-throat variety and canning practices left much to be desired. Faced with an outlet ill prepared to capitalise on the opportunity offered by modern can-making the Metal Box Company took upon itself the task of endowing the processors with the ability to fill their cans correctly and at high speed. The commercial policy adopted by Robert Barlow was in this respect a carbon copy of that instigated by ACC thirty years before. In 1973 William S. Woodside, Executive Vice-President of ACC, described his company's achievements in these early days:

> "Along the way (since the turn of the century) we have helped the farmer grow his crops better and smarter. We have taught the food processors how to pack food. We have designed and engineered packages and equipment to manufacture them, as well as the equipment to fill them in the customers plant. We were pioneers in establishing most of the thermal canning practices now in use".

In other important respects Robert Barlow adopted the techniques of ACC. The most notable of these was the company's policy of leasing closing machinery to the canners at a subsidised price with the proviso that they close only cans made by Metal Box. This contractual obligation on the canners effectively deterred any subsequent entrants who may have considered competing. As a result by 1937 the Metal Box Company had achieved a total monopoly on the sale of cans in the UK. This is perhaps the only case of such complete market dominance to have been achieved and maintained without statutory protection.

Whatever the ethical aspects of the Metal Box Company's policy there is little doubt that it was this monopoly position which allowed it to have such a crucial and beneficial influence on the development of the food processing industry. This industrial development is reflected in the growth of canned food production.

TABLE II

UK Production of Main Items of Canned Food

('000 tons)

| | 1924 | 1930 | 1935 |
|---|---|---|---|
| Fruit | 5.0 | 18.5 | 23.3 |
| Vegetables | 1.0 | 15.7 | 60.6 |
| Soup | 1.0 | 3.0 | 10.0 |
| Fish | 7.6 | 7.0 | 8.6 |
| Milk | 38.3 | 43.7 | 148.7 |
| TOTAL | 53.5 | 87.9 | 251.2 |

Sources

In addition to these items a minor amount - around five percent - of miscellaneous products, mainly meat, were also canned.

With the raising of the technological horizons, if not the threshold, of the canning industry and with the rapid increase in production a number of dominant firms began to emerge. Despite this the industry was characterized by small independent canners. Of a total of 197 canning firms in 1937, 153 were small scale operators. This represents a remarkable rate of entry since 1920. Of the total of 197 around one third concentrated on the processing of fruit and vegetables.

It must be remembered that Table II does not include imports of canned food, of which fruit was the main item i.e. consumption was greater than domestic production. One has a situation, therefore, of the rapid growth in consumption of a product, which was a luxury in as much that a premium was paid for the convenience it offered, during a period of economic depression. This apparent anomoly requires some explanation. The reason for it is a confusion over the meaning of an 'economic depression' in traditional long term economic analysis, i.e. before Keynesianism, an economic depression meant only a depression of business profits. It was not associated with such phenonomena as mass unemployment or a slowdown in business activity. A depression, on the contary, was a time when the consumer reaped the benefits of the investment undertaken in the preceding boom; it was the proliferation of competition at the peak of a boom which led to the downturn in business profits and a consumer bonanza as prices were forced down. Although the depression of the 1930's is now principally remembered for mass unemployment this aberration was caused by institutional factors and not the operation of the trade cycle. A careful examination of the 'Great Depression' will in fact reveal that it conformed pretty much to the predictions of traditional theory. A downturn in business profits was accompanied by falling prices and a considerably increased standard of living for the mass of the people. Between 1913 and 1939 income per head increased nearly twenty per cent. Even those who are aware of this overall picture may point to the hardships of the older industrial regions beset as they were by unemployment. Again, in terms of the standards of the time, this can be seen as a carefully fabricated myth since it can be demonstrated that the unemployed family man was better off in the 1930's than the unskilled labourer in 1913.

It is apparent, then, that the growth of the British canning industry between 1929 and 1939 was quite in keeping with socio-economic conditions and in no way represents an anomaly.

## 9. Conclusion

The foregoing historical survey indicates the difficulty with which one is faced trying to assess the impact of an innovation in any definitive cause and effect terms. Within, for example, can-making there was at any one time a number of themes to the pattern of innovation any two or more of which were often simultaneously in a dynamic phase. Similarly, the emergence of canned food into the Anglo and American diet was dependent upon a number of parallel developments. Progress in the production of tinplate, in the nature of the can and its method of manufacturer and also in food processing technology, were mutually supportive in increasing the acceptability of canned food. Further, it has been shown that external, or 'exogenous', market forces were also acting on each of these innovation systems to further complicate the matrix of interactions which underlay the rise of the thermally canned product. In spite of these difficulties it will be attempted to discern in the remainder of this chapter the extent to which can-manufacturing contributed to the overall scenario and also to what degree such an evaluation must be tempered by consideration of other salient factors.

The record of British can-making in the nineteenth century illustrates the important distinction between technical and economic progress. Without a market for the final product there was no incentive to invest in new manufacturing methods. The British can-makers made no attempt to exploit better quality tinplate as it became available because they could satisfy demand within existing techology.

A relevant dichotomy would also appear to exist between demand and potential demand. Where a potential demand exists the can-maker is able to invest in improved processes to both capitalise when demand materialises and, more importantly, to encourage the potential demand to early expression. This would seem to be what happened in America after 1847. The US industry mechanized while growth in consumption was still very slow because the resources and potential for convenience foods existed. This demand emerged dramatically, and perhaps slightly prematurely, with the Civil War but when it arrived the means existed to satisfy it. Because the product offered to the Union Army was far superior to the crude vessel supplied to the British Admiralty its use was consolidated when hostilities terminated.

The clearest example of the ability of an innovation to create its own demand was that of the sanitary can. Nineteenth century soldering restricted the variety of product suitable for the can. When the sanitary container was introduced the range and acceptability of canned food was greatly increased. Other less spectacular product improvements such as in can linings helped to reinforce this 'innovation push' growth. It will be appreciated that this relationship between market forces and technical change is complicated in that once the spiral of innovation and market demand is underway it becomes difficult to be certain which is the stimulus and which the response.

In assessing the role of can-making vis-a-vis canning it has already been argued that canning methods tended to advance at the behest of ACC and the Metal Box Company. This should not be taken to imply that can-making is inherently the dominant partner but only as an indication of the suitability of the large organization for carrying forward its own technical progress and, more importantly, for using its commercial strength to encourage compatible developments within those it supplies. (On the first point it will be remembered how the concentrated structure of the US tinplate industry facilitated innovation).

In the case of the relative role of tinplate and can-making technology in the growth in the acceptability of canned food the relationship is again not straightforward. The advance in can-making techniques between 1810 and 1939 demanded ever increased quality of plate and there is no doubt that the tinplate industry was always under pressure from the can-makers. It is also the case, however, that with the food can becoming the major single outlet for tinplate in the twentieth century it equally became in the steel industry's interest to improve its technology to secure its position against alternative materials. The former relationship can clearly be seen in the nineteen hundreds as the Welsh tinplate industry turned increasingly to the production of gauges and coatings suitable for the American can-maker rather than for industrial and household uses. (It must be remembered that another exogenous variable, the oil industry and the motor-oil can, were also involved here). In the early twentieth century the adoption of high speed bodymakers also kept the pressure on the tinplate manufacturer to produce consistent material which would not foul the machines. However, with two innovations as momentous as the hot strip mill and cold reduction one must set aside the perennial propoganda of the can-maker regarding quality and to some extent credit the steel industry with the dominant role. These two innovations produced less variation in gauge and the can-makers could consequently reduce the cross sectional area without sacrificing strength in the container. This innovation also benefited the canning industry considerably. Up until this time the canning business had been considered a risky investment not least because of the short and somewhat unreliable shelf life of corrosive products. The impact of cold reduced plate in the US on this end of the business was considerable.

TABLE III

Shelf life of Selected Canned Fruit and Vegetables - Central US.

| Product | Months | |
|---|---|---|
| | 1931 | 1944 |
| Apples | 12-15 | 36 |
| Blackberries | 9 | 12+ |
| Fruit Salad | 9-12 | 36 |
| Grapefruit | 9 | 36 |
| Peaches | 18-24 | 36 |
| Pears | 24 | 36 |
| Rhubarb | 6 | 12+ |
| Asparagus | 24 | 36+ |
| Beans, Lima | 24+ | 96+ |
| Sprouts, Cabbage, Cauliflour | 18 | 48 |
| Carrots | 24+ | 36+ |
| Peas | 36-60 | 96+ |
| Tomatoes | 15 | 48 |

This improvement was not reflected in the UK where the quality of plate in the 1930's remained a serious problem for the can-making industry.

# R E F E R E N C E S

The information on the historical development of the tinplate, can-making and canning industries has been compiled from a review of the following technical and commercial periodicals of the metal processing, food processing and packaging industries since 1945.

1. American Metal Market
2. Canning and Packing
3. Food
4. Food Manufacture
5. Food Processing Industry
6. Food Technology
7. Food Trade Review
8. Journal of the Iron and Steel Institute
9. Metals/Materials Today
10. Modern Packaging
11. Packaging
12. Packaging Review
13. Packaging Technology and Management
14. Sheet Metal Industries
15. Tin and Its Uses
16. Tin International
17. Tin Printer and Boxmaker

# CHAPTER III

## TECHNICAL CHANGE IN TINPLATE MANUFACTURE SINCE 1945

## 1. Introduction

The technological challenge facing the Welsh tinplate industry in 1945 was both considerable and diverse. The process and product advantages of continuously rolled plate were by now so well proved that there was no longer any question as to its suitability for UK conditions. In the war years another new process had emerged in the United States the impact of which was to rival the developments of the 1930s. This innovation was the continuous deposition of tin by electrolysis. With the rolling and the plating of tinplate now possible in continuous coil form the pressure to also convert the intermediate batch processes was considerably higher. As a result the task facing the Welsh industry in 1945 was a greatly increased one on that of 1939. Not only was it now desirable to abandon the old hand-mills, but also to forsake hot-dipping and most of the other batch processes which characterized UK production methods; in other words, a complete re-modernization of the tinplate industry was required. The task of implementing what has been largely pre-1945 technology has continued throughout the post-war period.

It has never been sufficient to simply adopt these innovations; competitive pressures have ensured that within the framework of new rolling methods and new coating methods there has been a continual need to exploit the possibilities offered by these advances to their fullest extent even to what, in some cases, has proved undesirable extremes. It is with the implementation of new technology and its further development, together with the demise of older processes, that this section is concerned.

## 2. Developments in Established Rolling Technology

### Introduction

Before embarking on an examination of the innovations which made their first appearance in the UK in the post-war era, it is appropriate to briefly update the progress of the hot-strip mill, cold-reduction, the hot-pack mill, and the temper mill.

### i. The Hot-Strip Mill

The unique importance of the hot-strip mill to the development of the tinplate industry warranted its inclusion in the pre-1945 section as if it were the first stage in the tinplate manufacturing dequence. There is some logic in such an ordering in the American context since the hot-strip mill was associated with the move to fully integrated steelworks. In the UK, however, the first stage of the tinplate manufacturing sequence is considered to be when the coils of steel arrive from the hot-strip mill ready for rolling to tinplate gauges. This review of hot-strip developments therefore constitutes something of a short digression from the central theme of the section.

When in 1945, Richard Thomas and Company and Baldwins Limited amalgamated, their integrated steelworks (coke-ovens, blast furnaces, Bessemer plant, continuous hot-strip mills, cold reduction mills, pickling, annealing and hot-dip tinplating) at Ebbw Vale incorporated the only hot-strip mill in the UK providing steel for tinplate manufacture. The mill itself could roll strip fifty six inches wide; in 1946 a sixth four-high stand was added to the mill.

In 1947, in order to find additional finance for a second hot-strip mill, the four leading steel companies - Richard Thomas and Baldwins (R.T.B.), Guest Keen Baldwins Iron and Steel Company Limited, John Lysaght Limited, and Llanelly Associated Tinplate Companies - were formed into the Steel Company of Wales Limited (S.C.O.W.). R.T.B.s association was only temporary. The second hot-strip mill was part of the rebuilding of the Margam and Abbey steel works at Port Talbot. For political reasons the Port Talbot plant was not planned as an integrated works; the hot-rolled band was to be transported to two separate locations for reduction to tinplate gauges. The strip mill was commissioned in 1951; it was the first such installation in the UK to be fully automated.

In August 1962 the UK post-war hot-strip development was complete when R.T.B. commissioned their second mill at Llanwern, near Newport. The plant was originally referred to as 'Spencer Works' by the Company in honour of their Chairman.

The actual laying down of wholly new plant did not constitute the end of hot-strip change and progress; at Ebbw Vale in 1959 major modifications including re-motoring were carried out, Llanwern had its annual capacity increased to 35m tonnes in 1976 and Port Talbot is scheduled for expansion to six million tonnes a year. As part of the massive tinplate development scheme Ebbw Vale was by mid-1978 completely phased out as an integrated iron and steel works and the hot-strip mill closed down. Only tinplate manufacturing facilities remain.

ii. Cold Reduction

Cold reduction, or rather the preparation of hot-rolled strip for cold reduction, is conventionally considered to be the first stage in the tinplate manufacturing process.

In 1938 Richard Thomas and Company had installed two cold reduction mills at Ebbw Vale. The original American-built five-stand mill worked through until 1956 when it was replaced by another five-stand mill constructed by David and United Engineering Company. This mill rolls strip upto a maximum width of thirty eight inches at a finishing speed of 5,000 feet per minute (f.p.m.). Its weekly production capacity is 10,700 tonnes, and it rolls to a minimum tinplate gauge of 0.152 mm. The second original cold-reduction mill started operations in 1938 with three-stands capable of rolling upto speeds of 800 f.p.m. In 1959 this mill was re-modelled and a fourth stand added at the delivery end. These alterations increased the possible finishing speed to 1,500 f.p.m. and also allowed the mill to roll thinner gauges than previously. It rolls strip upto a maximum width of 48" and has a weekly production capacity of 4,096 tonnes. It rolls to a minimum tinplate gauge of 0.356 mm.

At a time when both economics and the world-wide trend seemed to suggest that steelworks should be integrated, it was decided that the two cold reduction mills to be serviced from S.C.O.W.s new Abbey Works should be located so as to generate employment over as wide an area as practicable. As a result the first of S.C.O.W.s cold reduction mills was sited at Trostre, near Llanelly, a distance of some twenty five miles by rail from Port Talbot.

The mill installed at Trostre in 1951 was of the five stand four-high type and rolled coils of upto forty eight inches in width at speeds of 1200 f.p.m. Ideally S.C.O.W. would have constructed its second tinplate works concurrently with the Trostre plant, but for financial and other reasons this was not possible. Construction of the plant started in July 1953 at its chosen site, Velindre, near Swansea. The cold reduction mill was the now usual five stand tandem affair and was built by David and United. It began rolling steel in July 1956. The mill rolls strip upto thirty eight inches wide at speeds upto 1400 f.p.m.

from a maximum ingoing gauge of 2.7 mm. to a minimum outgoing gauge of 0.152 mm.

There was little that was technologically very challenging about what was, after all, possibly the most cataclysmic innovation in the history of tinplate manufacture. It was from the steel company's point of view simply a matter of raising the necessary finance and in single large capital outlays purchasing the already tried and tested technology of international engineering firms.

As the function of this section is essentially to 'round-up' the loose ends from the pre-1945 section details of the workings of these mills is left until an overall description of the modern tinplate manufacturing sequence is appropriate.

iii. Temper Rolling

It will be remembered from the pre-1945 section that the term 'temper rolling' was a new name for an old operation to restore work hardness to the plate. While from the point of view of innovation there is little to say about temper rolling, it is appropriate - while on the subject of rolling technology first adopted in the UK in 1938 - to also briefly review the implementation of temper mills. As this operation is an integral part of tinplate making it follows that each new plant must have incorporated a facility. At Ebbw Vale three single stand temper mills were gradually phased out in favour of two forty two inch two stand mills. The original mills handled coils upto 16,000 lb at speeds upto 1,000 f.p.m. The first two stand mill to be installed accepted coils upto 36,000 lb at speeds upto 4,000 f.p.m. The second two stand mill could handle coils at 6,000 f.p.m. A third mill - discussed later - installed primarily for a different purpose may also be used for temper rolling. At Trostre two tandem temper mills were incorporated when the plant was laid down, both facilities ran at a maximum speed of 1,000 f.p.m. At Velindre, similarly, two tandem temper mills were installed in the year of the plant being commissioned to work at a speed of 4,000 f.p.m.

iv. Hot-Pack Rolling

The cold reduction of hot rolled strip was so advantageous from the perspective of production costs (see Table 1), quality, consistency of the finished product and, also, the working conditions under which it was produced that there could be no long term future for the obsolescent pack-mill. The impact of the new technology on the older process was, firstly, to cause it to be concentrated under a few owners and, secondly, for it to be inceasingly abandoned as the newer type installations came on stream. Although it has been earlier mentioned that the appearance of the new rolling methods in the US in the 1930s produced some quite radical alterations in pack-rolling procedure, such changes were not (as they would be in the case of hot-dip tinning) sufficient to maintain viability.

As the tinplate producers prepared to adopt the newer technology they bought up large numbers of old mills so as to secure a large enough quota to permit a high operating rate for the strip mill. By 1937 Richard Thomas and Company already controlled 224 of the 518 tinplate mills in Wales. (1) When R.T.B. was formed in 1945 so as to build a second strip mill 340 of the 500 pack-mills in the industry came under one control. (2) When S.C.O.W. was formed a further 142 old type units in 18 works came under one control. (3)

The pressure of demand both at home and overseas in the decade after the war was such that, somewhat ironically, as the new mill at Trostre was getting into its stride there was still plenty of work for the old hand mills; in 1953 the old type mills still produced 300,000 tons of tinplate - over thirty eight per cent of the total. (4) This figure would have been even greater if it had not been for an acute shortage of labour which prevented the hand-mills working at anything like their rated capacity. This purple patch for the old type mills in the twilight of their days was never, however, anything more than a stay of execution during a transitional period; the coup de grace came in 1956 with the commissioning of Velindre after which the remaining 110 mills at around twenty works were more quickly closed down. By 1958 most of the works still nominally listed were no longer working and, finally, in 1961 the last remaining tinplate pack-mill at Pontardulais was closed down.

TABLE 1*

Comparative Production Costs in Old and New Type Mills (Shillings per Ton) (5)

| New Plant | | | Old Type Plant | |
|---|---|---|---|---|
| | | | 20% of Plants | Next 20% |
| Prime Costs | Capital Charges | Total | with Highest Costs | of Plants |
| 500 | 105 | 605 | 725 | 675 |

* Source: Warren

3. The Tin Coating

Introduction

Developments in the way in which the tin coating is applied to tinplate have been a continual theme in the post-war era. This trend has manifested itself primarily as a reduction in the thickness of the coating applied. It has already been mentioned that this has been a feature of tinplate manufacture since at least the early days of canning. The difference in the post-war period has been the much closer boundaries of possible reduction and the greater sophistication required to achieve them. Just prior to the introduction of cold-reduction it was considered that the two per cent tin content of tinplate which had been attained represented the minimum practical level, in fact the trend started to move towards slightly higher average tin coatings in the remaining pre-war years. The innovation which reversed this regression was electrolytic deposition. (This would seem to highlight what would appear to be a recurring pattern in industrial innovation, i.e. continued enhancement type innovation until one reaches a limit beyond which further improvement is uneconomic or even impossible. When this point is reached the industry can only advance along this particular avenue by a radical departure from existing practices). It is the implementation and subsequent progress of electrolytic tinplate that comprises the bulk of this section on the tin coating.

i. Electrolytic (elt.) Tinplate

Origins

If there was ever a classic example of a major invention known to an industry lying dormant then it is surely that of elt. tinplate. The case of elt. tinplate supports the argument that invention is a minor variable, perhaps even exogenous, tothe innovation system. A variety of factors combined to bring about the commercial exploitation of elt. coating methods by the tinplate manufacturers, but inventive novelty is notable only by its absence. References to electroplating go back as far as Rosleur in 1850, (6) though the most prophetic observation must be that of Trubshaw (7) in 1880.

"Tin plates have been coated by the aid of electricity but we do not hear of this process being extensively adopted. Possibly this invention is only in its infancy and ere long more may be heard of it".

In 1908 Schlotter in Germany was propounding the advantages of coating steel with electricity. Research work in electro-chemistry continued in all three major industrial countries, particularly after the first world war. It is in Germany, however, that we find the origins of the commercial production of electrolytic tinplate - at the Andernach works of Rasseistein A.G. in 1934. This was on relatively narrow strip.

Early Development

The modern development of the elt. process is - like the hot-strip mill - almost exclusively an American achievement. An account of the early American work is therefore appropriate.

In the mid 1930s all commercial tinplate was still produced by the tried and trusted hot-dip method. The economic advantages of keeping the cold reduced tinplate in coil form for as long as possible naturally produced attempts to apply the final coating in a continuous operation. The obvious course of action was to adapt the existing hot-dip tinning methods. The results were encouraging when this technique was first applied to narrow strip and there seemed little reason to suppose that any major problems would be encountered with the full width strip used in tin mills. (At about the same time the first pilot attempt at tin coating with the aid of electricity was being undertaken by United States Steel Corporation (Carnegie-Illinois) at their Gary Tin-mill). Contrary to expectation both the electro-chemical and, particularly, mechanical problems found in coating wide strip at high speed proved to be both different and more demanding than those in the narrow strip case. USSC went into commercial production of elt. tinplate between 1938 and 1941; it is probable that the new method would have been developed alongside a modified hot-dip procedure if events had been allowed to run their natural course. It is important to remember that the conditions in America prior to 1941 were completely different from those thereafter. In the latter 1930s there was no overriding pressure to abandon the hot-dip process, indeed, elt. plate was not considered an alternative to hot-dipped but as a complementary product. The newer material was originally envisaged for use in the non-critical dry goods area of tin boxes.

However, the capture of the major tin producing areas of the world by the Japanese in 1942 completely distorted the normal course of technological advance. This produced a situation whereby the supply of tin was simply inadequate for the demands of hot-dipping; as a result it created conditions which were bound to favour the immediate and rapid development of elt. lines. At this time 1.25 lb of tin per base box was considered the absolute minimum reduction of the tin content of tinplate under the hot-dip method. The elt. process, on the other hand, could produce usable plate with a coating as little as 0.5 lb, though in terms of the potential saving in tin these figures cannot be taken at their face value. The actual saving by USSC on their first line was in the order of sixty per cent - though the final product was not used for thermally heated foods. Heavier coating weights were needed in 1942/3 when elt. plate was used on a large scale for these corrosive packs. The advantage of the elt. method was that it was capable of employing less tin than hot-dipped even for very aggressive packs because of the greater precision of the coating operation. Owing to variations in the coating thickness with hot-dipping it had always been necessary to err on the side of caution, this entailed using more tin than was strictly necessary. The speed of installation of elt. capacity in the United States during the war years was staggering. In 1941 the Crown Cork and Seal Company (incidentally a food packer) was the only company beside USSC to be commercially producing elt. tinplate. Before the end of the war there were twenty nine lines (nine belonging to USSC) in operation distributed among thirteen mills. Correspondingly, production increased from negligible proportions in 1941 to around ¾m tons p.a. at the end of hostilities. This was consolidated by an even more dramatic increase in production in 1946 until, in 1947, output from the new lines outstripped that from hot-dipping. When considering this investment it should be remembered also that elt. technology was expensive, $1,000,000 being a typical cost for a line.

This remarkable example of the rapid diffusion of a major innovation should not, however, be allowed to cloud the real reasons which gave rise to elt. plate. The artificial tin shortage and the mitigation through war-time conditions of the risk factor one normally associates with new technologies, important as they both were, only served to accelerate a trend which was already underway. In terms of the relationship between innovations the elt. changeover, albeit a revolution, was essentially generated by the even more fundamental innovation which had arisen earlier in the steel industry - namely the hot-strip mill. The hot-strip mill generated the further development of cold reduction, and the improved physical characteristics and corrosion resistance of cold reduced plate, irrespective of the fact that it was also in coil form, encouraged the exploration of the possibility of reducing the tin coating below the 'minimum'.

UK Perspective

In 1945, with the pack-mills still dominating, the immediate advantage of elt. facilities was less applicable to the UK situation. Elt. capacity could only be installed as the output from hot strip mills via cold reduction plants increased to justify it. It was readily accepted at the time that the days of hand rolling were numbered, but since it was necessary to cut up all coils at some point before despatch it was not anticipated that the passing of the older rolling method would of itself affect the economics of hot-dipping.

In view of the rapid development of elt. tinplate in America the rate at which the innovation was adopted by the Welsh industry may seem somewhat laggard (see Table III). It must always be remembered when considering the post-war British steel industry, whether nationalized or not, that political considerations invariably served to slow down investment decision making. On top of this the tinplate industry was itself in a state of transition in 1945. The installation of additional hot-strip capacity was a pre-requisite to any long-term commitment to elt. tinplate; the industry in 1945 was fully pre-occupied trying to exploit the hot-strip option. The over-riding priority of generating sufficient finance to build another hot-strip facility militated against a concerted move to elt. coating.

There were, however, even more basic questions in 1945 concerning elt. tinplate. The high speeds and high outputs of elt. lines were more suited to large markets, such as in the States. In 1945, moreover, it was believed that it would be necessary to lacquer both the inside and outside of elt. place if thinner coatings were to be used for corrosive packs. It was thought possible that the additional lacquering might more than offset any cost advantage of electroplating. A further consideration was that the high capital cost of an elt. line, mentioned earlier, compared very unfavourably to adding additional hot-dipping pots - this high cost also meant that quality in the material and continuity of production must be reasonably assured if the higher initial outlay was to be recovered by lower variable costs. Problems with innovation related both to the technology and the attitude of the labour force are well known as common to many industries in the UK. These variables made for a large risk factor.

In spite of these uncertainties the first elt. tinning line to be laid down outside the United States was that at the Ebbw Vale integrated iron and steel works of R.T.B., the line was commissioned in 1947. This development illustrates a characteristic of innovation in the UK tinplate industry whereby benefits accrue from innovations by virtue of their installation some appreciable time after their first application in the US. Sometimes this was more by accident than design, though it is interesting to observe that once a decision to build new facilities was made the ordering of units of plant which were in a dynamic phase of development, eg. elt. lines, was consciously left until the last possible moment so that the most recent developments might be incorporated.

Three elt. Processes

When American manufacturers were having to make their early decisions on the commercial installation of elt. capacity there was still considerable disagreement as to what type of electrolyte was the most suitable for high speed electroplating. During the war-time proliferation of elt. capacity four different types of plating electrolytes were adopted; (8) these were: (1) the stannous phenolsulphonate bath, (2) the halogen bath, (3) the sodium-stannate bath, (4) the potassium-stannate bath. The stannous phenolsulphonate method was developed by USSC, the halogen bath method by Dupont, the sodium-stannate method by the Crown Cork Company, the potassium-stannate method by the Metal and Thermit Corporation.

From these four electrolytes came three general types of elt. line. The USSC development became known as the 'vertical acid' or 'Ferrostan' (literally 'iron plus tin') lines; the Dupont development, which was first commercially adopted by the United Engineering and Foundry Company, became known as the 'horizontal acid' or 'Halogen' line; the sodium and potassium stannate types became known as alkali or 'Stannate' lines.

Despite the debate in the 1940s as to the respective merits of alkaline and acid baths American experience of the performance of electrolytes per se may not have been particularly beneficial to R.T.B. when deciding on their elt. specifications. Although Jones (9) lists a number of 'fundamental' differences between the two electrolytes, Hoare would seem to suggest that the choice of chemical is pretty much determined by commercial and manufacturing factors.

"Generally speaking, therefore, choice of electrolyte depends on overall production costs, which in turn are influenced by initial cost of plant, engineering and electrical maintenance, labour, d.c.

power costs, heating costs, chemical costs, wastage, tin efficiency and amortization. A further set of factors to be considered are production rate, size of production unit in relation to the market envisaged, and flexibility in regard to thickness of coating plated. These latter considerations are closely bound up with plant design and, in the last analysis, electrolyte and the type of plant must be considered together". (10)

It would seem to be clear, then, that R.T.B. would have been able to benefit in 1947 by adopting the type of line which, taking all the variables into account, was most suitable for the UK situation, based on the evidence of US experience. The line which was decided upon was in fact the one which had already achieved the widest acceptance in the US - the Ferrostan line.

Ferrostan Line

The detailed layout and design of early Ferrostan lines varied in accordance with the prejudices and practices of the engineers and companies which installed them. All lines, however, conform to a basically similar arrangement. In the Ferrostan operation the prepared coils of uncoated steel go through five distinct stages; entry, preparation, plating, finishing, and coiling or piling. The function of the entry section is to change the stock of coils into an unbroken band ready for the continuous processes which follow. This is achieved by two pay-off reels which unreel each coil, pass them on to a set of double cut shears which trim and square the trailing edge of the spent coil and the leading edge of the new coil. The strip is then passed through a seam welder which effects each join in about fifteen seconds. A pinch roll unit then passes the strip into a deep looping pit, this acts as a reservoir so that it is not necessary (except in exceptional circumstances) to interrupt the plating operation whilst the weld is made.

The preparatory stage involves the cleaning and the pickling of the strip. At the front of this facility is a drag-bridle unit comprising of four rolls which hold the strip in tension and thus prevent tracking. At this point also are a pinhole detector and marker and a gauge micrometer which by means of memory devices serve to reject faulty sheets at the exit end of the line. The strip is then cleaned and pickled in three vertical tanks. In the first tank the band is electrolytically degreased, the current being passed through steel anodes and a conductor roll; in the second tank the strip is cleaned and rinsed using revolving brushes and water sprays; in the third it is electrolytically pickled. After pickling the strip is thoroughly washed and scrubbed by again passing through high pressure sprays and rotary brushes.

In the plating section the steel receives its coating of tin. This part of the installation consists of four rubber-lined steel tanks and is very similar in appearance to the cleaning and pickling section. The strip moves through this facility via a chromium plated copper conductor roll above each tank and a rubber-covered non-conducting guide roll at the bottom of each tank. The tin coating is drawn from tin anodes four feet long, three inches wide and two inches thick which are cast from a tin ingot. Sixteen anodes, four to each tank, are suspended in the electrolyte in pairs from an anode bridge. The anodes are replaced at intervals, depending on the rate of tin migration, from alternate sides of the strip. The positive and negative poles of the electrical equipment are attached to the anode bridge and conductor rolls respectively, the latter being in contact with the strip. About ninety five per cent of the tin leaving the anode is actually deposited on the steel. The electrolyte, which is continually pumped into the plating bath from a main storage tank, is an acid solution of stannous phenolsulphonate. An additional agent, phenone, controls the plating range of the electrolyte and grain refinement of the tin coating. The amount of phenone required is determined by meticulous monitoring of the electrolyte. An important variable in the plating operation is the temperature of the electrolyte, which should be kept constant. This is accomplished by water tube heat exchangers which counteract the heating effect of the heavy electrical currents being employed. As the tinned strip leaves the plating section it carries on it a coating of electrolyte. This is recovered by washing the strip with condensate water, the dragged out electrolyte then being pumped back to the main storage tank.

When the tinned strip leaves the plating section it has a dull matte-white appearance. In the very early days of elt. tinplating, when the new material was considered to be destined to a life as a different product from pot-coated, this difference in appearance was not considered disadvantageous. On the contrary Lippert observed in 1942 that:

"The tin can be plated with a mirror lustre, but this finish is considered commercially undesirable as it is rather brittle and shows abrasion marks, finger prints etc. Therefore, the metal is usually plated dull and subsequently brushed to a satin finish". (11)

It was soon appreciated, however, that it was desirable for the tinned surface to receive some form of post-plating treatment which would give it the appearance of hot-dipped plate. The first can-makers to take elt. plate were not happy with the practical problems of trying to use 'mirror finished' hot-dipped and the dull elt. material as if the two were interchangable. It was also soon realized that the new material did not exactly correspond to the physical properties of hot-dipped plate because of the nature of the tin-iron alloy layer which was formed when the blackplate was dipped into the molten tin. This deficiency in elt. tinplate adversely affected its can-making potential (discussed in can-making section). A technique was necessary whereby the strip was given these pot coated qualities.

The solution to the problem was to raise the temperature of the tin coating to just above its melting point for a fraction of a second followed by immediate quenching. This process is usually termed 'flow brightening' but is also variously referred to as 'fusing', 'flow melting', 'flash melting', and 'thermal re-flowing'. Technologically this operation appears to have presented no problem to the tinplate manufacturer, the only question was which of the variety of ways of achieving it should be adopted. In the war years in the States certain types of flow-brightening processes became associated with particular types of elt. tinplate lines. With the Ferrostan line resistance heating is the most commonly used method; in this process the dried strip is passed between two conductor rolls via an insulated muffle furnace. As the strip moves through this station resistance to the current being passed through the strip causes the metal to heat and the tin to melt. Since the second conductor roll is immersed in water in a quench tank the tin is almost immediately solidified again.

The desire to take plate in flow-brightened form by some customers manifested itself sufficiently quickly for most of even the early installations to incorporate a flow-brightening unit in their line. It was anticipated at the time that the facility would be run intermittently with a certain proportion of the output being mechanically brushed and the rest flow-brightened. However, as events turned out, flow-brightened tinplate became the norm. This particular development is one specific example of where RTB benefited as an imitator from the experience of the pioneers. It was not a particularly important factor though because even USSC, whose line did not originally include this facility, appears to have had no difficulty in adapting its unit to incorporate it.

Flow-brightening is only the first of three finishing operations. The second of these takes place immediately after quenching and is the 'passivation' or 'filming' process. This operation imparts to the tin layer a relatively impervious but invisible oxide film by passing it through an oxidising solution. The function of this operation is to minimise the heat tarnishing in subsequent lacquer stoving and to improve the lacquerability of the plate. The film is a dilute chromic acid solution and is applied to the strip by jet spray and immersion in a chemical treating tank. If the operation is aided by electricity it is referred to as electro-chemical passivation.

The final finishing operation is oiling. A weak emulsion of cotton-seed oil and water is sprayed onto the strip to improve stability during warehousing, to provide lubrication and thus prevent damage in all handling operations - particularly can fabrication - and, as with passivation, to facilitate the application of inks and lacquers.

The last operation on the elt. line is either coiling, or shearing and classifying. Ideally the latter is preferred to be an integral part of the line but the high speeds of many facilities defeat the resources of mechanical engineering. Where automatic shearing and classifying is possible the strip by-passes the re-coiling facility, is examined by a second pinhole detector, passed to a shear unit looping pit, and cut to tinplate lengths by rotary drum shears which are adjustable according to the speed of the line. The sheets are next passed to the classifier unit which on instructions from the instrument stand diverts plates that are too light, too heavy, or contain pinholes to one pile and allows sound plate to pass to the second and third piler where the sheets are counted automatically and fed to stillages ready for despatch. To ensure a high standard of quality and regularity, it is important that all these detecting devices be carefully controlled. When the engineering limit at which the tinplate can be sheared and classified is passed the strip is coiled at the end of the line and passed to independent cut up facilities.

A schematic cross section of tinplate produced on an elt. line might well have the following structure.[12]

TABLE II*

Tinplate Cross - Section

| Layer | Coating (inches) |
|---|---|
| Oil film | $10^{-7}$ |
| Tin oxide | $10^{-7}$ |
| Tin | $10^{-4}$ |
| Alloy layer | $10^{-5}$ |
| Steel base | $10^{-2}$ |

* Source: Bevan

The tinplate would comprise nine strata, four either side of the steel base.

Halogen and Alkaline Lines

As the only type of elt. tinplate line to be adopted in the UK has been of the Ferrostan type only passing mention need be made of the other two options which were open to RTB in 1947. The most distinctive engineering feature of the Halogen line is that the plating section is laid out horizontally, usually in three one-hundred foot decks. One side of the strip is coated on the lowest deck, the other side on the middle deck, and the electrolyte recovered and the strip cleaned on the uppermost deck. This type of unit has always been associated with the highest speeds and, consequently, involves the greatest degree of electrical and mechanical sophistication. A disadvantage of this type of installation is that the horizontal plating feature necessitates that the line is about twice as long as the two alternatives.

The fundamental difference between the alkaline unit and the acid types is that the plating pass line is around ten times as long. This is necessary because an alkaline bath plates only half as much tin per kw.-hr. as does an acid bath. Its main virtues are considered to be the simplicity of its equipment and the fine quality plate it produces. These types of plants are associated with lower speeds, smaller outputs and the tinning of narrow strip.

Apart from the actual plating section all the operations included in the three elt. processes are interchangeable. As a result features which were once identified with a particular type of line have been adopted by another; such an example is the case of looping towers instead of pits as strip reservoirs. These were originally identified with alkaline lines but have since been incorporated on Ferrostan installations.

Consolidation

The decision by RTB to adopt the USSC process has been vindicated by events. It is the most successful elt. line inasmuch that it has more than consolidated its immediate post-war position as the most widely adopted option. In 1977 the Ferrostan process accounted for sixty eight per cent of the world's tinplate and about seventy five per cent of the world's tin cans. This would seem to add weight to the hypothesis that the imitator, RTB in this case, benefits significantly by importing technology after the major mistakes (i.e. choosing an inappropriate line) have already been made. If this argument for delayed imitation were pushed to its logical conclusion, however, one would not adopt a 'new' process until the scope for its further development had been exhausted; by this time, as has been mentioned in another context, the whole technology is apt to be replaced by another one. It is true, though, that RTB benefited directly from earlier Ferrostan operating experience: the USSC installation originally handled strip at only 50 f.p.m.; by the end of 1941 this had been increased to 250 f.p.m. The line that was laid down at Ebbw Vale was capable of speeds upto 600 f.p.m.

While the elt. process today is very much the same as in 1948, every new line laid down in the UK since that time has incorporated important modifications. Ferrostan lines have been installed world-wide since RTB was the first licensee and the operational experience and refinements developed have also been exploited at each successive

UK installation. The proliferation in UK elt. capacity is as follows:

TABLE III*

UK Electrolytic Tinplate Facilities

| Yr. Commissioned | Location | Designation | Maximum Speed m.p.m. | f.p.m. | Nominal Capacity t.p.a. |
|---|---|---|---|---|---|
| 1947 | Ebbw Vale | No. 1 | 183 | 600 | 110,000 |
| 1951 | Trostre | No. 1 | 244 | 800 | 140,000 |
| 1951 | Trostre | No. 2 | 244 | 800 | 140,000 |
| 1957 | Velindre | No. 1 | 244 | 800 | 140,000 |
| 1957 | Velindre | No. 2 | 381 | 1250 | 160,000 |
| 1958 | Velindre | No. 3 | 381 | 1250 | 160,000 |
| 1961 | Ebbw Vale | No. 2 | 457 | 1500 | 220,000 |
| 1961 | Trostre | No. 3 | 457 | 1500 | 225,000 |
| 1964 | Trostre | No. 4 | 305 | 1000 | 250,000 |
| 1969 | Ebbw Vale | No. 3 | 533 | 1750 | 250,000 |
| 1971 | Velindre | No. 4 | 457 | 1500 | 250,000 |
| 1978 | Ebbw Vale | No. 4 | 533 | 1750 | 175,000 |

* Source: Various

The above table also shows that the maximum speed of UK elt. tinplate lines has steadily been increased; this in itself necessitated tremendous mechanical engineering feats to achieve. In the course of its treatment the very thin band of steel may be turned through $180^\circ$ as many as one hundred times. As speeds increased the problems in ensuring that the band would not break or slip, causing a stoppage or surface damage respectively, increased correspondingly. With higher speeds came longer plating pass lengths and higher d.c. power capacity, thus enabling the plating of higher coating weights at speeds over 800 f.p.m. Similarly, to implement the advances in mechanical engineering it has been necessary to upgrade the other inter-dependent technologies; as speed increased the length of time for processing was reduced, the reduction in the amount of time for cleaning, plating, etc., had to be solved by enhanced chemical engineering. A single one second operation at 1000 f.p.m. requires at least one up and down loop in a processing tank. Usually the plating operation takes only a few seconds, so making necessary the use of electrolytes suitable for high current densities.

As speeds increased so the problem of instrumentation and control was made far more critical if a uniform, high quality product was to be produced. By the adoption of electronic devices, including computers, it became possible to automatically monitor the complete Ferrostan operation.

We thus see that, as in the case of the hot-strip mill and rolling technology, the development of the Ferrostan operation was dependent upon continuous advances in wider fields. Mechanical, electrical, chemical and electronic engineering progress were all brought together to make this progress in the tinplate industry possible. It was always the case that when each successive decision to install further elt. capacity was undertaken not all the complexities of the operation were ironed out. One of the most important aspects of success was the extensive consultation in the initial stages by the engineering companies and the tinplate firms; this way many pitfalls were avoided. (13)

Although electrolytic tinplating is a much more efficient operation than hot-dipping the impact of the former process has not materialised in dramatic increases in tinplate production (see Table IV). This is partly because other innovations (discussed later) somewhat distort tinplate tonnage statistics. The continued post-war impetus to the diffusion of the elt. process and to its most economical application has been the rise, or the threat of a rise, in the price of tin. This cost reducing - or stabilising to be more accurate - motive has manifested itself in a pretty much continual increase in the percentage of tinplate produced by the new method.

Table V illustrates the material saving impact of the move to elt. tinplate for the tinplate industry. It illustrates clearly why the elt. line is considered to be the most important innovation introduced in the post-war period. If the earlier observation regarding the life cycle of an innovation holds true for elt. coating, then we may now be moving towards the point where further reductions in tin coating weight are impractical, thereby creating the conditions for a further radical development in coating technology.

ii. Differential Tinplate

When considering the causes of the trend in tin coating it must be remembered that the elt. revolution was only one factor, albeit by far the most important, in the continued reduction in the average weight of tin deposited. One specific advance which also made a notable contribution was the production of 'differential' tinplate. This is tinplate on which the gauge of tin coating on the two faces of the plate is different.

TABLE IV*

UK Electrolytic Production**

| Year | Electrolytic Production (000s) | Elt. as percentage of total production |
|---|---|---|
| 1948 | 38, | 6.4 |
| 1949 | 61, | 10.4 |
| 1950 | 62, | 9.6 |
| 1951 | 60, | 9.6 |
| 1952 | 79, | 9.6 |
| 1953 | 162, | 22.9 |
| 1954 | 231, | 28.8 |
| 1955 | 251, | 30.5 |
| 1956 | 281, | 32.8 |
| 1957 | 397, | 40.3 |
| 1958 | 558, | 55.8 |
| 1959 | 672, | 62.9 |
| 1960 | 756, | 63.5 |
| 1961 | 753, | 72.3 |
| 1962 | 912, | 77.7 |
| 1963 | 958, | 79.4 |
| 1964 | 939, | 81.0 |
| 1965 | 1,020, | 86.3 |
| 1966 | 1,043, | 88.2 |
| 1967 | 1,077, | 89.0 |
| 1968 | 1,116, | 90.9 |
| 1969 | 1,212, | 94.5 |
| 1970 | 1,216, | 94.8 |
| 1971 | 1,216, | 94.8 |
| 1972 | 1,131, | 97.1 |
| 1973*** | 1,238, | 96.7 |
| 1974 | 1,097, | 97.0 |
| 1975 | 962 | 98.1 |
| 1976 | 1,112 | 99.5 |
| 1977 | 1,176 | 100.0 |

** Long tons to 1970, metric tonnes thereafter

*** From 1973 production includes Tin Free Steel

* Source: Tin International

TABLE V*

UK - Tin in Tinplate 1948-1977**

| Year | Tin used in tinplate | Tin used as % of tinplate production | Index of tin in tinplate |
|---|---|---|---|
| 1948 | 9,536 | 1.594 | 100.0 |
| 1949 | 9,437 | 1.540 | 96.6 |
| 1950 | 9,821 | 1.495 | 93.8 |
| 1951 | 9,417 | 1.497 | 93.9 |
| 1952 | 11,491 | 1.419 | 89.0 |
| 1953 | 8,911 | 1.306 | 81.9 |
| 1954 | 9,896 | 1.245 | 78.1 |
| 1955 | 9,847 | 1.214 | 76.2 |
| 1956 | 10,100 | 1.176 | 73.8 |
| 1957 | 11,093 | 1.124 | 70.5 |
| 1958 | 9,984 | 0.998 | 62.6 |
| 1959 | 10,145 | 0.949 | 59.5 |
| 1960 | 11,279 | 0.947 | 59.4 |
| 1961 | 9,390 | 0.900 | 56.5 |
| 1962 | 10,339 | 0.881 | 55.3 |
| 1963 | 10,059 | 0.837 | 52.5 |
| 1964 | 9,507 | 0.820 | 51.4 |
| 1965 | 9,187 | 0.777 | 48.7 |
| 1966 | 9,089 | 0.768 | 48.2 |
| 1967 | 8,971 | 0.741 | 46.5 |
| 1968 | 8,645 | 0.704 | 44.2 |
| 1969 | 8,648 | 0.658 | 41.3 |
| 1970 | 7,960 | 0.620 | 38.9 |
| 1971 | 7,977 | 0.622 | 39.0 |
| 1972 | 7,119 | 0.611 | 38.3 |
| 1973 | 8,018 | 0.626 | 39.3 |
| 1974 | 6,997 | 0.618 | 38.8 |
| 1975 | 5,679 | 0.579 | 36.3 |
| 1976 | 6,403 | 0.573 | 35.9 |
| 1977 | 6,372 | 0.542 | 34.0 |

** Long tons to 1970, metric tonnes thereafter

* Source: Tin international

In terms of the relationship between innovations, particularly from a stimulus - response perspective, the differential development is in the category of a 'secondary ripple' inasmuch that it was not only made possible by electrolytic deposition but was an inherent feature. The basic function of the tin coating is to protect the steel base from attack from various corroding media. Hot-dipped plate has always been considered a superior product to elt. in terms of corrosion resistance, the latter having long been associated with wide variation in shelf life performance. This superiority, however, was accompanied by many wasteful aspects, a salient one being that with pot-coated plate one must have the same tin coating weight on both sides of the steel.

The different corrosion hazards which a can is subject to vary considerably in their intensity. With acidic products packed for the UK market, for example, the danger of internal corrosion is much greater than that of external corrosion. On the principle that one should produce a pack with the minimum necessary properties to fulfil its function then, in this example, an equal coating of tin on both sides of the plate must necessarily entail a needlessly thick coating on the exterior of the can.

With electrolytically coated plate, however, it is possible to independently control the weight of the tin coating; the deposition on the steel surface is directly proportional to the amount of electrical current used; a different current through the tin anodes used to electroplate each side gives two different coating weights. The potential cost saving of this feature of elt. tinplate lines was well appreciated from the outset and experiments to differentially deposit date back to the pioneer days of elt. tinplate lines in the late 1930s. This research continued slowly during the 1940s until in 1951 in America the first successful commercial trial of differential tinplate was undertaken. The specific reason which led to this commercial exploitation was that 1lb per basis box (11.2 $g/m^2$) material produced by electrolysis did not prove as economic as the same coating deposited by hot-dipping.

With differential tinplate came the new problem for both supplier and user of how to distinguish the different coating sides. In the early 1950s when only one grade of differential tinplate was available - 11.2/2.8 $g/m^2$ - the solution to this problem was comparatively simple, it being necessary only to mark one side. A number of practices were adopted for marking the side with the lighter coating - somewhat strangely in view of its lower corrosion resistance. By imparting a matt finish, or by printing a simple diamond mesh pattern, the lower coating could be identified. (14)

As the 11.2/2.8 $g/m^2$ coating proved itself so the range of differential coatings made available was increased. This necessitated some system of marking to correspond with each coating weight. The technique adopted was to apply a system of parallel lines running down the heavier side of the plate, the spacing between the lines indicating the specific coating weights.

The first production of differential tinplate in the UK was at Ebbw Vale in 1961 on the new No. 2 elt. tinplate line of RTB. The reason this technique was not adopted earlier was probably because of the equipment changes it required, which were expensive. Differential (sometimes called dual-coated) tinplate has been an unqualified commercial success and is used by can-makers wherever it is suitable. The ultimate exploitation of differential tinplate would seem to be a product with one tinned and one uncoated surface; there is undoubtedly scope for such a material. This particular extension of the technology poses some peculiarly difficult problems - presumably of an electrochemical nature. No such tinplate, if that would be the appropriate term, has been produced in this way in the UK, though at least one line of half tin - half galvanized sheet has been successfully operated in the US*.

iii. Hot-Dip Tinning

The corollary to the progress of elt. plate, with or without a differential coating, is the fate of hot-dipping. It is apparent from the section on elt. tinplate that there was a gradual reduction in the contribution of pot coated plate to total tinplate output in the post-war period. The actual figures are as follows:

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* A relevant point to remember is that the production of differential tinplate created an anomaly in the old and still widely used tinplate terminology. The designation 1.00/0.25 means that the material carries on one side a coating having the same thickness value as 1.00 lb per basic box tinplate (0.50 lb per basis box per face) and carries on the other side a coating having the same thickness as an ordinary 0.25 lb tinplate (0.125 lb per basis box per face). It does not mean that the coating weight is 1lb per basis box on one face and 0.25 lb per basis box on the other. (15)

TABLE VI*

UK Hot Dipped Tinplate Production

| Year | Output (Tons) | % of Total | Year | Output | % of Total |
|---|---|---|---|---|---|
| 1947 | 541 900 | 100 . | 1962 | 261 502 | 22.3 |
| 1948 | 560 000 | 93.6 | 1963 | 243 456 | 20.6 |
| 1949 | 551 500 | 90 | 1964 | 219 971 | 19.0 |
| 1950 | 594 000 | 90.4 | 1965 | 161 281 | 13.7 |
| 1951 | 569 000 | 90.4 | 1966 | 140 129 | 11.8 |
| 1952 | 730 975 | 90.4 | 1967 | 132 865 | 11.0 |
| 1953 | 520 123 | 77.1 | 1967 | 111 699 | 9.1 |
| 1954 | 563 170 | 71.2 | 1969 | 102 634 | 5.5 |
| 1955 | 559 746 | 69.5 | 1970 | 66 891 | 5.2 |
| 1956 | 577 065 | 67.2 | 1971 | 66 900 | 5.2 |
| 1957 | 589 328 | 59.7 | 1972 | 33 500 | 2.9 |
| 1958 | 442 024 | 44.2 | 1973 | 42 700 | 3.3 |
| 1959 | 396 002 | 37.1 | 1974 | 34 700 | 3.0 |
| 1960 | 434 821 | 36.5 | 1975 | 18 400 | 1.9 |
| 1961 | 289 237 | 27.7 | 1976 | 5 300 | 0.5 |

* Source: Various

The passing of hot-dip plating in the UK is obviously a classic case of the gradual displacement of an old technology by the new. There was never very much doubt that this was the course events would follow, it was not even considered appropriate as early as the mid 1950s to install hot-dipping capacity at the new Velindre Works. The pot coating for this plant was carried out at the nearby Elba Works. However, there were for most of the post-war period nine and ten pots at Trostre and Ebbw Vale respectively, though not all of course continuously in use.

Behind the superficial impression of an obsolete process being steadily replaced it is important to remember that a new, well designed plant such as the high speed single sweep Poole-Davis Units at Trostre represented the ultimate in the mechanization of hot-dipping and they also produced good quality plate. They were helped, as was elt. depositing, by the very high quality steel surface which was available through cold-reduction. On such material it was possible to produce tinplate of finish, consistency and at a speed all far superior to what passed before as pot-coated plate.

As demand fell back for hot-dipped plate so pots were successively abandoned. On December 31st, 1976 B.S.C. officially produced their last hot-dipped plate. There was still a demand for the product, particularly for export, but this was considered insufficient to justify its continuance. However, Metal Box, who had previously produced hot-dipped plate in four pots at their old Eaglesbush, Neath, tinplate works, purchased some of the redundant Trostre facilities. Metal Box are using the facility to re-process plate whose surface is defective for one reason or another (it is not practicable to re-tin by electrolysis).

4. <u>Annealing</u>

<u>Introduction</u>

It will be remembered that the annealing operation - the heating, 'soaking' and cooling of tinplate after rolling to bring it to fabricating quality - was directly affected by the introduction of cold reduction. This latter innovation, by producing a more uniform, consistent and ductile product, eliminated the need for two annealing cycles.

i. Continuous Annealing

Indirectly, the introduction of cold working affected annealing by encouraging consideration of the possibility of performing all the other tinplate manufacturing operations in continuous form. The first continuous annealing (CA) facility, installed by Crown Cork and Seal in 1936, did not lead to any immediate attempts at imitation. The introduction of elt. tinplate on a wide scale in the 1940s meant that the two major tinplate manufacturing processes were now carried out in continuous operations, this will have further encouraged the adoption of the new annealing technique.

Interest in strand annealing was given a further fillip in 1946 when Dominion Foundries and Steel Co. Ltd., Hamilton, Ontario, installed a duplicate of Crown Cork's furnace, but incorporated an alkaline cleaning process ahead of the annealing. This combination created considerable interest, and in 1949 Indiana Steel Company started production of a unit designed to clean and anneal continuously at a maximum speed of 1,000 f.p.m. (16)

The innovation of CA began to gain acceptance in the States in the 1950s and by 1964 more than half the tinplate industry's output could be processed by this method. (17) Outside America, however, producers were not quick to adopt it. The first significant European installation was commissioned in 1956 at Rasselstein's Andernach Works in Germany. Unlike other facilities this unit annealed the strip while horizontal in a three deck operation not unlike the Halogen elt. line. This construction was decided strategically rather than technically because of the existing building and crane height. (18)

The hesitancy in adopting CA plate by manufacturers was understandable because neither the case for its technical nor its economic superiority to batch annealed (BA) plate was totally convincing. The immediate technical advantages of the newer process were, however, attractive. Its first advantage was its speed; in the continuous method the whole annealing operation took only a few minutes, the strip speed being as much as 2,000 f.p.m. on the fastest lines.[19] This compared to the batch process which took days and tied up a large amount of material and factory space at any one time.

The second advantage of CA plate was seen as the diversity of uses to which it could be put owing to a unique combination of strength and ductility. Its uniform physical properties recommended it as a possible replacement for most qualities of BA plate. The varying array of steel base types, differing in composition and temper, made possible by the technological and scientific advances of the early 1930s led to increasing problems for manufacturers and users in keeping an adequate tinplate inventory, and to increasing complexity in manufacturing, shipping and purchasing operations. CA plate was viewed by some as a kind of panacea that would combine the qualities of several different tempers and base compositions without sacrificing the quality advantages inherent in each.[20] In America a reflection of this thinking was the designation of CA plate as 'universal temper' (TU) suggesting perhaps that it could replace all other plate qualities. BA plate did not have the metallurgical uniformity of CA plate because in any type of closed coil annealing system the heat must penetrate through the laps; when cooling the heat is removed in the same way. Since the hottest part of the coil has a slightly longer soak, it is very difficult to obtain consistent properties throughout the coil.[21]

The third advantage of CA plate was considered to be its greater hardness over the batch treated material. This was associated with a 'springiness' in the plate. It was envisaged that this greater tensile strength would allow reductions in plate substance for given applications and a consequent saving in direct material costs to the can-maker. The possibility of continuously annealed plate made of a base steel alloyed with nitrogen to improve its rigidity was considered particularly promising.

Subsequent experience was to partially vindicate all three expected advantages of CA plate, but with each advantage came a corollary disadvantage. Its most obvious benefit of speed was indisputable, but this was not achieved without its problems such as in obtaining consistent tracking. It is also necessary to completely stop the installation for as many as three shifts in as many weeks for routine maintenance and, moreover, when burner tubes have to be changed six shifts down-time is necessary. (22)

The second advantage of continuous strand annealing - its diversity of applications - proved to have been overestimated in some initial evaluations. Non-rephosphorized CA plate never lived up to its 'temper universal' label. This grade has never looked a serious substitute for the lowest temper grades of "extra deep drawing quality". Although most of the other temper grades have been successfully obtained, CA plate has proved most suitable for the higher grades. In the UK it became the practice to continue to produce the three lowest grades by BA, to produce the two highest grades by CA, and to offer a choice of batch or strand annealed for the intermediate grade, temper 4. So, depending on one's perspective, it is perhaps as easy to consider CA plate as inflexible as it is flexible. This inflexibility aspect arises because there is only one CA cycle, and for a given furnace any attempt at radical alteration results in problems of buckling and breakage. (23)

As regards the third mentioned advantage of CA plate - its greater hardness - it is probably here that the new process has lived up best to its early billing. For those uses to which it was applied CA plate did facilitate the gradual reduction of tinplate substance. This impact can best be illustrated during the 1950s in America before further innovations designed specifically for this end were introduced: In the early 1950s beer can bodies were made of 0.257 mm plate and the ends of 0.320 mm plate; by the late 1950s the bodies were constructed of 0.214 mm plate and the ends of 0.306 mm plate. (24) Again, however, this higher tensile strength had its drawbacks. The springiness with which it was associated caused 'fluting' which made for production problems in the manufacture of small diameter containers.

A further advantage in strength was made in the mid-1960s by the Inland Steel Company of the USA by what appears to have been a change in the CA cycle. In this method the steel is 'austenitized', that is, heated to temperatures of around 900° ; this is above the lower transformation temperature of steel and serves to convert the ferrite structure to austenite. The strip is then rapidly quenched by water in specifically designed equipment. This gives a structure described by Inland Steel as "tempered martensite". Nothing appears to have come of this innovation in the UK, though the patented process had produced steel in can-making gauges as early as 1965. (25)

One of the 'side effects' of CA is that it acts as a partial substitute for temper rolling.

As in the case of the rest of the world's tinplate producers the Welsh manufacturers bided their time during the early 1950s observing the results of American CA experience. In 1957, however, SCOW installed Europe's first vertical CA facility at their Velindre plant. This unit was built by the incandescent Heat Co. Ltd., under licence from the Drever Company. The entry section of this installation is similar to that at the tinning stand, with two pay-off reels, welder, shears and pinch rolls. This is followed by an alkaline cleaning unit. A fourteen stand looping tower provides a reservoir of plate and prevents line breaks. This tower is equivalent to about 600 ft. of strip - i.e. a one minute supply. In the heating section the strip makes five passes through a furnace heated by radiant gas tubes. From the heating section the strip passes through the soaking section, which is electrically heated for temperature equalization, and then travels to the controlled cooling sections. There are three controlled cooling passes where a temperature drop from 1350° F to 800° F is obtained by utilizing exhaust-type tubes. The tubes are designed to remove a given amount of heat from each furnace section. Cooling to below oxidising temperature is accomplished by the passage of the strip through sixteen water-jacketed chute sections. Final cooling to 150° F is achieved by two forced air cooling sections. The exit looper is similar to that at the entry stage and is followed by shears, a tension reel and a belt wrapper. (26)

The decision to invest in CA at Velindre was followed by similar decisions for the other two Welsh tinplate mills.

TABLE VII*

UK Continuous Annealing Facilities

| Year Commissioned | Plant Location | Capacity (weekly tons) | Maximum Speed (m.p.m.) |
|---|---|---|---|
| 1957 | Velindre | 2,500 | 180 |
| 1962 | Trostre | 3,800 | 366 |
| 1964 | Ebbw Vale | 3,800 | 380 |

* Source: Various

Installing CA is invariably a 'one-off' job at each plant in that - unlike elt. plating - one does not normally add additional facilities.

It was mentioned earlier that the cost advantages of CA were not cut and dried. In the case of this innovation comparative cost data on the two technologies is available.[27]

TABLE VIII*

Capital Costs (£)

| Unit | Tinplate BA | CA (Velindre) |
|---|---|---|
| Weekly output (tons) | 7,000 | 2,500 |
| Total Capital Cost (£) | 1,205,187 | 876,303 |

* Source: Ascough

It will be seen (Table VIII) that the capital costs of a CA plant to produce thirty five per cent of the output of a BA plant is only thirteen per cent less expensive. This suggests a prima facie case against CA. However, although the figures are not available, it is unlikely that the same ratio of capital costs to output applied to the larger Trostre and Ebbw Vale facilities because the higher outputs on CA lines can be achieved at little additional capital expense.

Given the extent of the capital cost disadvantage of the CA process in the Velindre case it is probable that even with the higher outputs it would be necessary to recoup the higher overheads by more favourable running costs. Table IX [(28)] gives a comparison of the Velindre running costs of BA vis a vis CA. Again it will be seen that BA cleaning comes out more favourably than CA. However, the use of tonnage figures creates a distortion here. CA plate is of the higher temper grades and has a lower weight to surface area ratio than BA; when this qualification is included BA loses much of its advantage. Secondly, running costs of a CA line do not vary in proportion to output, and with the higher outputs of Trostre and Ebbw Vale the variable cost per ton should also be more favourable. The CA plant also saves on other costs by reducing the stocks of tinplate held at any one time.

TABLE IX*

Batch Annealing, Cleaning, and Continuous Annealing Costs - Velindre

| | Batch Annealing | | Cleaning | | Continuous Annealing | |
|---|---|---|---|---|---|---|
| No. of lines | | | 2 | | 1 | |
| No. of furnaces | 7 | | | | | |
| No. of bases | 15 | | | | | |
| Tonnage per week | 7624 | | 6593 | | 2471 | |
| | Cost per ton | | | | | |
| | s | d | s | d | s | d |
| Productive labour | 1 | 1 | 1 | 10 | 2 | 9 |
| Productive supplies | | | | | | |
| Covers and plates | 1 | 9 | | | | |
| Detergents | | | | 10 | 1 | 10 |
| Gas | 6 | 5 | | | 7 | 9 |
| HNX gas | 1 | 9 | | | 1 | 6 |
| | 9 | 11 | | 10 | 11 | 1 |
| Services | | | | | | |
| Electric power | 1 | 11 | 1 | 4 | 3 | 7 |
| Steam | | | 1 | 9 | 2 | 4 |
| Other | 1 | 3 | 1 | 10 | 2 | 10 |
| | 3 | 2 | 4 | 11 | 8 | 9 |
| Maintenance | 1 | 4 | 3 | 10 | 9 | 1 |
| Expense | 3 | 3 | 3 | 4 | 6 | 6 |
| Scrap | | | 7 | 10 | 20 | 4 |
| TOTAL | 18 | 9 | 22 | 7 | 58 | 6 |

* Source: Ascough

From the above two sets of data it would seem to be the case that BA holds the advantage where low tonnage is concerned. The variables introduced to this discussion such as throughput mean, however, that no hard and fast general statement of the respective viabilities can be made. This is also the conclusion of Ascough:

"After touching briefly on the factors influencing costs of various types of furnace, one might be tempted to say that one is more economical than another, but this would not be true for the general case. Each new installation to be built has to be considered in relation to output of different grades, total output, coil size, etc., and the final choice has to be made after balancing all the cost factors. The iron and steel industry is far from static, and the correct choice now might be considered to be wrong in ten years time. To illustrate this, there have been continuous furnaces in Europe for 30 years*, but their slow speed, slow output, and high fuel consumption prevented them from becoming an economical venture". (29)

One is struck by the similarity of this analysis of the factors determining the choice of annealing facility with that of Hoare (page 14) on the suitability of alternative electrolytes for elt. tin-plating. Both seem in effect to be arguing for specific innovations to be assessed by management from a broad analytical perspective. This would seem to support the hypothesis that to make prescriptions or evaluations about innovation at one point in time as if they could be transposed to another place and time is to court disaster; it is akin to supposing that a particular institutional system can be successfully imitated elsewhere without any regard to the peculiar

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* First experimental line in Germany in 1931

social, cultural (or whatever) influences which gave rise to the institution in the first instance.

The innovation of CA plate differs in an important respect from many of the other developments in tinplate manufacture, eg. cold reduction, elt. tinning, and other innovations to be subsequently discussed. These innovations have a common denominator in that they may all be employed to the point where they completely replace the technology to which they are an alternative. This similarity allows the historical development of the industry to be conveniently analysed as conforming to a consistent pattern. CA, somewhat unfortunately perhaps, upsets this consistent development because at best it can only supplement conventional annealing methods.

It is a reflection of the failute of CA to live upto the claims of its early canvassers that conventional coil annealing has been subject to further major development.

ii. Coil Annealing

It will be remembered that the innovation of cold-reduction in place of pack-rolling allowed tinplate to be annealed in coil as opposed to cut-plate form. This led to the introduction in the 1930s of stationary multi-stack BA furnaces instead of 'in and out' plate annealing on crude railed ways. These multi-stack annealing furnaces have been the only BA method used for most of the post-war period. It was probably a certain disappointment with CA that encouraged the development of two new annealing processes - 'open coil' and 'single-stack' annealing.

In America in the late 1950s the Lee-Wilson Company developed what is usually described as a one-step advance on the conventional annealing process; the inclusion of a pay-off reel facility, however, gives the innovation something of the flavour of a continuous/batch hybrid process. In this "open coil annealing" method the furnace handles one coil at a time and by a process involving the use of a spacing material - usually a nylon strip - a pay-off reel and a re-wind mandrel, the coil is opened out prior to processing. The steel, still in coil form but now loosely wound, is about twice its original diameter with a uniform space between each lap. The advantage of this technique over the conventional batch method is that the loosely coiled strip allows the gases to circulate between the laminations while it is heated, soaked and cooled in a rotary furnace. This convector method overcomes a main disadvantage of traditional annealing whereby the rate of conduction varies at different points of the tightly wound strip. This new method therefore produces a more uniform steel base.

The first and only open-coil annealing furnace to be installed in the UK was that of RTB at Ebbw Vale in 1966. (30) This facility was subsequently closed down. (31)

Single-Stack Annealing

An alternative to covering a row of stacked coils with a portable furnace is to anneal each stack individually. By this method the coils are stacked four to five high on circular pedestals and enclosed with a dome-shaped heat resistant cover. The furnace looks not totally unlike the inner bell used in the conventional operation. The actual principles of operation are the same as in the conventional process. This fairly straightforward variation on the traditional annealing method is known, appropriately enough, as single-stack annealing. This method has the advantage that small urgent orders can be processed more quickly and, where a variety of cycles are necessary, small tonnage economies can be reaped. It also saves on 'complementary capital' in that annealing basements are dispensed with and the capacity of cranes and structures can be reduced. (32)

Although this technology was available in the 1950s UK tinplate producers for a long time considered their higher installation cost to make them uneconomic. It would seem, however, that when the decision to invest was finally made the operating results were favourable, since all three tinplate plants have now adopted the single-stack technique. It is somewhat ironic that it should be the least revolutionary of the three new annealing methods which should finally despatch the traditional method. This again points to the value of less dramatic developments.

TABLE X*

UK Single-Stack Annealing

| Plant | No. of Bases | Commissioned |
|---|---|---|
| Velindre | 18 | 1971 |
| Trostre | 18 | 1975-76 |
| Ebbw Vale | 51 | 1975-79 |

* Source: Various

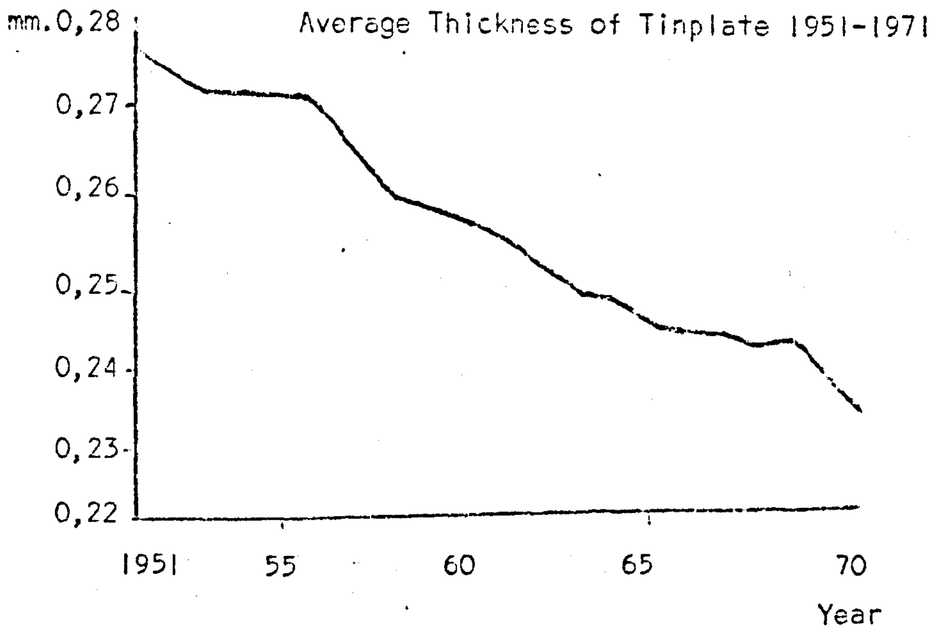
At Velindre and Trostre multi-stack annealing was completely closed down as the new furnaces were commissioned. At Ebbw Vale the phasing in and phasing out operations are being undertaken more steadily; the first six of the new bases were commissioned in May 1975, by June 1977 this number had been increased to twenty seven. By this latter time the number of multi-stack bases had been reduced to eighteen.

A reflection of the ever increasing importance of sophisticated control mechanisms is the fact that Ebbw Vale's single-stack facility is the first computer controlled annealing installation.

5. Double Reduction (DR)

The overriding reason behind technological change in the tinplate industry is cost reduction. One way of achieving this is to produce material in ever thinner average gauges. In the UK throughout the post-war period the average gauge of tinplate for a given application has been gradually declining, (Table XI).(33)

TABLE XI*




* Source: Barry

In the last year before the introduction of DR to the UK, 1967, average tinplate thickness was down to 0.246 mm.(34) The introduction of DR plate to the UK in 1968 resulted in a sharpe reduction in average plate thickness. This downward trend is still continuing.

The majority of this reduction took place before 1968, i.e. it was achieved within the conventional rolling technology, principally by changing the chemical composition of the steel base by the addition of phosphorus or nitrogen during steelmaking. (35) These lighter gauges were also encouraged by advances in cold reduction technique itself which have led to more consistent gauge control. (36) The introduction of continuous annealing as has been shown was also a contributory factor in that it resulted in a material of increased consistency and stiffness. (37)

Two principal reasons combined to bring about an end to this incremental tinplate gauge reduction within the framework of existing rolling technique. The first was that, in any case, the practical limit for conventional tinplate was reached at about 0.168 mm and that below this thickness the tinplate was not sufficiently strong for general line and open-top cans. (38) (Anything below 0.20 mm may be considered as thin tinplate).

The second major reason was direct market forces. In America as early as the late 1950s, and in the UK ten years later to a lesser extent, competitive packaging developments began to make inroads into the can-market. In America the threat of the non-returnable beer bottle to the 8.4 billion cans per year (1959) beer market, and the strong contention of the aluminium can for the citrus juice market - a traditional tinplate domain - were pressing reasons for lowering the price of tinplate. (39)

It was also reported that "thin tin" was developed to extend the range of tinplate uses rather than just to combat alternative materials alone. (40) This argument appears to have been an attempt to play down the threat of aluminium; significantly, later in the same article, the prediction of one USSC tin mill official is reported as "We'll have aluminium on the run soon in the juice can field".

The answer to these alternative packaging media was seen as a radically thinner tinplate of comparable performance to the existing type and which could be sold to the can-maker at dramatically reduced prices. This was to be achieved by subjecting the tinplate to an additional cold-reduction. (This second reduction became known as 'double reduction' although the amount of reduction is not doubled at all). The second cold working would not only be to reduce the gauge of the material but also to strengthen it through strain hardening.

It will be remembered that in the conventional tinplate manufacturing process the hot-rolled strip is given a heavy cold reduction to the final gauge in a five stand tandem mill. After annealing to restore ductility the strip is temper rolled to impact the final mechanical properties; during temper rolling an incidental reduction of two-four per cent takes place. After temper rolling the strip is tinned.

The first company to announce publicly that it was working on a thinner tinplate was, in fact, USSC. (41) The question facing US Steel, and anyone else contemplating DR, was at which point in the manufacturing sequence and by which rolling method the second reduction was to be effected. USSC decided to produce tinplate by conventional methods, including batch annealing, and to then apply a second cold working of fifty per cent on the 'finished' material.

Allowance thus had to be made when applying the tine coating for the reduction that it too would suffer. US Steel prodcued its first commercial quantities of DR plate in 1960. The material was about half the thickness of its conventional equivalent was was given the name 'Ferrolite'. When USSC launched DR plate onto the market in September 1960 its price was as much as $1.30 per base box down on standard weight tinplate.

The manufacturing sequence initially adopted by USSC was duplicated by the imitators who immediately entered the field. One of the early problems that had to be overcome was that the DR material from the different producers varied in the appearance and lustre of its matt-like surface. It was found necessary to quickly re-establish a uniform finish because can-makers had difficulty in matching the varying appearances sent from the different producers. The base colour is particularly important for the decorated can because it is used as a base in lithography. (42) As a result of this appearance problem, and also because of problems in the soldering operation and corrosion resistance of the original DR plate, the initial manufacturing sequence was quickly abandoned. By 1962 nearly all the American producers were adopting an alternative method whereby they cold worked the steel twice while it was still in blackplate form, the second rolling being an alternative to temper rolling. It has been reported that this method was first used in the UK; (43) if correct one can only suppose it was on some form of experimental basis. It has also been stated, however, (44) that one American steel company as early as 1960 contended that the steel must be reduced to final gauge before coating with tin, which makes the UK 'first' most unlikely.

The second question of what rolling technique was best suited to effect the second reduction resulted in all sorts of mill permutations. Some producers used single stand temper mills, others used two stand mills, and still others used three stands of their old multi-stand mills. Six of the first seven mills erected within the initial twelve months after US Steel's breakthrough were two stand mills and only one was a three stand mill. The first company to install a three stand mill specifically designed to roll DR plate was Jones and Laughlin in 1963 at their Aliquippa, Pennsylvania works. The first stand was operated as a 'dry' mill to provide controlled tension, with a one - two per cent reduction avoiding strain breaks and improving shape regularities. This served to improve flatness for the major cold-reduction which took place in the second stand. This stand could, if desired, reduce fifty per cent or more. The final stand could also reduce fifty per cent or more but was normally used for a one to fifteen per cent reduction as the occasion required. (45) The three stand mill despite its laggard initial popularity appears to be the standard unit for effecting DR and has been, until recently, the only type of DR mill in the UK.

The initial American DR plate was offered in four gauges of 0.125 mm, 0.139 mm, 0.153 mm and 0.167 mm, or 45, 50, 55 and 60 lbs per base box respectively. As the material became established the number of gauges and the variety of elt. coatings it received were increased. The success of this innovation is indicated by the fact that as early as 1964 twenty five per cent of all elt. tinplate sold in the US was of the DR kind. (46)

One of the unavoidable aspects of tinplate manufacture is that the finished material must satisfy two criteria; one is that the plate should be sufficiently malleable to withstand the severe fabrication requirements in can-making and, secondly, it must be sufficiently strong to perform its protective packaging function. The inexorable law of action is equal to re-action operates here, and these two criteria are diametrically opposed. The virtual doubling of the tensile strength of tinplate effected in the thirty per cent or so cold working has the disadvantage that it imparts to the material strong mechanical and structural directionality. This loss of ductility has important implications for DRs suitability as a can component. These aspects are discussed in the can-making section.

In the UK from 1962 conventional tinplate of thin gauges was used for some general line containers - ice cream tins and pastille tins to name but two. In the absence of both the large beer can market and the significant penetration of aluminium that existed in the United States, the pressure on the UK tinplate producers to develop or install a DR facility was not as urgent as in the US. However, by the second half of the 1960s these factors were beginning to change. In 1964 plans for a DR facility as part of a huge long-term tinplate development programme were approved. In 1966 SCOW placed an order with W.H.A. Robertson (of the Tube Investments Group) for a new type of rolling mill for producing extra thin tinplate. Robertson were marketing the mill for another Tube Investments subsidiary, Loewy Engineering, who had designed and developed the mill. At the time the mill was described as "a major breakthrough in a field hitherto dominated by American techniques".(47) The contract was worth £1m to Loewy-Robertson. The three stand mill was installed at Trostre in 1967. The cold reduction of steel strip on the DR mill is controlled by a digital/analogue process computer and is the largest installation of its kind in the UK under this type of control. [48] Teething troubles prolonged the commissioning period and commercial quantities were not produced on the mill until the latter half of 1968. By this time SCOW was part of the South Wales Group of the British Steel Corporation.

When the DR process was introduced to the UK the lowest gauge conventional tinplate available was 0.167 mm. This was itself being increasingly used in can-making. Below this gauge it was necessary to consider alternative ways of reducing substance since the decreased thickness had to be compensated for by an increase in strength. Of the alternative means open to them SCOW had decided that DR was preferable. Initially only two "DR'" gauges were available - 0.167 mm and 0.152 mm. This material had a tensile strength of 80,000 lb sq/in. compared to 52,000 lb sq/in. in its conventional equivalent. [49] By 1972 BSC was producing a second DR product - "DR9". This was offered at a gauge of 0.264 mm. The DR tinplate produced at Trostre was offered in the full range of elt. tin coating weights, including differential, and also with the same chemical passivation and oiling treatments.

The cost reducing impact of the DR mill was directly reflected in new price lists produced by BSC in early 1970. [50]

TABLE XII*

| Type | Coating Weight g/m² | £ per S.A.T.** |
|---|---|---|
| DR elt. tinplate | 5.6 | 8.929 |
| Elt. tinplate | 5.6 | 10.554 |

** i.e. 100,000 sq. in. of tinplate

* Source: Tin International

At 1978 prices the cost difference between elt. and DR tinplate has been eroded to less than 6½% (£57.61 per Sita*** against £53.31 per Sita respectively).

Britain lagged behind many of her international competitors in adopting a DR mill, and the single facility at Trostre remained the UKs only source of DR plate for a decade. In 1978 a second DR mill was commissioned at Ebbw Vale as part of the £57m. tinplate development scheme. The new mill is a hydraulic tandem mill having a two stand four-high arrangement. Almost all the cold reduction is achieved in the second stand. The facility is designed as a dual purpose mill, i.e. as either a second reducer or as a temper mill. The maximum DR output is around 4,000 tonnes per week and the mill will reduce to a gauge of 0.075 mm. It has a maximum running speed of 1,850 m/min. (51) It has been suggested, in fact, that BSC, somewhat ironically, now has an overcapacity in DR plate.

One of the features of DR plate, and a good example of the way in which a change at one point in the tinplate manufacturing sequence often creates problems at another point, is the somewhat poorer

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*** 100 square metres of tinplate

appearance of DR material as opposed to conventionally reduced. This difference arises because the cleaning facility on the tinning stand is not sufficient to compensate for the lack of a separate cleaning facility after second reduction.

It has earlier been mentioned how tonnage statistics for tinplate can be misleading; gauge reduction and particularly DR are principally responsible for this. The basis of tinplate trading is area - which is the only meaningful unit in which to purchase tinplate. Most of the production and consumption relating to tinplate, however, come via the steel industry's general statistical department - which thinks in terms of weight. The gauge reduction which has taken place therefore means that many statistics can actually mislead one as to the trends in tinplate manufacture and usage - a reduction in tonnage consumed, for example, may in fact conceal an increase in the number of articles fabricated.

The case history of DR tinplate shows an interesting similarity to that of elt. tinning. The latter innovation was introduced only when coating weights seemed to have reached their practical minimum by hot-dipping methods. Likewise, a second cold working was not developed until the scope for further gauge reduction by conventional means was nearly exhausted. This similarity would seem to reinforce the idea of the innovation process as an essentially incremental activity until one can go no further within the existing technology.

6. <u>Intermediate Operations</u>

The operations undertaken in the manufacture of tinplate may be said to roughly fall into two categories. There are, firstly, those operations in which the major physical changes are effected and, secondly, those operations which may be considered as preparatory or post-treatments around the central manufacturing units. The first category comprises such facilities as cold working and tinning, the second category encompasses what in the pre-1945 section were loosely termed accommodating operations, eg. pickling and cleaning.

It was also said in an earlier section that intermediate operations were developed principally so as to be in harmony with the major manufacturing processes. In the case of pickling and cleaning this harmonization constituted basically, a move to continuous processes. A description of the working of these intermediate operations is left until the complete modern manufacturing sequence is reviewed; here the main concern is with the implementation of these facilities. The growth in pickling capacity is charted below.

TABLE XIII*

UK Pickling Facilities

| Location | Date | Designation | Pickling Speed (f.p.m.) |
|---|---|---|---|
| Ebbw Vale | 1938 | No. 1 | 375 |
| Ebbw Vale | 1938 | No. 2 | 375 |
| Trostre | 1951 | No. 1 | 500 |
| Ebbw Vale | 1956 | No. 3 | 445 |
| Velindre | 1962 | No. 1 | 750 |
| Ebbw Vale | 1975** | No. 4 | 1000 |

** Replaces Ebbw Vale lines 1, 2 and 3

* Source: Various

As regards innovations it is worthy of note that No. 4 pickling line is of the modern hydrochloric acid type rather than the previous sulphuric acid. The action of hydrochloric acid is more rapid than that of sulphuric acid; this facilitates an increase in the throughput of pickle lines.

The role of the pickling operation has not been significantly altered as a result of the adoption of the major new technologies. This is not quite so true of cleaning; it has always been necessary to have the blackplate surface in as uncontaminated a condition as possible for subsequent tinning. With the use of oil as a cooling and lubricating agent in cold reduction the cleaning operation became more important. It has already been described how the introduction of continuous annealing facilitated the incorporation of the two processes in one operation. For batch annealed it was still necessary to have a separate facility. With the trend to continuous processing it was desirable to adapt the cleaning operation to handle coiled steel. Similarly, the principle of electrolysis was applied to assist the alkaline cleaning.

The growth in elt. cleaning facilities is as follows:

TABLE XIV*

UK - Electrolytic Cleaning Installations

| Location | Date | Designation | Maximum Speed (f.p.m.) |
|---|---|---|---|
| Ebbw Vale | 1938 | No. 1** | 800 |
| Ebbw Vale | 1938 | No. 2 | 800 |
| Ebbw Vale | 1938 | No. 3 | 800 |
| Trostre | 1951 | No. 1 | 2000 |
| Trostre | 1951 | No. 2 | 2000 |
| Ebbw Vale | 1956 | No. 4 | 2000 |
| Velindre | 1956 | No. 1 | 2500 |
| Velindre | 1956 | No. 2 | 2500 |
| Ebbw Vale | 1978 | No. 5 | 2400 |

** Scrapped in 1962

* Source: Various

7. Tin Substitutes

i. General

A common but erroneous impression often left on those with a passing interest in metal packaging is that the tinplate industry is concerned with the sale of tin. Nothing could be further from the truth. The steel industry has found that by coating its own basic product with a layer of tin it can enhance the former's applications. The association is therefore a marriage of mutal convenience but with the ferrous partner prepared to forsake its life-time associate at any time should a more suitable companion be found.

The fallacious idea of a tinplate industry committed to tin is due in great part, no doubt, precisely to the long standing and highly beneficial value of the coupling of both metals. As industries, however, the two are almost entirely separate. The majority of the world's tin comes from the Malaysian and Indonesian regions of the Far East whereas it is principally consumed in the developed countries. The tin is mainly mined, or rather dredged, in shallow water-side locations: it is transformed from concentrates into metal in smelters - of which only nine can be considered as of importance. The tin producing chain, unlike in the case of many other non-ferrous metals, has resisted vertical integration. The smelters have very few interests in tin mining, no tinplate plant in any country is owned or was owned by a tin smelter, nor does any tinplate plant own any large tin mine. (52) This independence in production and ownership is in sharp contrast to the trading relationships surrounding tin. Tinplate is the major user of tin being responsible for over forty five per cent of total world consumption. On top of this significant amounts of tin are used in solder for the fabricating of the alloy. Despite the proven track record of tin-coated steel, the tinplate manufacturers have for at least fifty years been actively considering alternatives to the tin layer. There have been a number of reasons behind this desire to find an alternative: no doubt the very principle that one should not be so dependent on one material drawn largely from one source has been a factor. A genuine innovative desire to widen one's product range may also have had a bearing; but the paramount reason has usually been cost reduction. This has manifested itself in two directions (in the present context) - one, to dispense with a top coating altogether, or, two, to replace tin with a cheaper alternative. This second option has gathered increasing support throughout the post-war period as steel-makers have become ever more worried about the danger of an escalation in the price of tin.

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It is sometimes assumed that since the tin coating is so thin and makes up such a negligible part of each can's total cost that any desire to replace it must be a very marginal consideration. It is certainly true that even the larger tin price increases do not affect the salebility of the final container, but because the tinplate producers buy tin metal in such vast quantities it does affect its substitutability at the manufacturing stage. The price of tin is extremely important, therefore, at the technological level where the real choice is made. (53)

As the price of tin increases so the pressure on the tinplate makers to consider alternatives rises. At times in the post-war era, particularly in America, the search for an alternative to tin has been frenzied. It can be seen from the figures below (Table XV) that apart from the Korean war crisis and post 1973 the price of tin has never really risen at sufficient levels or with sufficient consistency to justify this quest for substitutes.

TABLE XV*

London Metal Exchange - Average Annual Tin Prices**

| Years | Price | % Change | Years | Price | % Change |
|---|---|---|---|---|---|
| 1945-9 | 441.8 | | 1964 | 1219.8 | |
| 1950 | 744.6 | +22.9 | 1965 | 1390.4 | +14.0 |
| 1951 | 1077.3 | +44.7 | 1966 | 1255.3 | - 9.7 |
| 1952 | 964.4 | -10.5 | 1967 | 1209.4 | - 3.7 |
| 1953 | 731.7 | -24.1 | 1968 | 1302.4 | + 7.7 |
| 1954 | 719.4 | - 1.7 | 1969 | 1428.4 | + 9.7 |
| 1955 | 740.1 | + 2.9 | 1970 | 1529.5 | + 7.1 |
| 1956 | 787.7 | + 6.4 | 1971 | 1437.4 | - 6.0 |
| 1957 | 754.8 | - 4.2 | 1972 | 1505.9 | + 4.8 |
| 1958 | 734.7 | - 2.7 | 1973 | 1960.4 | +30.2 |
| 1959 | 785.4 | + 6.9 | 1974 | 3493.6 | +78.2 |
| 1960 | 796.6 | + 1.4 | 1975 | 3090.8 | -11.5 |
| 1961 | 888.6 | +11.5 | 1976 | 4254.6 | +37.7 |
| 1962 | 896.5 | + .9 | 1977 | 6181.2 | +45.3 |
| 1963 | 909.7 | + 1.5 | | | |

** £ per long ton to 1964, £ per metric ton thereafter

* Source: Various

The explosion in tinplate prices from 1973 requires some explanation. The price of tin has always been controlled; it is now subject to the international Tin Agreement. This is an accommodation between consumers and producers to prevent inordinate price fluctuations - it does not represent a rigging of the market. The price is manipulated by a buffer stock manager who maintains the price within accepted limits. The oil crisis of 1974 led to a recession in tin consumption when the producers were already restricted to a quote system. At this time a large number of producers opted out of their investment plans. When the tin market came out of recession the buffer stock manager was forced to unload all his stock onto the market. Production of tin began to increase again but the buffer stock manager, with no tin to sell, was unable to affect the market price. As a result prices have increased very rapidly. The United States could have alleviated the problem by selling off some of its strategic reserves of tin but was blocked from doing so at the opportune time by Congress. Experiments with various alternative steel packaging media were commonplace before 1939. As early as 1934 American Can Company had reported that containers without a tin coating had been satisfactorily produced, but were not as efficient as tinned cans. The effect of the war on the tin position made it expedient to manufacture these inefficient cans. The most obvious choice of material was the basic tin-mill product - blackplate. This material was produced covered with a lubricant and had very borderline corrosion resistance, both before and after lacquering. It was necessary to carefully control handling to minimize pin-point rust. Special organic coatings were needed to control both internal corrosion and external filiform corrosion. These 'plain' steel cans were increasingly tried during the war; in 1944 Metal Box produced 600m of them at the speed of forty-fifty a minute. At the time the Company evaluated them as follows:

"With regard to lacquered blackplate sheet and strip, considerable experience has now been gained. The results are on the whole satisfactory. Cans made of these materials have been used on a wide scale for many years and have successfully packed a wide range of products. If used for processed foods they require considerable quantities of lacquer, whilst their speed of fabrication is relatively slow". (54)

The use of blackplate cans was given a fillip when in 1954 American Can Company announced - to the amazement of the tin producers - the launching of the melodramatically titled "Operation Survival". (55) This programme had the avowed aim of eliminating the tin can altogether. This supposedly strategically orientated policy in fact appears to be a front for a very mercantilist attitude on the part of the American industry. It was certainly pursued with a nationalistic rather than a commercial vigour. By 1956 billions of these cans were being produced in America for oil etc. They have continued to be evaluated throughout the post-war period but they appear totally unable to challenge tinplate in its principal markets - food and beverage cans.

A reason for using lacquer on steel is that it is a partial substitute for tin. An intermediate alternative, therefore, is to reduce the tin coating and to increase the lacquer covering. This development has been encouraged by improvements in lacquer technology and in the improved composition and uniformity of the steel base. The logical conclusion to this process would seem to be a high quality steel base coated with an advanced lacquer, i.e. back to blackplate basically.

However, it was realized that the tin coating helps the adhesion of lacquer to steel and has a special effect in preventing chemical attack of the container by its contents. The logical counterpart to putting lacquer over a tin coating is thus to put a tin layer under the lacquer. For this reason one is unlikely to ever see a 'super-lacquer' replace tin.

All sorts of materials including zinc, terneplate and nickel coated steel have been tried as alternatives to tin only to be subsequently abandoned. Another potential substitute, aluminium coated steel, was launched in America in 1967.(56) By this method aluminium is applied by vapour deposition in a vacuum chamber. Again, however, like blackplate, this material is not satisfactory for processed food and beverage cans - except as an end.

ii. '<u>Tin-Free Steel</u>'

The only substitute to really threaten to make a commercial impact on tinplate has been the so-called Tin-Free Steel (TFS). Strictly speaking all steels with alternative coatings constitute tin-free steel; and the term has indeed in the past been used as such a common-denominator. However, with the emergence of chromium-coated steel as tinplate's only steel-based competitor, the generic 'tin-free steel' has been used as if synonymous with chromium-coated steel. The tin community has always objected to the term tin-free steel because it suggests the absence of tin carries some inherent advantage. Whatever the merits of the terminology it is now established.

TFS may be made by two processes, one is a chemical chromating process which might be described as a straight metallic coating of chromium. The other method, and the only one of interest to the UK situation, produces a chromium - chromium oxide coating. This is manufactured by electrolytically depositing a thin layer of metallic chromium on the steel base, which in turn is covered by a thin, passive, coherent layer of chromium oxide. Technologically, the elt. chromium coating process - while not a 'spin-off' - is an off-shoot of the conventional elt. process. The TFS system of electroplating is exactly the same as with elt. tinplate except for the use of different types of anodes. A TFS line looks exactly the same as a tinplate line except that the flow melting stand and chemical treatment sections are not required. Not surprisingly, therefore, it has been possible to adapt both acid and alkaline elt. tinplate lines to dual tinplate/TFS facilities.

The difference in the cross sectional structure of TFS and tinplate is as follows. (57)

TABLE XVI*

Tinplate/TFS Cross Sections

| Tinplate | | TFS | |
|---|---|---|---|
| Layers | Thickness (ins.) | Layers | Thickness (ins.) |
| Oil film | $10^{-7}$ | Oil film | $10^{-7}$ |
| Tin oxide | $10^{-7}$ | Chromium oxide | $10^{-6}$ |
| Tin | $10^{-4}$ | Chromium metal | $10^{-6}$ |
| Alloy layer | $10^{-5}$ | Steel base | $10^{-2}$ |
| Steel base | $10^{-2}$ | | |

* Source: Bevan

With the emergence of TFS as a possible successor to the established metal it is not surprising that the debate as to the relative advantages of the new material sometimes became over-heated. In an effort to get TFS off the ground it was felt by some observers that advocates of the new material were making wildly exaggerated claims. (58) It was the opinion of the tin producers that the steel men, in making these claims, were in danger of killing the goose that lays the golden egg and thereby being hoisted by their own petard:

"The recent development of the so-called tin-free steels (TFS) has caused a great deal of excitement and indeed to a number of observers there is a real danger that some tinplate producers (which are also taking steps to make TFS) may allow themselves to sell tinplate short, metaphorically, to boost TFS. Tinplate has, of course, many advantages, the most important of which is firmly established markets". (59)

The major advantage of TFS was seen in the material cost saving over tin. It was counter-argued that this was largely offset by the extra lacquering required. A second disadvantage of TFS was seen as the capital cost of installing the new equipment. Beyond these fundamental cost questions were the marginal considerations; advantages in this category were that lacquers adhere to chrome better than to tin, that chrome is resistant to sulphur staining, that it is possible to use much higher temperatures for baking lacquers because of the relatively low melting point (450° F) of tin. This last advantage was seen as favouring the development of high speed lacquering on continuous strip coating lines rather than the traditional rolling coaters and wicket ovens. Against this it was argued that TFS was brittle, that it had a more limited range of outlets and that, in any case, it would have to compete against double reduced, 5.6 $g/m^2$ coated elt. tinplate which was a very cheap material. (60)

TABLE XVII*

Companies Holding TFS Licenses (61)

| Licensing Company | Licensee: Country | Licensee: Company |
|---|---|---|
| Nippon Steel (Merger of Yawata Steel and Fuji Iron and Steel) | Belgium | Cockerill-Ougree<br>Providence** Phoenix Works SA** |
| | Brazil | Cia Siderurgica Nacional** |
| TFS trade names "Supercoat" and "Cansuper" | France | J.J. Carnaud & Forges- de Basse Indre.** Sollac |
| | Germany, West | Klockner-Werke**<br>Hoesch A.G. |
| | Netherlands | Hoogovens** |
| | Philipines | Elizalde |
| | Portugal | Cia Siderurgica Nacional** |
| | USA | Bethleham Steel<br>National Steel<br>Youngstown Steel & Tube<br>US Steel Corporation |
| Toyo Kohan | Canada | Stelco** |
| | Germany, West | Rasselstein |
| TFS trade name 'Hi-Top' | Italy | Italsider** |
| | UK | BSC |

** No TFS facilities known

* Source: Hoare

The alleged disadvantages of TFS were not sufficient to dissuade pundits from making grandiose claims as to its potential. In 1968 it was predicated that by 1975 tinplate might well be a rarity. (62)

TFS differs from most of the other tinplate industry innovations of the post-war period in that it was not an American achievement. Both of the commercially successful TFS processes were developed in Japan in the late 1950s and early 1960s. The two companies involved were Fuji Iron and Steel, and Toyo Kohan; the former marketed its product under the trade names 'Supercoat' and 'Cansuper', the latter under 'Hi-Top'. In the 1960s virtually all the leading tinplate manufacturing companies of the world took out licenses.

There can be few innovations which have been announced with such fan-fare and then been so widely licensed, (Table XVII), that have had so little ultimate impact. Production figures for TFS are usually aggregated under tinplate - itself a sign of the former's embarrassingly low penetration perhaps - and no statistics on TFS output are therefore available. It was, though, estimated in 1974 - possibly the year when TFS reached its peak - that the new material amounted to about ten per cent of total world tinplate consumption. Most of this usage was concentrated in the United States. This significant US penetration may reflect the mercantile attitude mentioned earlier, but it is true that when TFS was launched in the US in the mid 1960s it was at a price significantly below that of 5.6 $g/m^2$ coated double reduced tinplate.

In 1968, it will be remembered, BSC commissioned the first rolling mill in the UK designed for the manufacture of double reduced tin-plate at their Trostre plant. The decision in 1968 to install the TFS 'Hi-Top' process had, therefore, also to be implemented at Trostre. (It is an interesting question as to whether the TFS option gave SCOW the necessary stimulus to make the DR investment also). The necessary modifications were made to No. 1 elt. line.

TABLE XVIII (63)*

TFS LINES OF THE WORLD

| Country | Company & Plant, Location | Type of TFS Process | No. of TFS Lines | No. of Dual TFS/ Tinplate Lines |
|---|---|---|---|---|
| Brazil | CSN (Cia Siderurgica Nacional), Volta Redonda | | | 1 Commissioning 1976 |
| France | Sollac (Soc. Lorraine de Laminage continu) Ebange Florange | Supercoat | | 1 |
| Germany, West | Hoesch Huttenwerke, Dortmund Rasselstein, Andernach | Cansuper process Ancrolyt (Hi-top process) | 1 | 1 |
| India | Tinplate Co. of India Jamshedpur | | | 1 Commissioning end 1974 |
| Japan | Kawasaki Steel, Chita | (License from Nippon Steel) | | 1 |
| | Nippon Kokan KK, Fukuyama | Hinac Coat | | 1 |

| Country | Company & Plant, Location | Type of TFS Process | No. of TFS Lines | No. of Dual TFS/ Tinplate Lines |
|---|---|---|---|---|
| | Nippon Steel (Fuji Iron & Steel Co. and Yawata Steel - Yawata | Supercoat<br>Cansuper | 1<br>1 | |
| | Toyo Kohan, Kudamatsu | Hi-top | 3 | |
| Philippines | Elizalde Iron & Steel, Rizal | Supercoat | | 1 |
| UK | British Steel Corp. | Hi-top | | 1 |
| USA | Bethlehem Steel - Sparrows Point - Burns Harbour | Bethleham Steel BC Coatings also Cansuper Process | 2 | 1 |
| | Kaiser Steel, Fontana | | | 1 |
| | National Steel - Weirton - Steubenville | Weirchrome (basically Cansuper process) | | 1<br>1 |
| | - Portage | | 1 | |

TFS LINES OF THE WORLD (continued)

| Country | Company & Plant Location | Type of TFS Process | No. of TFS Lines | No. of Dual TFS/ Tinplate Lines |
|---|---|---|---|---|
| | US Steel Corp. - Fairless | USS TFS -210 & 111 | 1 | |
| | - Gary | | 1 | |
| | Wheeling-Pittsburgh, Yorkville | | | 1 |
| | Youngstown Sheet & Tube, Indiana Harbour | Cansuper Process | 1 | |
| USSR | Lysvenski Iron & Steelworks | ( NO DETAILS ) | | |
| Venezuela | CVG Siderurgica del Orinoco Matanzas | | | 1 (Start up May, 1973) |

* Source: Sloan

The decision to adopt a dual TFS/tinplate facility was no doubt due to the reduction in risk it involved over a uniquely TFS line. In a fast moving area such as metal containers there is always the possibility that the material supplier will go to considerable expense to set up a special line to provide even sample TFS quantities only for the can-makers to then reject the product.

BSC invested in Hi-Top because of the threat of an escalation in the price of tin, and also to keep steel in the forefront of packaging materials. BSC have, however, had their problems in persuading the can-makers to take TFS, in hindsight BSC would probably accept that they did not liaise as closely with the can-makers as they should have done. On the other hand BSC might well argue that their customers, in particular Metal Box, have been unnecessarily recalcitrant over this development. They would point out that TFS is cheaper than its elt. equivalent and that the cause of its slow progress in the UK is possibly due to a reluctance by middle management at Metal Box to create new problems for themselves by making an objective evaluation of Hi-Top when only marginal cost savings are involved. Metal Box would probably argue that their apparent back tracking on the TFS option was entirely for commercial reasons. They would point to the changes TFS necessitated in can-making at a time when a decision was also required regarding future investment in a completely new can-making technology. A strong case could be made out that Hi-Top failed to make the progress expected of it because of its unsuitability as a drawn container.

Whatever the reasons, TFS must now be considered something of a failure in the UK. BSC do not release figures for Hi-Top, but the company did say in 1972 that it expected to produce only 12-15,000 tons of it.[(64)] BSCs market research department were again in 1977 predicting a significant increase in demand for TFS owing to the dramatic rise in the price of tin. No matter what happens to the tin price, however, the success or otherwise of TFS will hinge on the policy adopted by Metal Box. Metal Box take only a very small percentage of their can-making material as TFS, unlike Reads Limited who use it wherever possible. The respective sizes of the two companies are such, however, that only Metal Box can really cause an about-turn in the fortunes of TFS. There has been no sign in the recent past of this happening, but Metal Box may have their hand forced; there are now signs that one of the companies manufacturing its own cans may adopt Hi-Top for food containers. If this happens it is probable that they will also want to buy TFS food cans. This may encourage Metal Box to take the Hi-Top plunge.

If this does happen and demand for TFS goes up by as much as BSC were predicting in 1977, then it will be necessary to bring a second TFS line on stream. If this is the case the new line will almost certainly also be a dual one. This in turn would create new problems for BSC as it is unlikely that it would be possible to run both lines permanently as TFS facilities, as has been the case with No. 1 line at Trostre. Although it is possible to convert a line in forty eight hours it is not viable to make regular changeovers. There are three options for making the switch: It could be achieved electrically, but this would be expensive; secondly, the line speed might be reduced so as to be suitable for TFS but, again, such a reduction would be undesirable. Thirdly, it would be possible to reduce the Hi-Top coating so as to allow the line to run at the faster speed.

The third option is the cheapest but agreement from the can-makers on the suitability of the lighter coating would have to be gained. Lighter coatings, in turn, would probably require changes in the lacquering operation.

This complicated array of possibilities emphasises the extent to which the tinplate-maker and the can-maker are inter-dependent and how each must carefully appraise the possible reprecussions on the other of any technological change.

It must be remembered when speculating on the possibilities of TFS that tinplate has been written off as a packaging material with monotonous regularity, only to later prove itself more than a match for the competition. The odds must be that it will also withstand any renewed challenge from TFS.

TFS is perhaps the most major innovation to lie outside the pattern in tinplate industry developments of the move to continuous processes - although TFS coating is of course a continuous process. The development of Hi-Top constitutes a form of internal competition in the tinplate industry, though it is direct external competition to the tin industry. This explains why the tin industry through its research body the International Tin Research Institute is always striving to reduce the amount of tin needed on tinplate. In the popular mythology of innovation these sorts of developments are suppressed within an industry. In the case of tin, however, we see that the threat of external competition makes for continual sacrifice so as to secure the long term interests of the product.

An interesting question concerning TFS is where the stimulus to the innovation came from. We have seen that it was developed by

Japanese steel firms but Dr. Hoare, one of the foremost authorities on the tinplate industry, points out that a tinplate maker would not be keen to make a material such as TFS which, since it must compete against a very low priced alternative, has an inherently low profitability. Hoare argues that the stimulus for TFS came from the American can-makers who were anxious to develop the highly sophisticated technologies that are the proper expertise of very large organizations.(65) It is somewhat ironic, then, that almost completely the reverse situation appears to have come about in the UK, i.e. a tinplate manufacturer anxious to persuade Europe's largest can company to make more use of TFS while Reads, certainly not a very large company, are prepared to employ the material wherever possible.

8. Appearance

The principal function of temper rolling, it will be recalled, is to restore work hardness after the annealing operation. It is at the temper rolling stage too that the surface appearance of the tinplate - subject to subsequent flow brightening - is determined. As the question of appearance is separate from that of mechanical properties the former is herein discussed in its own right.

Theoretically, BSC will supply up to six different surface finishes to tinplate of which only four may be said to be readily available. Of these four, two - 'shot blast matt' and 'silver glow' - lie outside our field of interest as they are used essentially for non can-making purposes. The traditional type of can finish is 'bright' - sometimes called 'mirror finish' - which is the standard flow brightened surface obtained by polishing the temper mill rolls. This finish is used for the majority of open top cans. In recent years, however, BSC, in common with many other tinplate producers, have been pressing their customers to take tinplate with a new appearance know as 'stone-finish'. This product is obtained by imposing a special ground finish on the temper mill rolls, and it exhibits a linear surface texture parallel to the rolling direction. (66)

The tinplate producers are canvassing for stone-finished tinplate as a way of improving the shape of the material and its resistance to abrasion while in the unlacquered state. Also, almost sinisterly, defects do not show up as much on stone-finished as on bright tinplate. Further, stone-finished plate offers a slight cost advantage. This new finish has not made the impact BSC would like to see because the can-makers have been very recalcitrant. Metal Box and at least one other can-maker have claimed that the corrosion resistance of the new finish is poor and that it is also difficult to solder. BSCs own experiences with the material do not bear these criticisms out; they concede that it is less corrosion resistant, but add that the difference is too small to be significant. An explanation for this disagreement that has been offered within BSC is that in this instance, as has been the case on other occasions, a bad sample of stone-finished plate has prejudiced opinion against the product en bloc. The view has been expressed that once a customer has made up his own mind one attempts to change it at one's peril.

Whoever is right, the example of stone-finished tinplate emphasises once again - as in the case of TFS - the vital importance of continual co-operation and inter-play between supplier and customer when bringing on a new development. There can be little doubt in the case of stone-finished tinplate that, despite the six-monthly technical meetings held between BSC and its customers, liaison was seriously deficient.

9. Tinplate Coils

It has been mentioned previously that an important distinction exists between technical and economic progress; the former may impoverish whereas the latter, by definition, can only enrich. This distinction is probably most often invoked to explain why major technological advances have not been adopted or, perhaps, why some that have been have not had any significant economic impact - except perhaps a negative one. The inverse of this relationship is correspondingly true, minor technical changes may have considerable commercial value. An example of such an innovation is coiled tinplate. To ship finished tinplate in coils involves virtually no technical novelty since such units have for some time been handled in and around the tinplate works; despite this few observers would exclude coiled tinplate from a list of the major post-war innovations in the tinplate industry.

It has also been remarked previously that the two major tinplate manufacturing innovations - cold reduction and elt. tinning - naturally created the conditions whereby the maintenance of the tinplate in band form for as long as possible would be canvassed. This was essentially the impetus to the shipment of tinplate in coils. Shipment and customer handling of coils of narrow stock, weighing perhaps a few hundred pounds, presented no difficulties and have, in fact, been so handled since the early post-war days. (67) Shipment of coils weighing around ten tons did not, however, become a possibility until the late 1950s.

For the reasons mentioned, despatching tinplate in coil form represented no significant challenge to the tinplate manufacturer and involved very little change to his operations. It meant that the shearing, classifying and piling stations could be by-passed which must have represented a convenience, if not also a saving. It has already been shown, in any case, that modern elt. tinplate lines operate at speeds too fast for the cut-up operation to be performed on-line. It will be appreciated that technologically there is very little to say about coil shipment from the tinplate manufacturer's point of view; it is possible, though, that the practice of stagger winding coils to prevent the thicker tin coating at the edge of the strip causing a bulge was not introduced until coils were shipped.

One tinplate operation where coil shipment definitely has had implications has been in the packing of the finished product. The most usual method for shipping tinplate sheets is in a multiple package of 1000 plates (1120 before metrication), each of about one tonne weight, on a wooden stillage equal in length and breadth to the sheets themselves. In the days of hot-dipped plate the package was enclosed in fibre board; with the advent of elt. tinplate special quality oil paper was used. The plates are held together, and the pack to the stillage, by thin steel straps. An optional extra are corner protection pieces made of galvanised steel.

In the packaging of coils the tinplate is placed on its wooden platform in the 'eye to the sky' position. A single wrap of paper, the edges of which are tucked well into the eye of the coil, protects the tinplate. A wooden 'lid' with crossed stiffening pieces may be placed on top of the coil. The tinplate is held together, and held to its wooden frame, by steel straps. (68)

The wooden frames and the oil paper are re-used, the former on a returnable basis, the latter by the can-maker for his own purposes.

The shipment of tinplate in coil form could not take place until a can-making plant was able to handle them. The first such shipment took place in 1957 to the Tampa, Florida, works of American Can Company. It is noticeable that in this comparatively riskless innovation the UK tinplate industry was quick to imitate. SCOW shipped their first tinplate in coil form from Velindre in 1959 for export to the US market. The first domestic shipment took place in 1964 to the Metal Box can-end making plant at Neath.

The extension of coiled tinplate further along the manufacturing chain generated interest in performing intermediate tinplate/can-making operations in coil form. The most notable example concerns the possibility of lacquering in coil form. BSC has been under pressure from can-makers to explore coil lacquering but feel that, as in the case of TPS, the risk of the can-makers withdrawing interest has been too high to justify the development. The technical feasibility of the process has been proved in the US, and with the new can-making technologies appearing to be moving towards tinplate it seems inevitable that this innovation, plus coil lithographing, will make an early appearance in the 1980s.

10. Tinplate Rationalization

The innovations discussed in this section have been manufacturing innovations, for it is changes in manufacturing processes and practices with which the section is concerned. A wide definition of innovation would be 'any new way of doing something', be it manufacturing, marketing, organizational, managerial or whatever.

It is appropriate to mention one such marketing innovation within this section because it is closely related to the manufacturing developments discussed. This change is BSCs 'rationalization programme' instituted from 1979.

An unpublished National Economic Development Office (NEDO) study of January 1978 "Report on Possibilities of Reducing the Number of Tinplate Specifications", and carried out by P.A. Management Consultants, showed that of the 2,000 different possible variations in the tinplate produced by BSC upto 350 applied to open-top cans.[69] This total is the permutation of all the different variables, eg. gauge, temper, sheet size, tin coating etc. The NEDO report argued that joint supplier/customer action should be taken to reduce the number of specifications. Although its recommendations were endorsed by both BSC and Metal Box the report had been specific that neither side should take any unilateral action. Not surprisingly, BSC were the focus of the investigation, but discussions were also held with the can-makers, Metal Box, Reads, Heinz, Crown Cork, Nacanco and others. The objectives of the study were:
"to identify the extent of the proliferation of tinplate specifications and its causes, to examine the scope for reducing the number and variety of tinplate specifications; to assess the benefits of such a reduction on unit costs and efficiency; and to identify the steps needed to bring about beneficial changes in the industry".[70]

Almost before the ink was dry on this report BSC declared its intention of instituting a 'rationalization by incentive' programme; this involves gearing their price structure to favour a small range of specifications. The original list of rationalized specifications produced by BSC was considered to represent a move too far in the new direction and it was, at the can-makers behest, subsequently enlarged.

The real significance of the rationalization programme from the inter-industry perspective is in the impact it has on can-making and the fortuitous gains and losses it creates for individual customers. For this reason discussion of the implications of the policy is left until can-making itself is directly treated. It is appropriate, however, to mention at this juncture one point in relation to tinplate manufacturing innovations. The changes which have taken place in the nature of tinplate in the post-war era have been due to those innovations previously mentioned, eg. elt. tinning and double reduction. The rationalization programme will similarly lead to adjustments in tin coating weights, steel substance, etc.; theoretically, adjustments by individual customers in their specifications should cancel themselves out so that average tin coating, average substance, etc., are not affected. However, it is a possibility that since customers in the past have been prone to err on the side of caution in their specifications that the tendency will be to standardise downwards, i.e. to a lower tin coating etc. If this happens then the direct impact of the post-war cost-reducing innovations may receive an indirect boost.

11. Modern Tinplate Manufacturing Sequence

Introduction

The various criteria determining the composition of this chapter has prevented a treatment of the innovations as they affected each step of the manufacturing sequence in turn. It is the purpose of this review to clarify the modern tinplate manufacturing sequence and to furnish some details of those operations passed over in the foregoing sections. The descriptive information is meant to be generally applicable to the whole BSC tinplate operation; where particular specifications are given, eg. length of tank, these apply to Trostre. Trostre has been chosen for this purpose in preference to Velindre or Ebbw Vale because, at the time when the plant visit was made from which most of the following information was provided, Trostre was the only plant with a working double reduction mill and is still, incidentally, the only plant with a Hi-Top line.

Continuous Pickling

The hot strip produced at either Port Talbot or Llanwern is taken to Ebbw Vale, Trostre and Velindre by either road or rail but usually the latter. In the tinplate works the coils of steel are first butt-welded prior to pickling; after the welding unit comes a thirty-feet deep pit reservoir which accumulates the steel so preventing line stops during welding. The coil passes from the looping pit through five pickling tanks each eighty-feet long, the scale on the strip is removed in pickling in less than one minute. Of the five tanks the last has the greatest acid concentration, and the slow flow of acid against the direction of the strip means a low concentration of iron at the head of the pickling line. Pipes run below the tanks to take away the hydrogen, which is exhausted into the atmosphere. At the end of the pickling stage the dried strip passes through an eight-feet deep looping pit. It is then given a side trim to take off the sharp edges which might otherwise produce splitting. After pickling and trimming the steel is coated with a film of palm oil, this provides lubrication for subsequent operations and also acts as a protection against rusting. The band is then coiled in an upcoiler and the welded coils passed on to a storage ramp from where they are removed by one of the fifty-ton cranes which serve the cold reduction unit.

Cold Reduction

The five stands of the cold reduction unit are each thirteen-feet apart from roll centre to roll centre. Each stand includes two twenty-one-inch diameter work rolls, one above and one below the strip. In each stand the thickness of the sheet is progressively reduced. The first mill contains rolls of comparatively rough finish so as to provide sufficient friction to drive the strip without slipping. The rolls in stands four and five are extremely smooth. Each work roll is driven by a fifty-three-inch diameter back-up roll. The term 'cold reduction' refers to the fact that no external heat is applied to the strip, large amounts of heat are of course generated in the operation. To dissipate this water and oil are used between each stand to cool and lubricate the strip. Unless there is to be a separate second reduction the sheet is now at the customer's required thickness. After emerging from No. 5 stand the strip is automatically re-coiled. The life of each roll is dependent upon the quality of the steel going through; production of five hundred tons of strip before a roll needed changing would be considered a very good return. Adjacent to the mill is the roll shop to which individual rolls are removed for re-grinding.

Elt. Cleaning

The oil applied during cold-reduction has to be removed or else it would carbonise during annealing and interfere with the subsequent tinning operation. The coils to be batch annealed are passed from the five stand mill area to the elt. cleaning lines, again by crane, where the coil ends are squared-off by shears to facilitate the double seam flash welding of one to another. The strip is first pulled through a twenty-two-feet long caustic dip tank via submerger and deflector rolls. On exit it passes through a scrubber and rinsing unit. The strip is then submerged in a sixty-five-foot long elt. tank containing a detergent of caustic soda plus additives similar to that used in the dip tank. After this electrolytically assisted alkaline cleaning the strip is given a second brushing followed by a hot water rinse, it is then air dried. At the end of the operation the strip enters a looping pit before shearing and re-coiling.

## Annealing

After cleaning, the effects of the cold working are removed by one of the annealing methods described earlier. (It will be recalled that continuous annealing incorporates elt. cleaning).

## Temper Rolling

After annealing the strip is too soft for use, coils of tinplate that have already been reduced to final gauge are skin passed in a two stand temper mill so as to improve flatness, to impart the required mechanical properties, and to apply the desired surface appearance. The rolls are arranged as in the five stand mill.

## Double Reduction

Coil to be given a further reduction go not to the temper mill but to a two or three stand DR mill where it is imbued with increased strength and directionality at the expense of ductility. The rolls are arranged as in the five stand mill.

Coil Preparation Lines

In the days of hot-dipping, steel to be pot-coated was now sheared and tinned prior to despatch. With elt. coating, however, the coils always pass to the preparatory line where they are trimmed by rotary knives to the correct width, squared off in down-cut shears, the trailing end of one coil welded to the front end of the following one, re-wound into large coils, weighed, and transported to the elt. lines.

Elt. Tinning

The coil now enters the tinning facility where it is pickled and cleaned to provide the necessary standard of cleanliness essential for coating. After elt. tinning the strip is flow-brightened. The strip is then given its post-plating treatments before being re-coiled or sheared and classified.

Packing and Despatch

The tinplate is packed according to whether it is in coil or plate form, the specifications etc., annotated on the package, and despatched to its destination by either road or rail.

12. Steel for Tinplate

Introduction

The most perfunctory review of the tinplate industry would show that the majority of its operations are concerned with the treatment of the steel base and that the bulk of the innovations introduced have been directed toward improving these operations. Although the tinning operation represents the very cornerstone and character of the tinplate industry it constitutes but a small part of the overall tinplate manufacturing sequence. This bias is indicative of the essential nature of a high quality base to the manufacture of tinplate. To a large extent the quality of the steel base is outside the control of the tinplate maker, being determined by the practices and processes from the blast furnace to the hot-strip mill inclusive. In a study which seeks to examine some of the inter-industry aspects of technological innovation it is important that the role of the steel-maker in tinplate manufacture be recognized. The steel industry in the post-war era has been such a hot-bed of innovation that it is only possible to mention here a few salient aspects of the steel-tinplate relationship.

i. Basic Oxygen System

During the development of the wide strip mill in the US, steel was provided almost entirely by the open-hearth process. By using the typically low phosphorus American iron together with low sulphur fuel oil, US open-hearth operators were able to produce a soft ductile steel consistent in quality and well suited to tinplate.

The UK was fortunate in also producing most of its steel by the open-hearth method, unlike on the continent of Europe where the majority of steel was manufactured in bottom blown basic Bessemer converters that produced steels of undesirably high nitrogen content for strip mill products. The problem facing the UK in 1938 was that the available pig iron contained an undesirably high phosphorus content. During the 1939-45 period practically all the pig iron in the UK was produced from indigenous ores, these gave pig iron that was neither low in sulphur, phosphorus or silicon, nor consistent in quality. (71)

In the early post-war years, partly due to the influence of strip mills, there was a slight move in favour of open-hearth steel in Europe. The steelmakers were in something of a dilemma, however, because - apart from its problem with nitrogen - the basic Bessemer process had advantages for strip mill production; one of these advantages was that it was easier to produce a consistently low carbon steel than from open-hearths. These were the conditions which led to attempts to adapt the basic Bessemer system and culminated in the invention at Linz, Austria, by Danowitz, of the basic oxygen steel making system (1952) - known as the Linz Danowitz (LD) process. Three types of oxygen blowing solution to the problem of high nitrogen steel were developed between 1945 and 1960 - the bottom blown, the top blown, and rotary blown converter. These developments were made possible by the increasing availability of oxygen. The LD process is the most famous and successful top blowing process and has taken its place alongside the Bessemer, electric arc and open-hearth furnace as one of the classic steelmaking processes.[72]

The steel produced by the LD process is well suited to tinplate manufacture. It gives a steel that is very low in phosphorus and nitrogen; the lower scrap ratio it uses allows easier control of the residual elements such as copper, nickel and tin, i.e. it is a 'cleaner' steel. This greater purity gives a product that is less stiff and more ductile. This means that the production of low temper tinplate is no problem; intermediate tempers can easily be produced by making use of the hardening effects of carbon and manganese. A further advantage of the low incidence of impurities is that the corrosion resistance of the steel is improved. All these characteristics have implications for tinplate manufacture, eg. in allowing shorter annealing cycles for 'cleaner' steel, and in complementing the protective function of the tin coating. (Such examples are only illustrative - the adjustment of tinplate manufacturing processes as a result of LD steel and the inter-play of the two sets of variables is obviously complicated and very much the preserve of the technical experts).

From an economic point of view the real difference between the basic oxygen system and the open-hearth process is in their through-puts. Modern oxygen steel-making furnaces can produce steel at rates of upto 400 tonnes/hr. as compared with around 60 tonnes/hr. for open-hearth furnaces. This tremendous advance in productivity has generated a revolution in the related processes in the steel producing chain. To complement the basic oxygen system a number of significant changes have occurred in the iron-making process; the most important of these has been the development of giant blast furnaces so as to produce iron at a rate commensurate with the steel furnace. The new oxygen making technology could not be based on the low grade home ore such as produced in Northamptonshire which carried only thirty per cent iron. It has been necessary to adapt to the use of richer foreign ores carrying upto sixty five per cent iron. Again, since these ores had to be imported, the cost of transport had to be kept within economic bounds by the introduction of the large ore carrier. This development, in turn, necessitated the construction of the deep water ports necessary to accommodate the carriers. This is the chain of events which has been set in motion in the UK since the adoption of the oxygen blowing system.

It was at Ebbw Vale - which in 1938 had seen the re-establishment of the basic Bessemer steel-making process in the UK for sheets and tinplates - that the new technology was introduced. In 1958 following the advent of the tonnage oxygen plant a fourth converter equipped with facilities for blowing oxygen/air and oxygen/steam was installed. In succeeding months these facilities were extended to the other three vessels. This development greatly increased the capacity of the converting department and also the quality of the steel. In 1960 a top blown LD/AC vessel was introduced to replace an existing bottom blown converter. By November 1962, when the remaining bottom blown converter was closed down, all three other vessels had been converted to either straight LD or LD/AC units. This marked the end of an era for Ebbw Vale and the beginning of a new one for the UK steel industry. Basic oxygen steelmaking subsequently ceased at Ebbw Vale in the iron and steel closure programme of 1975/77. The decision to pursue a dual oxygen/open-hearth system at Ebbw Vale was in contrast to the policy for Llanwern; when this plant was opened in 1962 the most notable feature was its commitment to the LD process as the sole method of steelmaking. The plant, like Ebbw Vale, contained three converters. In 1970 the basic oxygen steelmaking plant at Port Talbot with two converters was officially opened, together with the deep sea ore terminal to handle ore imports for both Port Talbot and Llanwern.

ii. Continuous Casting

A further development stimulated by the adoption of the basic oxygen system has been to continuously cast steel as opposed to the conventional method of ingot casting. The faster throughput of the oxygen process has encouraged commensurate increases in the speed at which the liquid steel is solidified. The former process of casting into moulds is now being complemented, and possibly ultimately replaced, by continuous casting - though not as yet for UK Steel destined for tinplate.

Continuous casting is not a new idea, the first such type of machine being patented by Sir Henry Bessemer in 1857. It was not until the 1930s that the first machine for continuous casting appeared commercially (in Germany). The first steel to be continuously cast in the UK was at Lowmoor, Bradford, in 1946 followed in 1952 at Barrow in Furness. The real growth in continuous casting has been seen in the 1960s and 1970s.

BSCs competitors in America, Europe and Japan already have continuously cast steel for tinplate. Its adoption in the UK for tinplate - strongly canvassed for by BSC and the can-makers - is dependent upon its sanction as part of the proposed £5 billion steel investment programme. Its location would be Port Talbot.

Continuous casting has a number of advantages for the steelmaker and tinplate manufacturer, (Continuous casting was not adopted at first for tinplate because of the difficulty in simulating the rimmed steel normally used). For the steelmaker it eliminates several steps on the route from molten to rolled product, uses less manpower, less space, and has a much higher yield of sound usable steel. For the tinplate producer it complements the oxygen-blown product in enhancing the cleanliness of the steel; he particularly welcomes it as a way of reducing the advantage of aluminium regarding purity. This greater cleanliness also offers the tinplate manufacturing advantages mentioned in connection with the cleaner oxygen steel. The can-maker would welcome it because it is particularly suitable for the newest can-making technologies involving drawing, and for the easy-open can end made of steel. Whatever its immediate future it seems inevitable that continuously cast steel must before too long be available for UK tinplate.

This brief overview of the trends in steelmaking illustrates perhaps three points. In the first instance there is the extent to which the tinplate manufacturer is dependent upon wider steel technology; it should be mentioned in this context that the tinplate manufacturer does have some influence over the course of steel developments and, indeed, in the UK the tinplate sector is to some extent more influential than its percentage consumption of total steel output would tend to indicate. The second major point is the detailed interplay between the two technologies, from the tinplate manufacturer's perspective. From the view of tinplate manufacturing innovations the progress in the manufacture of the steel base in the iron and steelmaking industry must always be closely monitored for implications in order that one's own developments complement rather than conflict with those of the supplier. The third interesting aspect relates to the theme of a 'ripple effect' in technological innovation. It would be simplistic and even misleading to say that the hot-strip mill generated the changes in steelmaking which have been discussed - other steel users in the 1950s began to encourage the adoption of the basic oxygen system also. It is true, however, that a strong association exits betwen the hot-strip mill and the oxygen system, the latter encouraging continuous casting. The hot-strip mill, being a continuous process, is dependent upon consistency from ingot to ingot, which could be enhanced by the oxygen process. The new steelmaking method, by its greater productivity thereby set in motion the developments mentioned, including continuous casting, that were designed to facilitate commensurate throughputs. In the case of the UK, and probably elsewhere, this chain reaction has still to run its full course.

13. <u>The Economic Impact of Tinplate Innovations</u>

It will be appreciated from the foregoing analysis of the nature of technological change that in the case of the tinplate industry innovation essentially takes the form of finding ways of varying the basic steel product, eg. reduced substance, lighter coatings, etc. The object of this type of development is to make tinplate economically more attractive to the can-makers, and thereby keep it in the forefront of packaging materials.

It would be a very difficult task to illustrate the economic impact of every single technological development. However, the following concentrated tinplate industry price data carries a wealth of information indicating the cost-reducing effect of the majority of innovations which have been discussed. It is not here intended to refer directly to every detail of the tables, only to draw attention to a few salient points.

Examining Table XIX, it is possible to see the economic impact of technological innovation within conventional rolling technology. It can be seen that the lower coating grades - increasingly available since elt. tinplate was introduced - have had a clear effect on costs; each successively lower elt. (E) coating weight carrying a lower price. This cost reducing impact of elt. deposition has been furthered by the introduction of differential (D) tinplate as may be seen, for example, by comparing E5.6/5.6 with D5.6/2.8.

It may also be observed that Hi-Top chrome steel offers a cost advantage over even the lowest coating by the alternative elt. process.

From the data under "Extras and Allowances" the very direct relationship between tinplate substance and tinplate cost is evident, with a descending scale of charges corresponding with a descending scale of plate thickness. This illustrates the effect of improvements in conventional rolling technology on the economics of the tinplate industry. It may also be seen under this section that these substance reductions restrict the maximum rolling width at the lower end of the scale.

From the charges for stamping and deep drawing qualities is indicated the premium attached to batch annealing vis-a-vis continuous annealing, the latter not being suitable, it will be recalled, for these ductile qualities.

Turning to Table XX it will be seen that the data is not exactly comparable with that of Table XIX because of the reduced range of rolling widths possible with this higher tensile strength, lower gauge material. In the middle of the rolling range (700-749mm), however, it is possible to compare the cost advantage of double reduced tinplate over conventionally reduced for cut lengths of 460-510mm. in the case of each corresponding coating weight, eg., conventionally reduced 0.22 mm. plate of E11.2/11.2 coating is significantly more expensive than the equivalent DR plate.

It will be seen that within the DR range the same economies

TABLE XIX*

Electrolytic Tinplate Prices - 30.6.74. Prices Per Sita (100 Sq. Metres) For 0.22mm Thickness. This Schedule Is Based On 25-49 Tonne Lots In Bulk Containers Of 1½ Tonnes And Over Nett Weight, Packed Without Corner Pieces

| Coating g/m² | Rolling Width mm | Cut Lengths (mm) 450-510 £ | 511-1015 £ |
|---|---|---|---|
| E1.4/ 1.4 | 635-699 | 33.08 | 33.00 |
| | 700-749 | 32.68 | 32.60 |
| | 750-965 | 32.08 | 32.00 |
| E2.8/ 2.8 | 635-699 | 33.99 | 33.91 |
| | 700-749 | 33.59 | 33.51 |
| | 750-965 | 32.99 | 32.91 |
| E4.2/ 4.2 | 635-699 | 35.14 | 35.06 |
| | 700-749 | 34.74 | 34.66 |
| | 750-965 | 34.14 | 34.06 |
| E5.6/ 5.6 | 635-699 | 36.29 | 36.21 |
| | 700-749 | 35.89 | 35.81 |
| | 750-965 | 35.29 | 35.21 |
| E8.4/ 8.4 | 635-699 | 38.58 | 38.50 |
| | 700-749 | 38.18 | 38.10 |
| | 750-965 | 37.58 | 37.50 |
| E11.2/ 11.2 | 635-699 | 40.66 | 40.58 |
| | 700-749 | 40.26 | 40.18 |
| | 750-965 | 39.66 | 39.58 |
| D5.6/ 2.8 | 635-699 | 35.26 | 35.18 |
| | 700-749 | 34.86 | 34.78 |
| | 750-965 | 34.26 | 34.18 |
| D8.4/ 2.8 | 635.699 | 36.41 | 36.33 |
| | 700-749 | 36.01 | 35.93 |
| | 750-965 | 35.41 | 35.33 |
| Dcr 11.2/2.8 8.4/5.6 | 635-699 | 37.54 | 37.46 |
| | 700-749 | 37.14 | 37.06 |
| | 750-965 | 36.54 | 36.46 |
| D11.2/ 5.6 | 635-699 | 38.69 | 38.61 |
| | 700-749 | 38.29 | 38.21 |
| | 750-965 | 37.69 | 37.61 |
| Hi-Top | 635-699 | 31.56 | 31.48 |
| | 700-749 | 31.16 | 31.08 |
| | 750-965 | 30.56 | 30.48 |

EXTRAS AND ALLOWANCES

| Thickness (mm) | | |
|---|---|---|
| 0.43 | ADD | 14.50 |
| 0.41 | " | 12.50 |
| 0.39 | " | 11.03 |
| 0.38 | " | 10.30 |
| 0.37 | " | 9.57 |
| 0.36 | " | 8.84 |
| 0.35 | " | 8.10 |
| 0.33 | " | 6.65 |
| 0.31 | " | 5.25 |
| 0.30 | " | 4.55 |
| 0.29 | " | 3.85 |
| 0.28 | " | 3.15 |
| 0.27 | " | 2.55 |
| 0.26 | " | 1.95 |
| 0.25 | " | 1.40 |
| 0.24 | " | 0.90 |
| 0.23 | " | 0.45 |
| 0.21 | DEDUCT | 0.30 |
| 0.20 | " | 0.55 |
| 0.19 | " | 0.55 |

Max Width for 0.19 + 0.20 is 915mm
Max Length for 0.19 is 865mm
Max Length for 0.20 is 915mm

| QUALITY | 0.30mm THINNER | OVER 0.30mm |
|---|---|---|
| Deep Stamping | T2 +0.16 | 0.23 |
| Deep Drawing | TIB+0.93 | 1.16 |
| Extra Deep Drawing | TIA+1.94 | 2.33 |
| Nitrogenised | T6 (0.30 - Thicker) | 0.75 |

TONNAGE

| | | |
|---|---|---|
| Under 18 Tonnes | ADD | 3.00 |
| 18 Tonnes To Under 25 Tonnes | ADD | 1.00 |
| 50 " " " 100 | " | 0.12 |
| 100 " AND OVER | | 0.23 |

* Source: B.S.C.

TABLE XX*

Double-Reduced Tinplate (DR8) - 30.6.74

Prices Per Sita (100 Sq. Metres) For 0.17mm Thickness, Based on 25-49 Tonne Lots In Bulk Containers Of 1½-2 Tonnes Nett Weight.

Prices Without Corner Pieces

| Coating g/m² | Rolling Width mm | Cut Lengths (mm) 460 - 510 £ | 511 - 865 £ |
|---|---|---|---|
| E2.8/ 2.8 | 691 - 699 | 32.49 | 32.39 |
| | 700 - 749 | 32.09 | 31.99 |
| | 750 - 895 | 31.49 | 31.39 |
| E4.2/ 4.2 | 691 - 699 | 33.64 | 33.54 |
| | 700 - 749 | 33.24 | 33.14 |
| | 750 - 895 | 32.64 | 32.54 |
| E5.6/ 5.6 | 691 - 699 | 34.79 | 34.69 |
| | 700 - 749 | 34.39 | 34.29 |
| | 750 - 895 | 33.79 | 33.69 |
| E8.4/ 8.4 | 691 - 699 | 37.08 | 36.98 |
| | 700 - 749 | 36.68 | 36.58 |
| | 750 - 895 | 36.08 | 35.98 |
| E11.2/ 11.2 | 691 - 699 | 39.16 | 39.06 |
| | 700 - 749 | 38.76 | 38.66 |
| | 750 - 895 | 38.16 | 38.06 |
| D5.6/ 2.8 | 691 - 699 | 33.76 | 33.66 |
| | 700 - 749 | 33.36 | 33.26 |
| | 750 - 895 | 32.76 | 32.66 |
| D8.4/ 2.8 | 691 - 699 | 34.91 | 34.81 |
| | 700 - 749 | 34.51 | 34.41 |
| | 750 - 895 | 33.91 | 33.81 |
| D8.4/ 5.6 or D11.2/ 2.8 | 691 - 699 | 36.04 | 35.94 |
| | 700 - 749 | 35.64 | 35.54 |
| | 750 - 895 | 35.04 | 34.94 |
| D11.2/ 5.6 | 691 - 699 | 37.19 | 37.09 |
| | 700 - 749 | 36.79 | 36.69 |
| | 750 - 895 | 36.19 | 36.09 |
| Hi-Top | 691 - 699 | 30.06 | 29.96 |
| | 700 - 749 | 29.66 | 29.56 |
| | 750 - 895 | 29.06 | 28.96 |

For 0.15mm Thickness Deduct £0.50

| | | | |
|---|---|---|---|
| Tonnage: | Under 18 Tonnes | Add | £3.00 |
| | 18 Tonnes To Under 25 | " | £1.00 |
| | 50 " " " 100 | Deduct | £0.12 |
| | 100 " And Over | " | £0.23 |

If Standard Packing With Corner Pieces Is Specified Add £0.04

* Source: B.S.C.

regarding coating weight and tinplate substance apply as in the conventionally reduced range. Further, it is also shown that Hi-Top benefits in the same way as tinplate when DR is used.

When analysing Tables XIX and XX the qualifications and detailed characteristics which were discussed in the case of each innovation must always be born in mind. For example, in the case of the price advantage of Hi-Top the extra lacquering required must be taken into consideration.

## 14. Conclusion

Technological innovation and its diffusion in the post-war UK tinplate industry has invariably been associated with very large capital outlays; this characteristic creates the impression that technical change in the industry is 'major' by nature. An initial examination of the changes that have been introduced would seem to bear this out; electrolytic tinplating, continuous annealing, double reduction, Tin-Free steel, to name but a few, would all be considered 'major' developments by most observers no matter whether one defines major according to some technological or economic criteria. At several points within this chapter attention has been directed towards important incremental developments, but it is indisputable that the industry shows a strong preponderance of major innovations.

Despite this it is held to be the case that the more detailed examination of the technical evolution of the tinplate industry since 1945 which it has been sought to undertake within this chapter provides cogent evidence in support of the argument for greater recognition of the role of piece-meal development. Perhaps the most important conclusion to be drawn from this study of the tinplate industry is that the undoubtedly major innovations which have been introduced represent only the manifestation, or exploitation, of a host of continual minor advances in the engineering industries. Progress in mechanical, electrical, chemical, electro-chemical and electronic engineering is the reservoir from which has been extracted the various incremental contributions of each discipline so as to overcome the particular problems facing the tinplate industry. The classic example of this phenomenon is the case of electrolytic tinplating. This one innovation has drawn particularly heavily on all the branches of engineering so as to overcome a problem unique to the tinplate industry - how to apply a layer of tin to a sheet of steel more thinly while maintaining consistent and uniform coverage.

It is important to remember while on the question of the role of small-scale change that at any time the greater part of the research and development effort within the tinplate industry is directed towards finding ways of doing better what is being done already. It is for this reason that emphasis has been placed, within the framework of the major technological innovations, on the continual improvement in performance as these large-scale developments are diffused. Faster speeds, in particular, has been a recurring theme in the case of most of the innovations discussed. There have, too, been detailed changes in operating practice about which little fuss is made outside the circle of tinplate boffins but which nevertheless have had important results. Such an example is improved rolling technique so as to permit the rolling of welds; this has increased the size of coil that can be handled and reduced down-time due to threading.

Still in the context of the respective contributions of the major and minor innovations, a useful aspect of the longer term detailed industrial study is that it may throw a different light on many incremental changes which have taken place. At various junctures in the cases of a number of innovations some feature of the instrumentation has been mentioned. In any one instance these tend to be overshadowed by the actual manufacturing role of the development in question; taken over a long period however the installation of miscellaneous line instrumentation apparatus to automatically monitor, control and provide data logging facilities for each manufacturing unit represents one of the most important post-war developments in the UK tinplate industry.

It is possibly because the major changes are little more than an aggregation of minor advances that the installation of many of the tinplate developments make for somewhat unexiting copy, this is especially true when one is dealing - as one is in most instances - with adaptation rather than original innovation. Similarly, the first incorporation of a strip line printer to an electrolytic line, for example, may be an important modification but it is unlikely to capture the imagination. Once a fundamental innovation has been made there is felt to be a certain inevitability in its further improvement. This attitude towards incremental development is perhaps the major reason why it receives so little academic attention even though it may be the bread and butter on which an industry depends.

A second important aspect of innovation in the tinplate industry apparent from this investigation is the inter-dependence of the processes involved. This feature manifests itself in a number of ways. One example is in the purely technological function in each separate stage in the manufacturing unit and the way one is complemented, impinged upon, and even substituted by another. An example is temper rolling whose function has been both complemented and impinged upon by better annealing methods, and replaced in the case of double reduction. On a somewhat different plane is the cross-fertilization of ideas from one manufacturing unit to another; the outstanding example of this is the similarity between the Halogen tinning line and the horizontal continuous annealing line. This inter-dependent characteristic extends too beyond industry boundaries as was seen in the case of tinplate and steel technology. When one is the junior partner in the relationship, i.e. as with the tinplate manufacturer, one must essentially be concerned with making sure that one's own particular developments are in harmony with the underlying direction of technical change.

Related to the idea of manufacturing process as being inter-linked, particularly beyond the confines of each industry, is the importance of the 'ripple effect'. Again this aspect was seen most clearly in the new steelmaking technologies and the way in which they have been influenced by strip mill users such as the tinplate makers. This chain reaction was seen to go right through the steelmaking industry to the ore carriers, deep sea terminals, and sources of supply.

One of the questions to be broached earliest in the chapter was the question of whether or not one benefited by not incurring the risks and penalties associated with pioneering type innovation. This has been a very popular argument to explain the economic success of

Japan and West Germany in the post-war period, it being argued that they have been able to exploit Western technology without incurring the costs of research and development, via American overseas investment. In the case of the tinplate industry it has clearly been seen that there have been benefits, some more important than others, which accrued in the UK by virtue of the 'wait and see' policy adopted. These benefits were, however, of a technical nature, the important question of whether economic benefits were also gained must remain conjectural since it is never possible to establish what would have happened if the pioneer role had been taken.

The lesson of the 'wait and see' policy is that it perhaps indicates the vital role accredited to the market situation both from an immediate and from a trade cycle prespective in investment decisions regarding innovation. Although Britain benefited technically by being able to incorporate the latest refinements, the delayed adoption of principally American developments was essentially due to the time necessary to evaluate their suitability to UK conditions - not their technical feasibility. It is interesting to note that one can apply a rule of thumb for estimating the gap between the first commercial exploitation of tinplate innovation and its British imitation, of ten yeas. This was approximately the 'technology gap' in the case of electrolytic tinning, continuous annealing, double reduction, and Tin-Free Steel, possibly the four most major tinplate developments since 1945. It must be added, however, that there does appear to be a trade-off with risk in that less time is taken to evaluate and adopt the less major innovations such as the coiled shipment of tinplate, Remaining on the theme of adoption, the case of continuous annealing illustrates an important, perhaps even fundamental, point. It would seem that each further application of an innovation should be treated as if it were a fundamental innovation from the economic point of view. While the technical advantages of a new development will be inherent, each adoption should perhaps be preceeded by its own unique evaluation of the projected costs and benefits, with only the most limited commercial assumptions being drawn from previous operating experience. The case of continuous annealing, and also Tin-Free Steel, shows that ante-post forecasts about innovations tend to be in wide variance with later demonstrations of real worth.

REFERENCES


1. Warren, K. "The British Iron and Steel Industry Since 1840", London, Bell, 1970.
2. Minchinton, W. "The British Tinplate Industry", Clarendon Press, Oxford, 1957.
3. "Technical Survey of the Steel Company of Wales Ltd.", Iron and Coal Trade Review, Industrial Newspapers Ltd., 1952.
4. Minchinton, W. Op. cit.
5. Warren, K. Op. cit.
6. Lippert, T. W. "Food in Cans", Iron Age, April 30, 1942.
7. Trubshaw, E. "On the Tin Plate Manufacture", Journal of the Iron and Steel Institute, Vol. 2, 252, 1883.
8. Hoare, W. E. "The Development Production and Manufacture of Tinplate", Sheet Metal Industries, April 1951.
9. Jones, G. E. "The application of Tin Coatings in the Manufacture of Tinplate", Iron and Steel Institute Special Report, 97, 1960.
10. Hoare, W. E. Op. cit. p.320.
11. Lippert, T. W. Op. cit. p.39.
12. Bevan, J. R. "Recent Developments in Steel Based Materials for Packaging", PIRA/IAPRI Conference on Packaging Technology, 1972.
13. O'Brien, A. F. "Design and Commissioning of Equipment for a Tinning Line", Electrical Review, December 1972.
14. Hoare, W. E. "Tinplate Handbook", Tin Research Institute, 4th Edition, 1965.
15. Hoare, W. E. Ibid, p.17.
16. Ferguson, C. A. "Changes in the Processes and Products of the Tinplate Industry", Yearbook of American Iron and Steel Institute, New York, 1952.

17. Cooper, W. L. "Double Reduced Tin Plate", Yearbook of American Iron and Steel Institute, 1964.

18. Ascough, H. H. "Annealing of Cold Reduced Sheet and Coil at the Steel Company of Wales Ltd.", Iron and Steel Institute Special Report, 97, 1960.

19. Hoare, W. E. "The Technology of Tinplate Manufacture", Tin Research Institute, 1964.

20. Hogan, W. T. "Economic History of the Iron and Steel Industry in the United States", Heath and Co., Lexington, 1971.

21. Ascough, H. H. Op. cit.

22. Ascough, H. H. Ibid.

23. Roberts, W. J. S. "Metallurgical Principles and Practice in the Manufacturing of Cold-Reduced Tinplate", Iron and Steel Institute Special Report, 97, 1960.

24. Cooper, W. C. Op. cit.

25. Anon, "Search for Stronger Tinplate", Tin and its Uses, No. 68, 1965, Tin Research Institute.

26. Ascough, H. H. Op. cit.

27. Ascough, H. H. Ibid., p.141.

28. Ascough, H. H. Ibid., p.143.

29. Ascough, H. H. Ibid., p.143.

30. Pitt, R. S. "South Wales - the Modern Home of British Tinplate", Iron and Steel, August 1972.

31. Sowerbutts, J. A, "BSC Tinplate - A Profit Centre of the Welsh Division", Steel Times, June 1977.

32. Ascough, H. H. Op. cit.

33. Barry, B. T. K. "An Examination of the World Tinplate Industry", Proceedings of the Conference on Tin Consumption, 1972.

34. Anon, "Double Reduced Tinplate", Swansea Lab., BSC, South Wales

Group, 1968.

35. Hoare, W. E. & Barry, B. T. K. "Properties and Applications of Tin Coated Steel Sheet and Strip", Sheet Metal Industries, February, 1968.

36. Smith, A. "A History of Tinplate", Tin International, Tin Publications Ltd., June 1978.

37. Anon, "Double Reduced Tinplate", Op. cit.

38. Anon, "Search for Stronger Tinplate", Tin and its Uses, No. 68, 1965.

39. Stone, M. D. "The Rolling of Very Thin Tinplate", Iron and Steel Institute Special Report, 97, 1960.

40. Anon, "US Steel Takes Up the Challenge", Tin International, October; 1960.

41. Anon, "US Research for Lighter Tinplate", Tin International, March 1960.

42. Cooper, W. L. Op cit.

43. Anon, "Lightweight Tinplate", Packaging Review, October, 1960.

44. Anon, "US Steel Takes Up the Challenge", Op. cit.

45. Cooper, W. L. Op. cit.

46. Anon, "US Trend Towards Thin-Tin", Tin International, November, 1965.

47. Anon, "UK Thin Tinplate Mill", Tin International, April, 1966.

48. Pitts, R. S. Op. cit.

49. Anon, "Double Reduced Tinplate", Op. cit.

50. Anon, "BSC Home Trade Price List No. 13", as reported in Tin International, May 1970.

51. Sowerbutts, J. A. Op. cit.

52. Fox, W. "Tin - The Working of a Commodity Agreement", Mining Journal Books Ltd., 1974.

53. Hedges, E. S. "Tin in Social and Economic History", Edward Arnold, 1964.

54. Anon, Tin International, January, 1965.

55. Anon, Tin and Its Uses, No. 71, 1966.

56. Hotchner, S. J. & Poole, C. J. "Recent Results On the Problems of Can Corrosion", 5th International Congress on Canned Food, Vienna, 1957.

57. Bevan, J. R. Op. cit.

58. Anon, "The Threat to Tinplate", Tin International, October, 1966.

59. Dunne, W. T. "Tin in Your Industry", Tin Publications Ltd., London, 1968.

60. Sloan, J. "Bibliography on Tin Free Steel (TFS)", Information Services, BSC, Sheffield, 1974.

61. Hoare, W. C. "Tinplate Developments Reviewed", Tin International, September, 1968.

62. Cannon, H. S. "The Tin-Free Steel Revolution", Paper Packaging Institute, 30th Annual National Packaging Forum, October, 1968.

63. Sloan, J. Op. cit.

64. Anon, "Will Tinplate Hold Its Own Against Competition From Other Packaging Media", Industrial Packaging News, July, 1972.

65. Hoare, W. E. "Tinplate Developments Reviewed, Op. cit.

66. Sowerbutts, J. A. Op. cit.

67. Hoare, W. E. "The Technology of Tinplate Manufacture", Op. cit.

68. Hoare, W. E. Ibid.

69. Anon, "Metal Box Ltd. - Open Top Food, Beverage and Aerosol Cans", Price Commission Report, 1978, HMSO.

70. Anon, "Tinplate Bulletin", BSC Information Unit, Swansea, May, 1977.

71. Evans, R. W. "Oxygen Steelmaking for Flat Rolled Products",

Iron and Steel Institute Special Report, 97, 1960.

72. Evans, R. W. Ibid.

73. Hoare, W. E. "Tinplate Handbook", p.16, Tin Research Institute.

# CHAPTER IV

# TECHNICAL CHANGE IN CAN MANUFACTURE SINCE 1945

## 1. Introduction

The essential elements in the method of manufacturing the traditional open top can - body and two separate ends - has remained very much the same since the 1920s. Changes to the conventional process have been more noticeable since the mid-1960s, but it is still possible to give a description of the three-piece can-making system which has general applicability throughout the post-war period. It is the intention in the following section to make such a presentation. This is followed by an account of the detailed innovations which have been introduced to the traditional can-making method since 1945. New three-piece can constructions associated with Tin-Free Steel are treated separately. Lacquering developments following the traditional can-making analysis and the chapter concludes with an account of the new two-piece can-making processes.

## 2. The Traditional Can-Making Process*

In the traditional can-making process the tinplate arrives at the can factory in units weighing about 2-3,000 lbs and containing the (pre-metrication) quota of 1,120 sheets, each twenty inches by thirty inches. After trimming, cleaning and lacquering the flat uncut plate is ready to be made into a can.(7)

### (i) Bodymaking

The making of the can body and its two ends is undertaken in separate manufacturing units; the bodymaking process may be conveniently split

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* The following description of a can-making line is compiled from a variety of primary and secondary sources; the main secondary sources are listed as chapter references Nos. 1-6.

into six operations: the cutting of the body blanks, body forming, soldering, flanging, seaming and testing. For reasons of economy and efficiency each line is usually set up for only one can size.

## Cutting out the Body Blanks

The sheets of tinplate are cut to the requisite body size on a machine known as a 'duplex' or 'tandem gang' slitter. This operation must be performed accurately as it is uneconomic to attempt adjustment to the body line equipment to cater for inaccuracies in the blank. In order to produce the body piece, two sets of perpendicular cuts must be made across the sheet. An automatic sheet feeder delivers single sheets into the first slitting station where the tinplate is cut at intervals equal to the length of a body blank by rotary slitters. The sheets are trimmed along the edges at the same time as they are cut. The slit strips then change direction by ninety degrees so that they may be presented to the second set of cutters where each strip is simultaneously cut into lengths equal to the width of a body blank. In order that the operation is performed accurately, positive control of the tinplate as it moves through the machine is maintained; a variety of features are employed to ensure this, e.g. magnetic separator rolls and mechanical hold down pads.

## Body Forming

Body forming is accomplished in one fully integrated unit which forms the focal point of the can-making operation. In the later 1940s and early 1950s a bodymaker would normally operate at speeds of around 350-400 cans per minute (c.p.m.). The bodymaker is a complicated piece of machinery which is best understood as a series of individual operations.

The bodymaking process begins with the one manual operation which has survived throughout the post-war era - the transfer of piles of cut blanks from the feed out tray on the duplex slitter to the bodymaking hopper. The reason for the hand feeding is that the blanks must be fed in perfectly square if they are not to foul the subsequent stations; the operative handles the wads, as one would a pack of playing cards, to align them before placing them in the magazine of the bodymaker. Rubber suction cups rise to contact the lowest blank in the magazine and convey it to 'breaking down' rollers. At this station the blank is bent around a roll in the direction in which it is to be formed into a body; by breaking the grain this facilitates the subsequent forming of a body of good shape, otherwise the can might well end up as a series of flat surfaces. i.e. a polygon.

After pre-stressing, the blank enters a transfer station wherein the tin-plate passes to the main feed bars. At this point an electronic sensing head is used to detect double blanks. The tinplate then passes to a knurling station where the edge of each blank is serrated so as to promote the flow of solder through the seam.

The blank is then 'notched'; this involves the cutting of two small square sections from each corner of one side of the plate and the cutting of two small slits in both corners at opposite ends of the blank. The function of notching is to reduce the number of thicknesses of plate which will be present when the can is double seamed.

The notched side of the blank is next folded downwards and inwards at an angle of thirty degrees, and the metal between the slits on the opposite side is folded upwards and inwards by a like amount; this operation is known as 'edging'. The blank next moves through a fluxing station where rotary brushes apply flux to the edges of the body blank ready for soldering. It is at this point that the blank begins to take the shape of a can. The blank enters the forming station, is clamped still, and swept around a mandrel. In this position one hook is firmly pressed against the mandrel with the other hook overlapping. The mandrel then expands and engages the hooks which are then locked by the action of a flattening hammer. The mandrel then collapses so as to allow the cylinder to be fed horizontally along a second mandrel with its seam undermost. The unbroken line of cans then pass over a row of gas flames designed to heat the side seam and thereby help the solder that is to be next applied to flow into all the recesses of the seam.

The moving can next passes over a molten solder bath so that the seam comes into contact with projections on a solder roll which is protruding from the bath. After soldering the cans are given a second heating to further promote solder flow. A buff wipes off any excess of solder. The position of the seam at the lowest point of the can prevents solder contaminating the rest of the cylinder; as additional protection a splash eliminator is added to ensure that wipings do not contaminate the following can. An air blower is used to cool the joint. Can bodies made in the above way are not perfectly round, this is corrected by a simple fluxing process between internal and external rollers.

(ii) Can End Manufacture

While the can bodies are being made another set of machines is producing the can ends on an auxillary or sub-assembly line. The sheet for can ends is of the same dimensions as that for can bodies, though detailed specifications may vary.

Scroll shearing

To facilitate high speed feeding, the sheet for can ends is first cut into strips. The cut is staggered along the length of the strip in wavy line fashion. This technique is reminiscent of a cook pressing out circles of dough so as to achieve the maximum number of pie bases without re-rolling. In the case of can end manufacture this staggered cutting, or scroll shearing, is performed to save waste; it results in a three-five per cent material saving. There is still waste at the perimeter of each sheet. The only advantage of cutting the ends from straight-sided strips is that it can be done on an ordinary slitter; it is doubtful if this was very practised in the UK in the post-war period in the case of Metal Box, but it may well have been carried out by a canner producing a small quantity of ends for his own use.

On some early slow-speed lines the scroll shear was fed manually from a stack of tinplates; with high-speed machines it has always been usual to fit automatic sheet feeders. From these the plate is trimmed to width and then cut into strips. As at the bodymaking magazine, a double sheet detector is used. The scroll shear itself is in effect a small double-sided press. The cut strips - excluding the last one which has a trailing edge - are delivered to a stacking department.

<u>Strip-feed press</u>

From the scrolled strip must next be punched out the can end. This is done on an automatic machine known as a strip-feed press. Scrolled strips are stacked into the magazine of the strip-feeder from which, as in the bodymaker, suction is used to pass the strip onto feeders which carry it towards the back of the press ready for punching. Two dies, usually, punch ends of the required shape at widely varying speeds; some still operate at speeds of less than 600 ends per minute, which had been well surpassed in the early 1960s. To give the can end its strength, it is provided with concentric expansion rings. Cam operated 'fingers' contact the ends and eject them prior to the dies making their following stroke.

Wheel curling

Although the strip-feed press makes a suggestion of a curl in the can end, this has to be further rounded in order to take the gasket necessary for final hermetic sealing, and also to prevent the ends nesting in one another when stacked and thereby interfering with subsequent automatic feeding operations. The wheel curler completes the forming by trapping the end between a rotating inner wheel and a fixed outer guide. The can end is carried between the gradually reducing gap between wheel and guide until an end of the required diameter and curl is formed. The curler usually has two curling wheels, complementing the end punch dies, each rotating in opposite directions and delivering the curled ends down discharge guides. The end is transferred from the wheel curler to the next machine by a conveyor. Since ends must arrive at this machine the opposite way up to the way they are discharged from the press, a twist used to be required in the guiding, though this complication has since been overcome.

Lining

The final operation in end-making is in the injection of the sealing compound. From the stack of ends provided from the conveyor, the machine separates the lowest one and transfers it to the solution applying station. The type of gasket used will vary according to the can usage. A chuck rotating at high speed engages the end and rotates it underneath a nozzle from which flows the lining compound. Integral drying ovens were incorporated in the early post-war years to solidify the solution. After drying the ends are stacked in a packing station ready to be fed to the double seaming machine.

(iii) Joining Body and End

After leaving the bodymaking machine the continuous line of cans pass through a separator which introduces a gap between each cylinder; this also allows the longitudinally moving cans to be turned through ninety degrees, which is done immediately after separation. The cans then pass to the 'flanging' machine; this bends out each end of the cylinder in preparation for double-seaming. Before entering, the cans are elevated so as to prevent any congestion. The forming of the two flanges is accomplished simultaneously by forcing die plugs into each end of the can. The flanger is a multihead machine of perhaps eight stations; these revolve about a horizontal shaft and the die plugs are carried on slides operating against stationary cans at each end of the machine. As the flanging dies retract the cans fall away from the turret down a discharge chute. The flanging operation not only shapes the body but also greatly increases the rigidity of the cylinder.

After flanging the can body is ready to receive the single end that is attached to each can in the can factory. This operation is known as double seaming. Upright can bodies are fed by a screw feed to an in-feed turret. They are then transferred to a second turret which carries them below an end feed magazine where an end is separated from the stack and placed on top of the can. The can end is held in place by a seaming chuck to the can body - the curl of which fits loosely into the curl of the can end - and grooved rollers with a specially designed profile fold the curl of the can end round the body. These high-speed rollers are then withdrawn and, in a second operation, rollers with a shallower recess flatten the seam tight. There are five thicknesses of tinplate in the double seam, except at the position of the side seam where they are seven. This relates back to the notching operation; if this had not been carried out there would be eleven thicknesses of tinplate at the double-seam/side-seam union. Eleven layers of tinplate at one point would militate against the attainment of a perfect hermetic seal. During the seaming operation the cans are carried round the base of the machine and are removed automatically when the operation is completed.

With one end secured the last stage in can-making is complete and the cans may be tested. The can, with its axis horizontal, enters a large test wheel via a feed screw and an input turret. The tester wheel uses compressed air to check for any leakage during the time the can travels the circumference of the wheel. Air is forced into the container, which is sealed at the open end and connected to a test space. Any leak in the can creates an increase in pressure in the test space. When this happens a light switches on as a signal and the faulty can passes off-line by way of a reject chute. If leaks are persistent, the rejected cans are tested by compressed air under water, as one would for a bicycle tyre puncture. The test wheel itself operates at 97 per cent efficiency.

After testing, the sound cans pass to the despatch area where they are packed and then transported by forklift truck to waiting lorries.

## 3. Changes in the Traditional Can-Making Method

This analysis of the changes which have been introduced to the traditional can-making process divides the developments into three categories. In the first instance those developments which have been introduced by the can-makers of their own volition and which are of an in-house nature are considered. Secondly, there are those changes which have been introduced as a result of developments on a raw material side. Finally, there are those changes in general engineering practices which the can-maker has adopted. Although in reality these categories are not mutually exclusive, they do provide analytical convenience. The first two categories have been loosely differentiated as 'process orientated' and 'material orientated' innovations.

(i) Process-Orientated Innovations

The changes which have been introduced since 1945 into the traditional can-making method are very much of the 'enhancement' type; some observers would, perhaps, be reluctant to class many of these very minor developments as innovations at all. These types of innovations have not been popular topics for innovation case studies, nor indeed for industry studies. In the case of can-making however, they are the very essence of progress.

A major problem in an account of very incremental innovation is in selection - how and where does one draw the line between minor development and purely routine change. In the following analysis this problem has been approached by moving along the manufacturing units in the can-making sequence in turn, and mentioning one or two of the developments which have been most regularly mentioned in the technical publications.

Bodymaking

In the cutting of tinplate sheets into body blanks, it may well be the case that in the early post-war period some UK can-makers were still using the old-inter-war slitters which performed the two length and breadth cutting operations; if so, the duplex slitter will have been a significant improvement to this stage of the operation. In the case of the duplex slitter itself, the feeding of the cut strips to the second cutting operation received some serious attention so as to perform the operation without any deflection of the strips. Back-up rolls were fitted to the feed rolls so as to allow the same positive control to be exerted on the central strips as could be achieved on the outside ones.[8]

The bodymaker, being the central manufacturing unit, has been the object of a number of changes. The most notable change, perhaps, was the introduction to the UK in 1964 of the 'roll-form' bodymaker. The type of bodymaker most usually employed, and the only one to be used in the UK prior to 1964, was the 'wing form' model. The popularity of this latter machine has been put down to its versatility, ease of changeover and its high rate of output.[9] Opinion on the respective merits of the two types is very much a source of professional disagreement amongst the two largest UK can makers, Metal Box and Reads. Metal Box believe the criticisms which have been expressed of the wing form bodymaker by Reads are unjustified.[10] Reads, whose parent company American Can Company developed the roll form bodymaker, argue that their machine has a comparable output rate with that of Metal Box, and is also easier to run.

Multi-high Can Making

One of the most oft quoted innovations concerning can-making is the 'multi-high' bodymaking system. Can-makers have long toyed with the idea of forming and seaming tinplate into a continuous cylinder as an in-line operation, and then slicing the cylinder into individual cans at so many thousand a minute in a sausage machine type operation.

In 1956 Continental Can Company announced the successful operation of a new method of can-making by which they claimed to increase speeds from the then current maximum of 550 c.p.m. to 750 c.p.m. The new process did not entail any major alterations to existing can-making plants; the can bodies are made in pairs, partially cut along a dividing line between the two cans before the cylinders are formed, then formed into cylinders and soldered in the usual way. The cans are then separated. This method is obviously best suited to small size cans, and before long 'three-up' can-making was achieved. Continental installed their first line in 1957 and reported that it operated completely satisfactorily. Metal Box, who maintained an agreement on technical co-operation with Continental, first employed the new method about 1959. Similar techniques were in due course developed by other big companies when the standardisation of can sizes warranted the change.

Somewhat unfortunately, the publicity which Continental's innovation and Metal Box's adoption received, has been taken at its face value by some observers. If, as is sometimes reported, multi-high systems led to a doubling in can-making speeds at a stroke, then here would undoubtedly be a major can-making innovation. The true facts of the matter, however, are somewhat different. Although Metal Box have continued to use the system many other large companies have not; even companies taking equipment from Metal Box's own Machinery Building Group do not use the method. It is true that the fastest conventional lines in the UK are multi-high and that the most efficient two-up systems cannot be matched for speed by the best single high lines in the UK. Single high lines though while they may be around 20% slower are still very effective and competitive.

Soldering

An area of can manufacture which has also seen a number of diverse developments is soldering. Most of these developments have been associated with changes in the base metal, and these are discussed later. Others, however, were associated with purely process considerations, and yet others with product factors. In the US, a significant change was the adoption of silver lead solder instead of the usual tin-lead solder, while immediate post-war restrictions lasted. This does not appear to have been used at all in the UK. A war-time stimulus which did not have an influence on the post-war UK scene was the search for 'tin-less' solders. As a result of war-time investigations into the properties of solders containing very low amounts of tin, it was discovered that a lap joint made with an alloy containing roughly only 2% tin and the remainder lead was in fact superior to one made with the conventional alloys containing 35-40% tin. By the early 1950s it was common practice to use no tin at all in the 'solder' fed to the machines, since the tin on the plate was sufficient to provide the necessary concentration of 2%. With this tin-less soldering the open laps that occurred when cans were stored unused from one season to another became a thing of the past.(11)

Another soldering development aimed at reducing the consumption of tin was 'margin-plating'. This process, developed by American Can Company and first used in 1956, involves plating only the narrow margins of steel plate which form the soldered side seams of cans.

With the development in the UK of canned beer in the 1950s, and canned carbonated beverages in the 1960s, attention turned from the problems of tin cost to that of lead pick-up. This trend was encouraged by statutory restrictions on the parts per million lead content of food and drink. In the UK in the early 1970s when the legally permissible lead content in solder for soft drinks cans was reduced to 0.2 parts per million, the canner found that the only way he could keep below this limit was to use a solder made of commercially pure tin. This significantly increased the price of the can, but no other solution to the problem of lead pick-up was available.(12) Another development in the soldering process has been the 'high-tin fillet' can: in some instances it is essential to leave areas of the tin can exposed in order to inhibit general corrosion. The high-tin fillet method was adopted in the 1960s for the canning of very aggressive packs such as spinach and asparagus.

There have, too, been incremental soldering process changes. In some cases these have been, as with high-tin fillet, related to product considerations. With the move to solders of low tin content in the late 1940s more heat was necessary to help the solder flow into the deepest recesses of the seam; this in turn created greater demands on post-soldering air coolers. It became the practice to augment the standard cooling fan with a second unit. Another incremental process change directly related to product factors has been 'jet soldering' as opposed to the conventional roll soldering. In the new process the can seam is brought into contact with the stream of molten solder which is usually directed upwards towards the pre-heated can seam. The process was developed for the beer and soft drink can where external decoration is important. Jet soldering reduces the side seam width from 25 mm to 6 mm.[13] The original method was developed in the US about 1967; Metal Box patented an improved process (British Patent 1 273 903) and applied the method in 1970.

End-making

A process introduced to overcome a long standing limitation on the maximum speed of strip feed presses for can end-making was automatic 'kickers'. These ensure that the punched ends clear the press area before the next stroke of the die.

Double Seaming

End seamers perform the crucial role of clinching the can end and body in the can factory, and hermetically sealing the can in the cannery. Every canner must have end seamers and the machine has been perhaps the single most active area of can-making development. Metal Box, E.W. Bliss and F.M.C. are possibly the three largest suppliers of seamers to the UK market. Each of these operates under conditions of on-going research and development in order to make the breakthrough that heralds a new generation of seamers. Although an improved seamer may provide an important competitive edge, a new generation seamer still only represents an incremental innovation; those firms who own double seamers would not normally obsolete a machine until it is in itself no longer efficient.

The post-war innovation in end seaming which has received most attention is the Metal Box 'Differential Double Seamer' - DDS. The company rate this as one of their most important developments.(14) The main barrier to increasing the speed of the final hermetic sealing has been the problem with spillage. This is caused by centrifuging, which is a problem also in the can factory end-seaming operation. The DDS, developed in 1957, allows the filling of cans without the gap between cans previously necessary, and without the need to rotate the cans at the previous high speed to effect seaming. A typical standard machine performing this operation in the mid 1950s and with an output of 200 c.p.m. required the can to be rotated about its axis at a speed of at least 1000 r.p.m. The DDS, on the other hand, it was claimed, would at an output rate of 400 c.p.m. require the can to be revolved at only 260 r.p.m. There were two prototypes of the DDS, one of which was designed to operate in the can factory and the other in the cannery.

For those who have adopted the DDS, it represents a new generation seamer. There are those outside Metal Box, both among its competitors and customers, who are very sceptical of the claims made for the machine.

It is pointed out that the DDS has never achieved the maximum speeds which have been claimed for it. It would now appear to be the case, although Metal Box are keeping a brave face on the DDS, that none of the canners wishes to use the machine because of its complexity, and all the problems it is alleged to have given in the past. Within the industry the DDS is often referred to as the 'Disastrous Double Seamer'.

Less controversial double seamers have been developed by Metal Box with great success; in 1969 the company announced a new high-speed seamer capable of closing cans at the rate of 1000 per minute, the first time a seaming machine of such speed has been achieved in the UK. In 1978 the company further announced that after 'four years intensive research and development they had made another important advance in seamer technology'. The M3 10-6, as the new machine has been designated, is a six head, 600 c.p.m. seamer which is claimed to signal the inception of a completely new clan of closing machine. Although basically a conventional seamer the M3 10-6 incorporates many important improvements and modifications to meet the present and future demands likely to be made upon it.

A somewhat different innovation related to the double-seaming operation has been the adoption in 1968 by Reads of 'Cerafilm'. For many years can-makers have recognised that the countersink bead area of the can end undergoes great stress, strain and stretch when the can end is made and when it is double-seamed. There has always been the possibility of lacquer abrasion or fracture which would expose the tinplate below.

Reduction of metal exposure in the countersink area had become especially important precisely because of the greater stress imposed by faster can-making and seaming machines. It was to give protection against this exposure problem that Cerafilm was introduced. The Cerafilm 'shoulder guard' acts as a padding for the countersink area and as a lubricant and shock absorber when the ends are rolled onto the can body. The Cerafilm technique was developed by American Can Company.

An area of early development worthy of note while on the subject of double-seaming has been in the lining compound. This is the least obvious but in some ways the most important part of the can. Apart from a change of colour from red to grey, only an expert could tell that the sealing compound had changed at all since it was first introduced at the turn of the century. They have, however, improved very significantly in sealing quality, particularly in their ability to render the seams more resistant to the mechanical abuse inseparable from high speed can-making. The major development has been the change from natural rubber latex to synthetic rubber.(15) The technology of synthetic rubber is radically different from that of natural rubber; the problems of developing synthetic compounds for can linings were different to those associated with normal synthetic rubber applications e.g. tyres; the research problems are intensified because the chemicals used must meet rigid standards of taste and toxicity. The new synthetic compounds made the sealing compound stay in the seam instead of softening under steam, and did not squeeze out all over the closing machine under the pressure of the seaming operation. This same modification also opened the way to the development of compounds sufficiently steam-resistant to permit steam injection at the moment of closure, in order to enhance vacuum and so prolong shelf life and permit processing at higher temperatures. The essential development of synthetic compounds took place during World War II, but they continued to be improved - usually imperceptibly - in the immediate post-war years and after by companies such as W. R. Grace Ltd., the major supplier of sealing compounds.

## Packing

The final operation in the can factory is the packing of the containers. This operation has changed considerably, due in no small part to the role of Metal Box. They have instigated the bulk palletisation of cans since the 1950s and have offered their customers discounts to take their cans in this form. The concentration of the canning industry since the late 1950s has eliminated the small operator not suited to bulk palletisation, as a result this packing method is now the only method used for despatching cans. For most of the 1950s the method of packing cans was in cartons; around 1959 Metal Box introduced caged palletisation. Both techniques have now disappeared. In the modern method the cans are packed onto wooden stillages with a layer of cardboard between each row; the package is compressed into a compact unit of around 3,500 cans. The cans are loaded onto the platform by a semi-automatic mechanism not unlike that to lift pins in a bowling alley. The shrink wrapping of empty cans has not caught on in the UK. It is a relatively expensive method because of the energy input to the shrink-wrapping oven.

## Conveyors

One further development in can-making which might be mentioned is the system of conveyance tables, elevators and overhead runways which festoon the modern can-making plant so as to carry the containers from one manufacturing unit to another. These machines have been the object of continual development in the post-war era; the increasing speeds of can production call for the exercise of ever greater care in the design and manufacture of can conveying equipment. This is necessary to ensure the smooth and controlled flow of production and thereby keep to a minimum damage to the cans by impact, or rubbing in various form through the can-making stations. This has become particularly important with the introduction of lithographed open top cans to the UK in the 1950s. Any marking of these containers is objectionable.(16) Any number of developments in gravity runways, cable-ways, magnetic belting and electrical controls might be mentioned as contributing to a general improvement in efficiency; one specific innovation which has had a uniquely identifiable impact is the adoption of plastic covered steel cable. This has resulted in the virtual elimination of 'cable-burn'.

(ii) Material Orientated Changes

Electrolytic tinplate

The first metal material change which the post-war UK can-making industry had to adapt to was electrolytic tinplate, introduced in 1948. The major implications of electrolytic tinplate were in the lacquering operation, and these are discussed separately. The second most important aspect of electrolytic tinplate from the can-makers point of view was its solderability. In this respect the can-maker had to realise he was using a different rather than an alternative material to hot-dipped plate and so adjust his operation accordingly. Consequently, can-makers adapted their entire soldering procedure; the composition of the flux, venting of side seams, pre-fluxes, pre-heaters, solder roll speed, solder temperature, solder composition, solder bath height, after heater, and wiper all had to be adjusted to accommodate the soldering characteristics of electrolytic plate. The somewhat trial and error methods of the American can-makers in the 1941-45 period established what were the best practice techniques in regard to the new material. In the UK in the 1950s it was a case of implementing these methods.

Thin tinplate

One of the most significant changes in the raw material from the can-makers perspective has been the continual trend towards the manufacture of tin-plate in ever thinner average and the introduction of double-reduced plate in particular. This (on-going) innovation is not noticeable in having led to a dramatic change at any single point in the can-making sequence, but rather for the way its repercussions have permeated virtually the entire process of can manufacture.

The move to the use of thinner tinplate in the UK, although present in the 1950s, may conveniently be dated from the end of 1960 when the price structure of the tinplate trade was adjusted in a way that made it more worthwhile for the can-maker to consider using thinner gauges. This piece-meal process culminated in 1968 with the introduction of double reduction which led to a considerably more dramatic drop in average substances. The important point about thinner tinplate, and DR material in particular, to the can-maker is that the higher tensile strength necessary to give the lower gauge material sufficient strength entails a loss of ductility in the plate. This less workable plate creates problems in handling and fabricating throughout the can-making chain. Although the can-makers have always had trouble - which they have been able to overcome - with occasional lots of brittle plate, the material which is now used for many cans would simply not have been processable without the incremental changes to can-making of the 1960s and 1970s. As thinner material came into use so special techniques were developed, and in some cases patented, to handle it. In the double-seaming operation, for example, imperfections known in the art as 'pleating', 'veeing', 'spurs' and 'droops' may occur in the can body. These defects are much more serious when the can body and can end are formed of very thin sheet metal. To overcome or reduce these tendencies, Metal Box developed a modified double-seaming operation in 1964 (British Patent No. 1 012 528).

Further purely process implications of double-reduced tinplate are concerned with the flanging operation. In can body forming the grain of the plate must always run circumferentially around the mandrel - if this is not so the extension of the metal during the flanging operation may result in flange cracking. Consequently in some cases the sheet layout for bodies had to be changed to accommodate DR plate.[17] Similarly, Metal Box patented two new flanging processes in 1970 and 1971 after adopting DR plate; both were designed to reduce the danger of flange splitting (British Patent No. 1 273 903 and British Patent No. 1 356 462).

The use of thinner body plate led to a noticeable difference in some can constructions in the UK from the early 1960s. In the larger standard size food cans for which DR was adopted, it was necessary to compensate for the thinner gauge by the use of circumferential corrugations around the can body - known as 'beading'. To institute this change requires only a minor alteration to the mandrel on which the can body is hooked, indentations in the mandrel being transferred to the can body when it is compressed.

The bead profile is extremely important to the strength of the can in the same way as panel rings are to the can end; an increased bead depth increases the resistance of the can walls to external pressure - but it decreases the vertical resistance because of the 'concertina effect'. When beaded DR cans were introduced in 1969, it was realized that the increase in side-wall strength would be at the expense of compression strength, but initially this did not seem critical. What was not realized, however, was that the beaded can was particularly susceptible to compression when vertical pressure was imposed at an angle of ten degrees. At this angle the beads on the most burdened side are prone to give in. The importance of this offset pressure phenomenon was soon demonstrated in the handling area: in the stacking of empty cans by fork lift truck, each pallet was put down on top of another at an angle of some ten degrees. This did consequently lead to whole cases of 4-high pallets collapsing during stacking.

Reads took a lead in the adoption of DR plate, introducing it without modification for the shorter container and with beading for the taller can.

DR has been found most suitable for 63 mm and 73 mm diameter plate, but over this size it tends to lack strength. Metal Box adopted DR plate in 1969, it being particularly suitable for the beer and soft drinks can where reduced container wall strength is compensated for by the internal pressure of the gases. Metal Box*, however, probably use DR plate for a smaller percentage of their can output than do Reads. The latter company believe that their roll form bodymaker is more suitable than Metal Box's wing type for the DR material because the former machine flexes the tinplate; this is felt to be particularly advantageous for the smaller size can.

This trend to thinner tinplate also affected can end production. Originally in the US DR plate was only used for bodies, whereas in the UK it is preferred for ends. The can end was redesigned to incorporate additional panelling rings. One of the most important areas of modification in can-making as a result of thinner tinplate was in can handling operations on runways etc. These had to be modified to avoid damage to empty cans.[18] Prior to conversion to DR plate the points at which body dents occur with standard cans must be eliminated. The harder, stiffer DR plate may crack at such points. If there is considerable pressure against the cans in the runways, cans of DR plate may become out of round. When the heavy double-seam edge strikes the lighter area of can body it is apt to cause a small crack in the can wall. Inclined gravity tracks should be as narrow as possible, so that can-to-can contact will be on double-seam to double-seam.

The higher strength of DR plate means that higher forces are required in

* When Metal Box promoted their DR can they decorated it with a clipper ship design symbolising 'lightness with strength'. This is believed to be the first time surface design has been used to promote a technical development.

all the forming operations; the thinner plate has to be cut more cleanly at the duplex slitter, notcher, etc., and the new plate has necessitated better machine tools. It will be clear that thinner tinplate has led to a complete refining of the whole can-making process. It is somewhat simplistic to say that lower gauge material has been solely responsible for all the changes mentioned because many of the developments connected with thinner tinplate also represent a move toward best practice techniques. One could say that it has necessitated the adoption in standard can-making of practices which though desirable have been previously neglected.

Coiled Tinplate

The shipment of tinplate in coils, which began in the UK in 1964, represented a noticeably non-incremental innovation. The advantage of this development to the can-makers was in the material saving which it allowed in can-end making. It will be appreciated from consideration of the scroll-shearing process that at the edge of each and every sheet of tinplate there is material wastage; although this is recycled it represents a cost to the can-maker. By cutting can ends from coiled tinplate the dovetailing of rows of ends can be continued in an unbroken sequence throughout the coil. The rolling of coils by-passes the classifying section in the tinplate mill; for this reason the can-maker has to accept tinplate with all the defects, such as welds. The shipment of coiled tinplate therefore creates an added quality control function for the can-maker who must sort out the defective areas of the coil for himself.

The introduction of coiled tinplate not only affected the traditional scroll-shear operation, it also involved the installation of expensive coil-handling equipment. When the innovation was first adopted there were still a number of technical problems to be overcome, but the material and operating economies inherent in the utilisation of tinplate in coil form must have been considered by Metal Box as sufficient to justify the effort of tackling and solving these problems.(19)

Apart from the associated capital costs of machinery to handle the coils one must, of course, incur the financial outlay of the coil cut-up facility itself. The type of unit which appears to have been most widely - and perhaps even uniquely - adopted is the Littel coil cut up line. The Littel apparatus installed around 1970 at Metal Box's Wisbech factory cuts 20,000 ft coils of 3 ft wide tinplate with two scrolled edges. The sheets are subsequently cut into scrolled strips in the opposite direction. The line operates at speeds of up to 800 c.p.m.

For some users there are drawbacks associated with coil cut-up lines. In the first instance one must be a sizeable can-maker to be able to utilise the ends at the rate at which they are produced. A second disadvantage of the facility is its size; it is often not possible to incorporate the line at any existing plant and one must wait, if one wishes to adopt the development, until a new location is justified. In the UK both of the largest can-makers have situated at least some of their can-end facilities, for reasons of transport economy no doubt, in South Wales; Metal Box at Neath and Reads - who adopted the innovation in 1970 - at Rhymney. At these two locations the coils are cut and transported to the various body-making plants up and down the country.

There is no reason why traditional can-bodies cannot also be produced from coil, though as yet this is not practised. This is no doubt due to the negligible, if any, material savings that would be involved. This is, however, an area of active consideration in the can-making industry.

(iii) <u>General Engineering Changes</u>

The continual progress in the manufacture of the conventional three-piece can, it has been observed, has involved the incremental upgrading of processes. To a certain extent these sorts of advances depend on the in-house expertise of the technical and manufacturing personnel. In addition to these can-making orientated innovations, there have in the post-war period been (on-going) advances in general engineering technology. It is partly the function of the engineers employed by the can-makers to keep abreast of these wider industrial developments in their own specialized fields and to exploit them wherever possible in their own processes; this industrial cross-fertilization is known as 'techology transfer' and the personnel involved as 'technological gate-keepers'.

Some of the features of can-making are by no means unique. In such cases the interchange of ideas and techniques is almost mandatory; the basic cylinder-forming process of traditional can-making, for example, is used in many industries. Similarly, the base materials used are fairly conventional - either low carbon steel or aluminium.

Three important distinctions between canmaking and these other industries exist. In the first instance there is the extreme thinness of the metal used. Secondly, the steel used in can manufacture carries with it a coating on both sides - usually of tin - which is in turn covered by organic coatings. All these surface additions are expected to stay bonded to the basic sheet material while it is undergoing the severe deformations of can-making. The third major distinguishing feature is that, compared to most other activities, the required output figures reach astronomical proportions. In order to keep the amount of machinery deployed to manageable levels, very high operating speeds are necessary.[20] The most important factor concerning these three features is the tooling; although the problems presented may be unique their solution has depended very much on general engineering techology. The first problem of very thin material requires extremely high tooling accuracy.

The second problem of surface coatings requires that tool surfaces in contact with the material must have a very high standard of finish to avoid damage to the coating by scratching. The third problem of high output requires that the tooling has a long life. Long tool life is important because each tooling component tends to be very expensive, changing worn tools frequently would cause high output losses.

Innumerable general engineering advances have contributed to accommodating the three features of thin material, surface coating and long tool life. The one advance which has singularly been of most value in all these three directions is tungsten carbide tooling. This advance in mechanical engineering was pioneered within the can industry by Metal Box. Up until about 1970 Metal Box went to the US for its tooling requirements because of UK inadequacies. They have, however, since partly satisfied their own requirements at their precision toolrooms at Alperton and East Kilbride. At these works, according to Metal Box, 'A number of new tooling developments are in the process of being finalised'.[21]

Several other advances in various branches of engineering adopted by the can-makers may further illustrate the relationship. Improved roller bearings, particularly 'sealed for life' bearings with a guaranteed minimum life of 90,000 hours, have been employed at various can manufacturing stations. On bodymakers there have been a host of standard engineering improvements including linear bearings; these allow a very precise control compared with roller and tapered bearings. Gas and air mixture controls have contributed to the automation of heating stations. A further general technological improvement has been improved heat sensors; these have been used in the solder bath. Formerly, mercury and vapour have been used in the sensor probe, now it is a thermocouple. Yet another general engineering advance has been solid state controls. This has been adopted for use instead of thermionic valves on can wheel testers. The old thermionic value had many disadvantages including large size and a short life; if controls were faulty it was necessary for an electrician to go through the old type, time-consuming electrical testing procedure. Now with the use of electronic panels correction is greatly hastened and simplified. A further advance has been the use of extended life oils now common in many industries; it is now no longer necessary to change the oil at regular intervals but only to keep it topped up - with perhaps an annual change. Still another external advance adopted by the can-makers has been plastic and semi-plastic rubbing strips. Formerly soft metals such as brass were extensively used. Nylon was tried for a while and initially seemed appropriate because of its very good self-lubricating properties. It was subsequently found unsuitable because of expansions when wet. A final advance which cannot go unmentioned is computer control systems. Mardon Illingworth's can-making operation is so controlled, as is Metal Box's Braunstone plant.

4. New Three-Piece Can Constructions

(i) Tin Free Steel

The availability of Tin-Free Steel (TFS) from B.S.C. in 1968 required significant changes in the method of can construction. These new techniques were so recognizably different from the traditional way of manufacturing three-piece cans that it is convenient to consider the new methods separately. The feature of TFS cans which created the departure from conventional technology was their inability to be soldered at high speed.

Irrespective of the emergence of TFS there had in the post-war period been continual efforts to find a better way of joining a can than by soldering. The cans which had been made in the nineteenth century with a simple lapped side-seam presented no problems in resisting the high internal pressures developed in cans during sterilization. These mechanically strong containers had the serious disadvantage of exposing the can contents to an unprotected edge of bare steel which was subject to severe corrosion, even when the remainder of the body was tin coated. Sulphur-containing products reacted with the exposed iron to form black iron sulphide. Other chemical reactions could also occur such as bleaching of the contents. Burrs on the cut edge added to this problem. The advent of lacquers failed to completely solve the problem, since it was difficult to cover the sharp edge adequately. Furthermore, no known commercial lacquer was, or is today, completely satisfactory for the protection of bare steel against the attack of oxygen and other agents, particularly in acid media.

It was to eliminate the exposed edge of bare steel that the lock seam was developed. As now used in combination with a short section of a lap seam at each end of the can-body - 'lock and lap' seam - only a small area of the bare steel is exposed to the contents of the can. Corrosion and product contamination have been remarkably reduced as a consequence. With the lock and lap seam construction, however, came a number of other problems. A locked seam is not as strong as a lapped one and additional metal is employed, raising raw material cost by several per cent. With beer and other carbonated beverages which were canned from the 1950s, which involve unusual thermal sterilization, it was necessary to revert in part to a lap construction to achieve the strength necessary to resist the high internal pressures developed.

Machinery to form lock and lap seam bodies at high speed must be precision made by special materials at high capital cost; the clearances and dimensional tolerances in some parts approach those of a watch, calling for manufacturing skills of the highest order. The need for the complete synchronization of numerous motions is a drawback. Maintenance and change-over for different sized bodies both necessitate the services of highly skilled mechanics. Downtime is costly, and engineering and material costs are likewise high.

With these can constructions the cost of solder and flux is substantial and their use requires additional expensive maintenance schedules because of the corrosive nature of soldering flux. In addition, blower devices must be installed to reduce the annoyance and corrosive effects of fumes and dust.

The speed of conventional bodymakers is limited by the rate at which discontinuous motions of heavy machine parts can be repeated. It is thus advantageous to employ a continuous process in order to increase the production speed still further.

It is apparent then, that there has been plenty of incentive for can-makers to find a new method of joining three-piece tinplate cans throughout the post-war period. The very fact that can-makers in the UK have never commercially adopted any alternative process to soldering is testimony to its suitability for joining cans vis-a-vis alternative methods. Almost by implication, therefore, any rival process adopted to overcome the limitations of a new can-making material is unlikely to be either as technically or as economically attractive as soldering.

The advantage of TFS was initially in its cost advantage over tinplate; until a method could be found to side-seam TFS at commercial can-making speeds it had an outlet as ends on tinplate bodies. The advantage for the can-maker in finding a sound system for joining TFS was in the possibility of a very narrow lap seam that would allow all-round decoration; this was an important consideration in the beer and soft-drinks market where the conventional lock and lap seam configuration necessitated what the can-makers considered as aesthetically displeasing wide side-seam margins.

When TFS was introduced to the USA in 1965 the two major American can manufacturers - American Can Co and Continental Can Co. - set about mastering the joining problem which had defeated them since 1945. The fact that within less than three years both firms had accomplished the first two commercially successful processes for the side-seaming of tinless containers suitable for carbonated neverages is an indication of the galvanizing impact of a commercial stimulant to innovation.

The innovation developed by American Can was an adhesive bonded, or cemented, side-seam. Cemented side-seams were not in themselves new to can-making. Such cans had found a substantial degree of commercial success for the packing of products which generate no significant internal pressure. The problems with these early cements was their low degree of bursting strength, particularly when the can is subjected to conditions necessary to process certain products - such as the sterilization of fruit and vegetables or the pasteurisation of beer. The very high strength adhesives which were tried by can-makers were either deficient as regards adhering to the metal or else completely unsuitable for high speed can-making wherein sufficient bonding strength to hold the can body must be achieved within seconds or less. American Can's successful technique, patented in 1966 (British Patent No. 1 148 401) was termed the 'Miraseam' process. This method used a thermoplastic cement which was sandwiched between the plate and organic coatings in a narrow lap seam. The body is formed on a modified bodymaker, and the process is based on the control of heat input and removal. In 1972, Reads successfully adopted the process for beer and beverage cans.

The solution to tinless side-seaming developed by Continental Can in some respects represented the cracking of a tougher technological nut than in their rival's case. In 1968, Continental Can patented (British Patent No. 1 173 108) what was the very first successful commercial can-welding process. This 'pressure' or 'forge-welded' can is also made on a modified bodymaker. Coated TFS body blanks with bare edges are fed into the bodymaker wherein the margins are cleaned so that a uniform electrical resistance will be presented to the electrical current provided to weld the side-seam. Containers made by this method are termed 'Conoweld' cans. For reasons best known to themselves, Metal Box opted not to pursue their option on this can and instead, in 1971, introduced a Japanese process involving the application of a cemented nylon strip to the side seam instead of a solder; this process was obviously closer to that of American Can than Continental Can. Metal Box designated these containers 'A Seam' cans. Both types of TFS can have a number of common factors. They have stronger side-seams than tinplate cans; both eliminate the wide plain margin required at the side-seam for lithographed soldered cans, and both are technically suitable for a wide range of products. The cans are economically more suited to the decorated can market where no additional lacquering is required over conventional cans. In the very largely unlithographed food can market however, the necessity for external coatings to compensate for the lower corrosion resistance of TFS are both impractical and uneconomic.[22] Neither the 'A Seam' or the 'Miraseam' can are able to be produced at speeds as high as by conventional soldering. This has been the problem with another non-soldered can - the Soudronically-welded container. This technique was first used in Switzerland in 1958. This seam is recognizable by its narrow, black, serrated appearance. This type of join is used on some aerosols and large beverage cans. Its slow bodymaking speed, about 120 c.p.m., makes it unsuitable for high volume can lines.

The development of two-piece can-making technology has over-taken these side-seam innovations before they had really got off the ground. Although the Miraseam process is likely to remain, the future for the 'A Seam' can seems much less certain.

(ii) Aluminium

A new material to UK can-making which has had an important impact on the construction of the conventional can is aluminium. Aluminium has long been used for shallow-drawn fish cans, but its cost has always prohibited its use for standard open-top cans; the material has never been used in the UK on a commercial basis for the three-piece can body. Aluminium has had its influence on the traditional can in its use as an end. A major factor in the beer and soft-drinks market is impulse buying; this makes it important that it should be possible to open a can on impulse i.e. without the need of an implement ready to hand. Aluminium, being a soft malleable metal, was suitable for the ring-pull ends that were first applied to UK cans from 1965. The adoption of aluminium introduced pressing to the end-making operation, but did not directly affect conventional can-making equipment. The additional material cost of aluminium over tinplate, however, stimulated ways of economising; the idea was developed in the US of 'necking-in' the end of aluminium topped cans from 66 mm to 63 mm. This concept not only reduced the aluminium requirement but also, by virtue of eliminating the protruding lip or 'chime' at either end, had a number of product implications. The 'necking-in' technique was first adopted in the UK by Metal Box in 1973 on a two-piece 'Neck-line' container. The necking-in process first developed was suitable for two piece cans, but was not initially found satisfactory when the can body had a soldered or cemented side-seam because it was not possible to control the thickness of the lap seam within acceptable limits. This problem was overcome in the UK by Metal Box in 1970 - British Patent No. 1 301 270. For those three-piece cans which were to be necked-in it was necessary to add an extra station to the bodymaker to perform the operation; in this way the conventional manufacturing method was altered.

Faced with two diameters of beverage can, the beer and soft drinks manufacturers had the problem of deciding whether to adopt the new size can with the attendant alterations it would involve to their own filling lines. For a number of reasons there was a concerted changeover to the 63 mm diameter size.

The adoption of the aluminium end is an interesting innovation in that it not only led to a change in can-bodymakers but also in its spin-off effect in also saving tinplate on the non-aluminium end of the can. This diameter reduction in turn allowed the use of thinner tinplate.

## 5. Coatings

### (i) Background

In the following paragraphs it is intended to discuss the developments in conventional coating technology, particularly as it has been affected by can-making innovations and to round off with a brief mention of the new coating technologies which seem destined to overtake traditional methods.

Can coatings may be split into two categories: those that are used on the inside of the container and those that are employed on the outside. The former are lacquers and the latter paints and varnishes. Both lacquers and paints serve two basic functions of protection and decoration; lacquer is primarily concerned with protection and paints with decoration.

As protection is a far more important role than decoration for the processed food and beverage can, the problems of lacquerability tend to receive more attention in can-making. Traditionally, the technology of metal coatings in the can industry is the covering of a flat sheet with both liquid coatings and printing inks, the curing of these materials by heating them in ovens, followed by the fabrication of the plate into a container. The actual deposition of the lacquers and inks is performed by a roller-coating machine. This, basically, is an arrangement of four rollers - feed, transfer, impression and pressure rollers. A feed tray and main container make up the apparatus. The coating material is pumped from the maincontainer to the feed tray where it is picked up by the feed roller which is partly immersed in the solution. The coating passes directly from the feed roll to a transfer roll of similar size, and then to a larger impression roller. A pressure roller lies directly below the impression roller and the sheets move between the two. The lower roller is adjustable to exert a predetermined pressure against the impression roller as the sheet passes between them. The setting of this pressure determines the thickness, or weight, of coating applied. The impression roller has a recessed portion extending across its full width to provide an interval between successive applications; the means of feeding the sheet is synchronized so that the roller 'gap' coincides with the feed gap. In the interval between each sheet the pressure roller is in contact with the impression roller and coating material is transferred. A doctor blade removes this liquid from the pressure roller from where it returns to the main tank.(23)

In the early 1930s virtually all the lacquers used were made by fusing natural gums and resins, and blending them with drying oils such as linseed oil and tung (wood) oil. These types of coatings are termed 'oleoresinous' or oil-based lacquers.[24] The technology of metal coatings was revolutionized in the 1930s by the very rapid development in the US of a variety of new man-made coatings; these synthetic coatings are based on materials which, though they may contain some natural raw materials such as oil, are essentially produced by chemical synthesis under carefully controlled conditions. In 1943 at least 75% of the mixtures used for lacquers in the US contained synthetic materials.[25] In the UK many of the raw materials being used across the Atlantic were not available to the metal decorating companies; as a result systems had to be developed from indigenous sources. This served to delay the development of these new materials by a few years.

Since the vast majority of the output of the metal decorating industry goes into the packaging industry, and the metal packaging industry is in turn dominated by the processed food and beverage can, then the metal decorating industry must adapt its products and processes to keep in harmony with the changing requirements of the can-maker. The proliferation of synthetic lacquers, pigmented coatings and varnishes can be directly related to two major developments in the metal container industry. The development of the screw cone top beer can (similar to a well known metal polish tin) in the early 1930s created a whole set of new and more demanding problems for can linings both inside and outside the container. The emergence of electrolytic tinplate after 1937 was a similarly tremendously important influence on coating technology; the reduced amount of tin coating deposited on the steel and its greater tendency to porosity as compared with hot-dipped plate had to be compensated for by increased use of inside organic protective coatings.[26]

Technologically, the post-war period in the metal decorating industry has been characterized by the continual development of solvent-borne coatings. The ideal conclusion in this process, from the can-makers point of view, would be the emergence of a universal coating, but consideration of the diverse properties that would be required of such a coating suggest it may never be found:

"Of all the coatings applied to metals the physical and chemical properties required for food can linings must be among the most exacting. As well as the normal properties coatings for metal require, such a good adhesion, sufficient hardness and stability, a number of special properties are essential. Can linings must have sufficient adhesion and elasticity to withstand the forming operations of can manufacture; they must have sufficiently short storing times to meet the requirements of highly mechanized can manufacture; they must be unaffected by the high temperatures used for sterilisation; they must be non-toxic and free from taint, and they must resist the corrosive action of food in cans. In addition they must not be expensive and they must be able to keep their initial clean appearance; these last two points are vitally important from the sales point of view".(27)

Although it was briefly thought possible in 1962 that a Du Pont Company development known as 'Budium', based on a butadiene polymer, may prove to be a universal can lining the varying requirements of the can industry are still met by a wide range of often complex types. Before discussing the can-making developments which contributed to this proliferation, it is appropriate to list the various resins currently being used as media for coatings in the metal packaging industry and also their end uses:

TABLE I*

Conventional resins and their uses

| COATING | RESIN TYPES | ADVANTAGES | DISADVANTAGES | END USES |
|---|---|---|---|---|
| Sizes | Alkyd<br>Epoxy-amino<br>Vinyl | Good flexibility<br>Good substrate and inter-coat adhesion | High volatile solvent content | As size coatings where improved fabrication required |
| Enamels | Styrenated-alkyd | Cheap<br>Good flexibility<br>Good processing resistance | Poor chemical resistance<br>Poor colour retention | Low flexibility non-process and processing cans |
| | Polyester | Good flexibility<br>Good colour retention<br>Good process resistance | More expensive than alkyds | Processing and non-processing cans, caps, closures.<br>Deep drawing caps<br>Aerosols |
| | Acrylic | Good flexibility<br>Good colour retention<br>Good process resistance | Odours<br>Expensive | Processing and non-processing caps<br>Processing bodies |
| | Epoxy-ester | Good product resistance<br>Good hardness | Limited flexibility<br>Expensive | Toothpaste tubes |
| | Vinyl | Very good flexibility<br>Good processing resistance-if modified | Low solids<br>Very expensive<br>Thermoplastic unless modified<br>UV/heat degradable | Deep drawing caps<br>Toothpaste tubes<br>Drawn processing cans |

| COATING | RESIN TYPES | ADVANTAGES | DISADVANTAGES | END USES |
|---|---|---|---|---|
| Varnishes | Alkyd | Cheap<br>Good hardness | Fair processing resistance<br>Poor colour retention<br>Flexibility fair | Low flexibility non-process cans |
| | Polyester | As Enamels | As Enamels | As Enamels |
| | Acrylic | As Enamels | As Enamels | As Enamels |
| | Epoxy-ester | Good hardness<br>Good-fair flexibility | Expensive<br>Fair colour retention | Screw caps<br>Crown corks |
| | Vinyl | As Enamels | As Enamels | As Enamels |
| | Epoxy-amino | Good-fair flexibility<br>Good colour retention<br>Good processing resistance | Expensive | Caps and ends |
| Lacquers | Phenolic | Good produce resistance<br>Excellent sulfur resistance<br>Good processing resistance | Very poor flexibility<br>Poor plate wetting | Can bodies |
| | Epoxy-phenolic (E/P) | Good product, sulfur and processing resistance<br>Good flexibility | Expensive<br>Lowish solids content | Can bodies and ends<br>Internal and external non-compound caps |
| | Epoxy-ester/ phenolic | Good flexibility<br>Cheaper than E/P | Only fair product sulfur and processing resistance | Can bodies and ends |
| | Epoxy-urea formaldehyde | Good product and process-resistance<br>Alcohol resistance good<br>Cheaper than E/P | Only fair drawing properties | Internal spray lacquers for beer/beverage cans |

| COATING | RESIN TYPES | ADVANTAGES | DISADVANTAGES | END USES |
|---|---|---|---|---|
| Lacquers cont'd... | Vinyl | Excellent flexibility<br>Good alcohol resistance | Low solids content<br>Expensive<br>UV/heat degradable<br>Monomer thought to be carcinogenic | Internal spray lacquers for beer/beverage cans |
| | Organosol | Excellent flexibility and adhesion<br>Good product resistance<br>Excellent compound adhesion | Only fair flow-out<br>Low process resistance<br>High film weights required<br>Monomer thought to be carcinogenic | High flexibility cap and closure linings<br>Deep drawing lacquers |
| | Polybutadiene | Very cheap<br>Good product resistance | Odour<br>Only fair flexibility | Beer can bodies |
| | Oleoresinous | Cheap<br>Good product resistance<br>Good sulfur resistance, with ZnO or ZnCO. | High baking schedules required | General good can bodies |

* Source: Newbould.

(ii) Food Can Linings

The mainstay of the can-making industry for most of the post-war period has been the processed food can. The ever-widening range of foods packed in cans and the increased use of chemical additives in food have put ever greater demands on the can's lining. Food types may be split into two categories: acid-bearing and sulphur-bearing products - each adds its own problems to the basic lacquer requirements. For highly acidic fruits and certain vegetables the lacquer must provide a barrier against the corrosive action of the product which might otherwise break down the tin coating and attack the steel. Theoretically, the lacquering operation applies a continuous film to the plate; sometimes however, the film does not remain continuous and dewets over small areas.[28] This behaviour is influenced both by the metal surface and by the lacquer. Improvements in the manufacture of tinplate helped to lessen this problem but modifications in the lacquer were also necessary.[29] The dewetting problem is particularly important in acid packs because the pinholes in the covering film form the centre of attack, and the contact between the juice and tin or iron eventually causes discoloration of the contents and a gradual breakdown of the lacquer film. This meant that the development of good acid resisting lacquers was outflanked by the dewetting problem. This problem is usually solved by applying an additional internal coat which effectively covers any imperfections in the first film.

The second type of food pack, those which contain sulphur, present two different problems for lacquers. With vegetable and liquid packs a sulphur-absorbing lacquer is necessary whereas for solid meat or fish packs sulphur-resisting lacquers are needed. In wet packs the prevention of undesirable odours due to concentration of the sulphur in the head-space, and the prevention of discoloration, is achieved by pigmented lacquers, usually containing zinc oxide, which neutralise the sulphur compounds in the product. For solid packs a lacquer that will prevent sulphur-blackening of the container is necessary; in recent years epoxy has been blended with the formerly used phenolics to provide greater resistance to polyphosphates and preservatives. In these solid meat packs waxes are also incorporated in the lacquer as 'meat releasing agents' - otherwise there is a tendency for the lacquer to adhere more firmly to the pack than the container.

(iii) Beer Can Linings

The greatest stimulant to lacquer technology was the beer can. This was because the canning of beer created problems not previously encountered in unpressurized packs. The pre-war cone top beer cans were coated internally with a wax lining, but this was associated with a 'metallic' taste which seriously retarded consumer acceptability. To overcome this problem, it was necessary to develop a taint-free vinyl resin which was capable of standing the internal pressures of carbon dioxide. The second main problem with beer packs is protection; it is essential that contact between the product and the metal is reduced to a minimum. Small traces of tin or iron dissolved into beer may upset the delicately poised protein equilibrium and lead to loss of clarity.

It is therefore necessary, besides developing lacquers with good barrier resistance, to adapt the straightforward roller coating process to ensure optimum metal coverage. There are five coating operations involved in beer can-body production. In the first instance an epoxy-phenolic lacquer is applied by roller coater to the flat sheet. The sheets are then turned and the exterior coating applied. This consists of an enamel base coat or, more commonly, a printed base followed by the printed design and then a finishing varnish. The varnishes used are normally based on alkyd or modified alkyd resins. After the sheets have been slit and formed round the mandrel an internal side stripe lacquer is applied along the length of the side-seam to compensate for any damage to the perimeter of the base coat when the blank is notched etc. This application may be undertaken before or after soldering, but normally the former. On beer cans with a wide external side-seam margin this non-decorated area is coated with a clear lacquer to prevent rusting. When the factory end is seamed on a final top coat is applied to the can body interior to provide a flavour-free barrier between the case coat and the pack. This last application is made by automatic spray, unlike the others which are all roller coated. In the first ten years of its life, the flat top beer can included a tinplate end that was seamed on in the can factory. As the same barrier properties are required for the end as for the body, so it too receives two internal coatings on an external coating applied to the pre-scrolled sheet. From the mid 1960s, easy-open aluminium ends were often seamed on in the can factory. The aluminium end requires only one internal coating when used for beer because the beverage is not a corrosive product and its flavour is mainly affected by iron pick-up. When the aluminium end was applied to the soft-drinks can it was necessary, however, to apply a sprayed on top coat to the end of the formed cylinder. This additional coat was required because soft-drinks, being more corrosive, would attack any lacquer breakdown which may have occurred when the easy-open end was scored. Subsequently, however, it was possible to dispense with this extra operation by the development of special organosol 'non-repair' internal end coatings.

(iv) Miscellaneous Developments

The beer can is an example of a whole new system of lacquers and coatings having to be developed to overcome new problems. The new materials and can constructions which have been introduced by the can-makers to food and beverage containers alike have required a continual widening and deepening of lacquer technology. The underlying post-war developments of thinner steel, thinner tin coatings and faster line speeds tended to accentuate rather than change the role of organic coatings; for example, in all three cases the lacquer function of providing lubrication in forming operations became more important.

An instance of how even minor change has implications for lacquering is the case of differential tinplate; the system of identifying markings which was employed led to trouble with lacquer adhesion, along the parallel identification lines.

Similarly, Tin-Free Steel led to the development of adhesive side-seams; although the internal and external coatings used for TFS are the same as those used on tinplate, the base lacquer used when cemented side-seams are employed must have excellent adhesion not only to the metal but also to the adhesive.

In addition to the changes in lacquer type and application technique required by can-making changes, there is also the on-going work of the lacquer makers themselves - and can-makers who do their own lacquering - to improve their own processes. This contributes to the continual fight against rising can costs by performing the application or stoving operations more efficiently.

An example of minor innovation to the roller coating machine is the technique whereby the pressure and impression rollers are drawn apart during the feed gap between each sheet so as to ensure that no lacquer contaminates the reverse side of the sheet should the doctor blade fail to perform correctly. (Metal Box British Patent No. 661 456, 1950). Similarly, on the printing side the use of detachable blankets on the coating roller makes for quick and simple design changeovers on short runs. Innovations in printing inks have also greatly speeded up the printing process as well as rendering material cost savings. Examples are the 'wet on wet' or 'two colour line', followed later by the 'three colour line', which remove the need for the stoving of each separate application. The printing plates themselves have been improved by the use of bi-metallic and tri-metallic types, and a revolution has come about in production techniques with the introduction of electronic devices.[30]

At the stoving stage conveyor, continuous tunnel, or 'wicket' ovens of up to twenty-five metres in length have been used instead of box ovens. There has been a continual shortening in the baking time. The peak time - that crucial period when the plates are held at maximum temperature - has been reduced from as much as two hours to as little as eight minutes.

(v) New Coating Technologies

In addition to the development of the technology of conventional solvent-borne resins, new coating technologies are currently being developed. The stimulus to this departure from existing practices has been environmental pressures, particularly in the US, to eliminate the use of organic solvents in lacquers. UK coating manufacturers and users are at present evaluating and adopting the new systems.

The alternative technologies fall into four categories:[31]

1. Same application techniques/same curing method as conventional coatings.
2. Same application technique/different curing method.
3. Different application technique/same curing method.
4. Different application technique/different curing method.

Traditional coatings are 20% solids - the actual coating substance - and 80% solvents. Curing is done in gas-fired hot air ovens and the baking process throws off large volumes of hydrocarbon solvents, creating air pollution and noxious fumes. After-burners can be used to oxidise these fumes, but the process involves high capital and operating costs and consumes large quantities of gas. Can companies in America have found that after-burners were not an acceptable long term solution to the air pollution problems. The only alternative was the development of new coatings that would not create pollution during application and stoving, and which would permit lower baking temperatures or less energy-intensive curing methods. In about four years the metal decorating industry had developed the new coatings and inks that would meet these requirements.

Category (1) above, contains the area of the new technology which is most similar to conventional organic coating - water borne coatings. The aim with these water-reducing coatings is to decrease or eliminate the organic solvent component and thus give advantages of lower atmospheric pollution, higher flash point, and a generally healthier workshop environment. Water-based coatings are already being used for printing inks and are under active study for lacquers. This category also includes high solids solution coatings which reduce solvent omission.

In category (2), - new curing methods - must be mentioned the innovation of ultra-violet curing. First used commercially for lacquers in America in 1973 and in the UK by Metal Box in the same year, this innovation not only reduces to a minimum the pollutants generated during the drying of conventional inks, but also has a number of economic attractions. It uses less energy, it requires much less plant space, and it has a curing time of less than one second. Ultra-violet curing has proved satisfactory for external inks but not for internal coatings owing to toxicity.

In category (3), one may mention the application of lacquers in powder form, which is in use for coating the exterior side-seam of beer cans.

In category (4) are hot melt coatings based on microcrystalline waxes which are being evaluated as replacements for low solids vinyls on the inside of beer and soft drink cans.

The development of can coatings is characterized by, and would be impossible without, an extremely close relationship between the metal decorating industry and the can industry. Although many canned products could no doubt be safely packed today in a lacquerless, heavily tinned can, the present omnipotence of the metal container industry in much of the processed food and beverage field is due to the availability of a wide selection of inexpensive oleoresinous and synthetic linings which serve to protect the can and its contents from one another and, often, to be visually attractive enough for the canned product to 'sell itself'.

## 6. Two-Piece Cans

### Background

The construction of the open-top can with its three separate component parts of body and ends has remained virtually unaltered since the sanitary container was perfected at the turn of the century; the method of producing these cans has also been the object of no radical changes since automatic high speed techniques were established in the 1920s. The first fundamental advance in both of these respects was the method of drawing a cylinder from a flat metal disc so that can body and one end are integral.

Drawing metal is an age old technology, and shallow drawn fish cans have been produced in a single pressing operation at low production speeds since pre-war days. The process of deep drawing cylinders may be traced back to the 1939-45 period in Switzerland, when the Kellver system was originally conceived for the production of cartridge cases.[32] In the subsequent forty years, this process has been extended to a wide variety of non-ordnance hardware; the extension of the technology to the production of open top cans remained, however, a demanding problem. The principal criterion which any new process must satisfy before it qualifies for consideration for use in can-making is compatibility with very high production speeds. The introduction to the shallow drawn can-making process of a system of 'ironing' the container walls made possible the application of the Kellver method to high-speed can-making.

Drawing and Ironing

The new process is known as drawing and ironing (D & I), or drawing and wall ironing (DWI). The conventional can-making operation, it will be recalled, is a multi-step, stop-go operation wherein coils of steel are cut to plate size, lacquered, slit to body blanks, rolled into bodies, flanged and end seamed. Although each individual step is performed quickly, it may take days for the steel to work its way through the system. In the D & I process, on the other hand, cans are manufactured in a more or less continuous process in which a coil is fed into the system and a finished can emerges half an hour later.

More specifically, the D & I process is as follows:

The coil is turned from the horizontal to the vertical plane in a down-ender, a coil car then takes the coil and deposits it onto a reel mandrel. This uncoils the metal, after which it is inspected for thickness and pin-holes, lubricated, and then passed to the cupping process. The multiple die press blanks and cups a number of discs - usually three to six - from across the width of the coil in one stroke. The shallow drawn cups are then relubricated and fed into the ironing press (bodymaker) wherein they are forced through a series of progressively smaller annular dies by a ram; large amounts of lubricant are used at this station. The forcing of the cup through these discs reduces the sidewall thickness by stretching, and thereby increases it to the desired height. Whilst in the ironing press the base of the can is indented to give it greater strength. The cylinder is removed from the ram by a stripping mechanism and passes next to a trimming machine in which it is cut to a uniform height, since any projection or notch in the trimmed edge of the can could result in a crack when it is flanged. The can then passes through a washer to remove any surface contaminants such as oil which would interfere with the subsequent lacquering. When the dried cans leave the washer they are bright and free of water spots. The can is then lacquered by a roller, cured, decorated by offset lithography and given a further baking. On leaving the curing oven the can is necked-in and flanged in one operation. The can is then electronically tested and, finally, given two further protective inside spray lacquerings. The cans are then ready for palletisation. The essential operations might be considered the blanking and cupping, ironing, trimming, coating and flanging. The end, which must be strong, retains the original thickness of the coil whereas the portion of the blank that is drawn is reduced in gauge.

Aluminium Vs Tinplate

Although patented by William Van Leer in Holland in 1945, the D & I can did not appear commercially until 1958 when produced by Kaiser Industries in the US. This can disappeared when its customer was sold to new management, and did not re-emerge until further perfected by Reynolds Metals in 1964. This container was considerably lighter than its predecessor.

Until 1971 when Crown Cork and Seal introduced the first D & I tinplate can, again in America, all tall drawn containers had been made of aluminium. The original stimulus to the D & I can had, indeed, come from the American aluminium manufacturers who saw an opportunity to establish their product in a market dominated by tinplate. Aluminium, being a purer, more ductile metal than steel, was more obviously suited to the severe deformation which the metal is subjected to in the D& I operation. In other drawing processes, such as impact extrusion, the non-ferrous metal had proved its suitability ; there were, therefore, good reasons to suppose that aluminium would enjoy a decisive technical edge over steel in the new can-making technology.

The steel industry's original competitive response to aluminium cans was in the cemented and welded containers which allowed all-round lithography. Behind the scenes however, both the can-makers and steel producers were immediately evaluating the suitability of tinplate as a drawn container. While it was initially accepted that it would be more difficult to fabricate steel by the new method, its cost advantage over aluminium was sufficient incentive to try.

The problem with tinplate was that it tended to fracture while being drawn due to its much higher tensile and yield strength than aluminium, and sometimes even for the bottom of the cup to be pushed through.[33] When the actual problems associated with tinplate drawing were tackled, however, it was found that only slight modifications to tooling, and some changes in the chemical processing after can forming, enabled D & I equipment to be used for tinplate cans. Again it was the unique properties of that remarkably resilient metal, tin, which provided the essential lubrication for satisfactory steel container drawing.

In the UK, Metal Box took an early lead in plate D & I technology in the late 1960s, and in 1972 produced semi-commercial quantities of D & I tinplate cans. These were termed 'Sheerwall' cans and were first supplied to Coca-Cola. Although Metal Box effected their entry into the D & I field by means of a technical agreement which gave them access to the machines and know-how of Standun Inc. of the USA, the British company have now developed a considerable expertise of their own. Since producing their first D & I cans in tinplate, Metal Box have considered it appropriate to install two-piece lines which will operate on either aluminium or steel as commercial conditions dictate. It now appears that tinplate, certainly in the UK, is becoming the favoured material for D & I cans. This ascendancy is to some extent based on the interesting belief that aluminium has reached its limits as regards further gauge reduction by the D & I method whereas tinplate, by virtue of its shorter history as a drawn container, must offer scope for further substance reductions. Alternatively one could perhaps argue that aluminium being a much younger metal than steel, has greater potential for more fundamental cost-saving innovations, e.g. by a changein the metal's chemistry.

Cost factors

The reasons which gave rise to D & I technology constitute an interesting case study of innovation in their own right; basically this boils down to an argument as to the respective merits of two-piece and three-piece cans. The fundamental criterion controlling technological change in the can-making industry is cost reduction. The cost impact of D & I can manufacture is, however, far from straight forward. In conventional can-making, body blanks are cut from rectangular sheets, which means virtually no waste; in the D & I operation circular blanks are cupped from the sheet.

Although each row of discs is dovetailed as in scroll shearing there is still considerable wastage. This wastage must be offset by a reduction in the substance of the container; this is made possible in D & I can-making because the process allows selective distribution of the metal so that the areas which have to withstand the greatest force - such as the base - have more substance than the less critical sidewalls.

There are less apparent material cost factors: steel for two-piece cans requires a heavier tin coating; this adds to the cost. The exposure of large areas of bare steel during the drawing operation makes lacquering more critical, which again adds to the cost. It appears, though, that when all material cost factors are taken into account the D & I can involves less expense on materials; Metal Box report that thier D & I operation uses 40% less material by area and about 20% less by cost than for the equivalent conventional container.

This saving in direct material costs is, however, only one factor in the cost equation. The first qualification to be made is that a lighter gauge can does not necessarily mean a cheaper one because steel processing costs are high. The steel used for D & I has to be of higher quality than for three-piece cans. There are other economic factors involved too; D & I can-making equipment is extremely expensive, which means it must be worked on a shift basis to reduce capital costs per unit of output as much as possible. The very high productivity of a D & I line means that it needs a large market for a homogenous product, such as beverages. Three-piece cans are printed on flat sheets in an off-line operation which allows for the storing of brand labels in compact areas; the continuous D & I operation necessitates that a label change (or more correctly print change) shuts down the entire operation for up to four hours. In a three-piece can-making operation the labels can be changed without affecting the actual can-making lines. Further, the fact that in the D & I operation a number of cans are made on every line means that it is more costly if there is a breakdown. Moreover, two-piece lines are less reliable than three-piece.

Draw Redraw

The D & I operation is particularly suitable for beer and soft drinks cans because the internal pressure of the pack itself compensates for the thinner side-wall; it was initially considered that the D & I operation was far less suitable for food packs which tend to involve a vacuum rather than internal pressure. It was recognized that the strength of the D & I can could be increased significantly by beading; this was not contemplated for beverage cans because it would be very difficult to print onto the beaded configuration. The paper label is not as attractive as lithographing. It was not considered worthwhile beading a D & I can for food products because the increase in the strength of the side walls would lose the cost saving which is the very rationale of the new technology. In the 1970's therefore, a second two-piece can-making operation known as draw - redraw (DRD) was developed. This is a similar process to D & I except that the final can body configuration is obtained by a second or third cupping operation instead of ironing. This operation transforms a large diameter shallow cup to a small diameter tall cup. The main implication of this difference is that in DRD the thickness of the material is the same at the end of the operation as it was at the beginning. This means that the container is the same gauge as the conventional three-piece can which, given the points mentioned earlier, would mean a can of higher direct material cost.

Metal Box have developed their own DRD operation wherein the presses operate on a rotary principle as opposed to the reciprocating principle of American origin. The former technique is considered in the industry to be the most satisfactory DRD process available. The Metal Box development is an advance on a method which has been used for several years for drawing heavy cans and kitchen utensils at slow speeds. The technique is similar to a process developed by Karges-Hammer in Germany.

There are some significant minor differences between the D & I and DRD processes. Although both are fully lacquered, the DRD can is coated before forming. This puts severe demands on the lacquer performance and expensive linings have to be used. It means also, however, that the lubricating function of tin is no longer critical. This has led to speculation that the real potential of DRD is in eliminating the tin coating; TFS may well be suitable for many products where the cathodic protection usually supplied by tin is not required; this would include many meat and vegetable products.

As far as capital costs and output levels are concerned, the DRD process is nearer three-piece proportions than D & I. Estimates of respective plant costs between D & I and DRD vary widely mainly because the height of the container is a very important variable. It may safely be said, though, that DRD - although capital intensive - is usually at least only half the capital cost of a D & I line.

Although a number of non-carbonated products, particularly pet food, had been packed in the US in DRD cans, the situation in the UK in the mid-1970s seemed to be fairly clear cut, ie D & I would continue to be developed for the beverage market and DRD would shortly make an appearance in the food can market. Between these two branches of deep-drawing technology a number of hybrid processes which were under active development. It came as something of a bolt out of the blue then when, as most observers were waiting for an announcement concerning commercial quantities of DRD cans from Metal Box's pilot plant, a new entrant to the can-making field announced in 1977 that they were to supply D & I cans to Pedigree Petfoods. The first two-piece cans to be used for food in the UK thus turned out to be D & I cans, although DRD cans quickly followed in 1978.

Product Considerations

In addition to the process and capital cost considerations concerning two-piece cans there is also the product dimension. D & I and DRD may be considered jointly under this heading, but it must be remembered that any product improvement in the two-piece over the three-piece is considerably more important for the DRD can where the same material saving potential does not exist.

The can-makers claim two types of product advantage for two-piece over three-piece cans; the former is a better quality can and, secondly, it is more aesthetically pleasing. The quality argument surrounds container integrity. Because there is no side seam, no bottom seam and, thirdly, no side-seam/top seam cross-over junction on the two piece can, three possible areas of product leakage or recontamination during processing are eliminated. The absence of a soldered side-seam eliminates the possibility of lead migration from this source; this is not particularly important for beverages but is more so for food. Further, lead regulations are more stringent for baby food than for adult food;

only 0.5 parts per million of lead are allowed in baby food compared to 2 parts per million in adult food.

As far as the aesthetic merits of the container are concerned, it is considered that the factors which make for a better integrity can also make for a more pleasing one to look at. Wide side-seam margins, and to a lesser extent the lap joint in TFS cans, are considered to be ugly. On those three-piece cans which have $\frac{1}{8}$" protruding chime it is considered that the profile is less pleasing than the flush sided, necked-in two-piece container. A final, and often quoted, aesthetic aspect is that the absence of a side seam allows all-round decoration.

The can-making companies are very anxious to promote the product aspects of the two-piece container; the question from the perspective of the worth of the innovation is to what extent the alleged advantages can be taken at their face value. As regards product leakage and recontamination the question begs itself whether this is anything more than a negligible problem with the three-piece container anyway. While it is desirable that any improvement that can be made should be, it is not a consideration in which, perhaps, too much store should be placed. It is worthwhile to remember that improved can integrity may also be provided for conventional soldered cans. The practise has been instigated of flowing solder all the way through the third fold of the side seam; this type of solder bond is known as 'inside solder fillet' and has a higher level of can integrity than conventional soldering methods.

Lead migration from the side-seam solder is also an interesting question. A pertinent qualification here is that one is talking about a comparatively small and declining baby food market. Again in this instance there is scope for reduction in the lead content in conventional cans; in the past in the UK baby food cans have been made from commercially pure tin solder. This is expensive and it does contain some lead but it indicates that advances can be made within conventional technology. The problem of lead in the atmosphere means that it will be very difficult to eliminate the metal completely from canned food. In the final analysis, however, it should be mentioned that present levels of lead in conventionally canned food do not pose a health hazard.

The aesthetic aspects of two-piece cans must be largely a subjective issue and one's initial reaction to claims of marketing advantages on these grounds must be cautious, if not sceptical. The alleged aesthetic advantages of the two-piece container do not seem to be supported by any consumer survey evidence, from which fact alone one might draw one's own conclusions. One observation on this point is interesting:

> 'The consumer is not much concerned about how water gets to the spigot, the electricity to the light bulb, the gas gets to the oven, the message to the telephone receiver, or whether you pop the top off a beer can made from three pieces of metal or two'.[34]

It could well be argued that if one were to do a consumer appreciation test on can construction, that the average consumer would be unable to offer the most elementary observations on the way a can is put together, beyond perhaps that some types have easy-to-open attachments. Would he or she, for example, be able to refer to the fact that some cans have an uncoated margin running down the side? It is interesting to recall on this very point that in the days before two-piece cans, the container manufacturers used to argue that an advantage of cans vis-a-vis other packaging materials was their 'transparency', i.e. the shopper bought the product and paid no notice whatsoever to the can.

Consideration of the construction of some three-piece cans may serve to put the aesthetic merits of the two-piece into perspective. A three-piece can may be necked-in in the same way as a two-piece giving virtually identical profiles. By the use of inside soldering or cemented seams it is not a problem to apply all-round lithography; the lap of an inside soldered or cemented can is virtually undetectable by eye if consideration is given to the printed design. A difference which may be noticed is in the rigidity of the opened can. There seems no reason to suppose that there is any greater intrinsic pleasure in holding a flimsy to a rigid container; indeed, in the predominantly children's soft drinks market there may be a certain satisfaction in being able to crush the empty steel can in one hand.

General

One or two other points regarding the two piece innovation may be made. Although the machinery to produce two-piece cans represents higher technology than that for making three-piece, the former removes the 'mystique' and art from can-making. This reduces the edge of established manufacturers over new entrants; where the new entrant is also a canner he may not be able to exploit the process unless he has high outputs and long runs on one label. This may change with the development of low output (75 to 150 c.p.m.) D & I lines.

Hitherto, all UK D & I lines have been of the high output variety, usually being as productive as a pair of three-piece lines. At its Westhoughton plant four Metal Box D & I lines are as productive as ten three-piece lines. This means that large scale, world-wide, investment in two-piece lines, particularly for the undynamic food market, must ultimately release three-piece capacity; this has two important implications. In the first instance, it means a new entrant can buy into the three-piece market on the cheap and, secondly, it depresses the building of new three-piece machinery. The freeing of displaced conventional machinery onto the world market from American sources seriously affected Metal Box's Machinery Building Group in 1972; as a result, at least £1 million in orders were lost and one factory had to be closed.

The development of two-piece technology has created a number of spin-offs for three-piece manufacturers. The greater demands on tooling etc. of the even thinner drawn material have also benefited three-piece can-making. Three-piece manufacturers benefit from R & D of the steel producers who are anxious to counter the threat of aluminium in D & I. This will amost certainly lead to an improvement in general plate quality. The physical and mechanical properties required from tinplate used for the manufacture of two-piece containers differ significantly from those required when tinplate is used to produce the conventional three-piece can. The nature of the additional requirements is such that success in commercial can-making operations is even more dependent on close and continual co-ordination and development between all the interested parties. This greater communication and interplay can only be to the benefit of all can-makers. Continuously cast steel, by virtue of the fact that normal impurities are finely divided and uniformly distributed, is a clean metal. This development in steel technology is particularly important to two-piece can manufacture. When it is available for tinplate in the UK it will also benefit three-piece manufacture because of its inherent reduction in steel production costs, which must ultimately be reflected in the base box price of can stock.

## 7. The Economic Impact of Can-Making Innovations

Assessing the economic impact of the continual incremental innovation in the can industry during the post-war period is dependent on the available statistics. There can be few industries more barren of published statistics than that of can-making. The available Central Statistical Office (CSO) data is of little assitance because of its broad brush nature. In these Government publications can-making has always been aggregated with metal box making. Since 1968 some CSO publications further subsume can-making into the still larger metal manufactures. The input output tables are, however, of some value in illustrating the industrial web into which can-making is woven, and therefore in indicating the areas of probable secondary effect from can-making innovations.

To examine the long term effect of technological change in the can-making industry would ideally require similarly long term data. There are only two firms who could theoretically provide this - Metal Box and Reads. The former are extremely averse to releasing any information whatsoever about their operations, an attitude which to a lesser extent permeates the whole UK packaging industry. Metal Box feel that as the market leader they are particularly vulnerable. Reads, although they have been can-makers for over twenty years, are not in a position to fill the void left by Metal Box because their early data would be unrepresentative of the industry as a whole.

These problems in illustrating the economic impact of can-making developments, while they cannot be completely overcome, can to some extent be circumvented. In 1968/9 Metal Box was obliged to furnish data on its efficiency to the Monopolies Commission. The statistics provided were for comparatively short periods; there is no reason to suppose however - and much reason to doubt - that the material provided to the Monopolies Commission was unrepresentative of the post-war era as a whole.

The question of the impact of technical change is essentially a question of the efficiency with which a can is produced. One way of expressing this is in terms of ratios, this was the method adopted by the Monopolies Commission Report. In the period 1959 to 1963 the number of employees in Metal Box's Open Top Group increased by 21% over 1959 levels, in the same period plate consumed per employee increased 38%, i.e. an increase in plate converted per employee of 14%. By 1968 consumption of plate was 82% above the 1958 level, yet employment over the period increased only 18% - an increase in productivity per employee in the eleven year period of 53%. For the period 1963 to 1968 it is possible to relate this data on the productivity of labour to the employment of capital:

TABLE II *

Operating Trends - Metal Box Open Top Group 1963-1968

| | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 |
|---|---|---|---|---|---|---|
| No. of employees | 100 | 104 | 101 | 99 | 97 | 98 |
| Tinplate consumed | 100 | 105 | 110 | 115 | 122 | 132 |
| Output value | 100 | 107 | 114 | 123 | 128 | 140 |
| Profit | 100 | 123 | 133 | 145 | 150 | 148 |
| Average capital employed | 100 | 103 | 105 | 109 | 115 | 119 |

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|---|---|---|---|---|---|---|
| No. of employees | 100 | 104 | 101 | 99 | 97 | 98 |
| Tinplate consumed | 100 | 105 | 110 | 115 | 122 | 132 |
| Output value | 100 | 107 | 114 | 123 | 128 | 140 |
| Profit | 100 | 123 | 133 | 145 | 150 | 148 |
| Average capital employed | 100 | 103 | 105 | 109 | 115 | 119 |

TABLE II Cont'd...

| | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 |
|---|---|---|---|---|---|---|
| Tinplate consumed per employee | 100 | 101 | 108 | 116 | 126 | 135 |
| Output value per employee | 100 | 103 | 112 | 124 | 132 | 143 |
| Profit earned per employee | 100 | 118 | 131 | 147 | 155 | 151 |
| Capital employed per employee | 100 | 100 | 103 | 111 | 119 | 122 |
| Tinplate consumed per unit of capital | 100 | 102 | 104 | 105 | 107 | 111 |
| Output value per unit of capital | 100 | 104 | 109 | 112 | 112 | 118 |

* Source: Monopolies Commission Report.

Technological innovation is all about getting more for less or, to put it differently, reducing the ratio of inputs to outputs. It is for this reason that, arguably, the best measure of the impact of technical change is 'added value'. This is defined by Dr Frank Jones as 'the difference between the sales achieved and the costs of the goods and services bought in'.(35) This represents the wealth that is created by a firm. Technological innovation is crucial in maintaining this gap (in the face of commercial pressures on sales income) by reducing the physical inputs per unit of output. The above table indicates how this has been successfully achieved in the UK can-making industry. The trends illustrated are as one would expect from the foregoing investigation of the nature of technical development in can-making, i.e. overwhelmingly a very steady, continuous, incremental activity. The following breakdown of how Reads' 1976 sales revenue was used indicates why, in the can-making industry, increasing the added value hinges mainly on material reducing innovations.

TABLE III *

Destination of Sales Revenue - Reads 1976
(per pound of sales)

| | |
|---|---|
| Tinplate, Steel, Aluminium .. .. .. | 56 |
| Inks, Solders .. .. .. .. .. .. | 8 |
| Wages and Salaries .. .. .. .. .. | 18 |
| Services .. .. .. .. .. .. .. | 7 |
| Rates, Depreciation and Insurance .. .. | 3 |
| Taxation .. .. .. .. .. .. .. | 4 |
| Retained .. .. .. .. .. .. .. | 4 |
| | 100 |

* Source: Reads Ltd.

(The key operating statistic in the can-making industry is a reflection of the importance of materials and material reducing innovations - the 'standard variable margin'. This is a similar concept to added value being the difference between the selling price and the standard variable cost).

One of the most reliable indicators of the impact of technological innovations is the ability of an industry to absorb cost increases. In the case of the can industry the overwhelmingly most important cost to the can-maker is his fabricating metal, which is very largely tin-plate. Metal Box have a record throughout most of the post-war era of consistently absorbing part, and sometimes all, of the increase in tinplate prices. Although there have been periods, sometimes as long as five years, when tinplate prices have been comparatively stable, the trend increasingly has been one of regular price increases. If there is any single period when the price of open top cans has been most heavily criticised, it is in the period since the Monopolies Commission Report. A look at the trend in raw material and can prices in this period, should therefore, be particularly instructive.

TABLE IV *

Trend of Raw Material Costs (Base Year 1970)

| | 1970 % | 1971 % | 1972 % | 1973 % | 1974 % | 1975 % | 1976 % | 1977 % |
|---|---|---|---|---|---|---|---|---|
| **TINPLATE** | | | | | | | | |
| Annual %age increase | | 10 | 66 | 24 | 39 | 8 | 26 | 23 |
| Cumulative | 100 | 110 | 117 | 145 | 201 | 217 | 273 | 336 |
| **ALUMINIUM** | | | | | | | | |
| Annual %age increase | | 5 | 5 | 5 | 45 | 11 | 9 | 9 |
| Cumulative | 100 | 105 | 110 | 116 | 168 | 186 | 203 | 221 |
| **INKS & LACQUERS** | | | | | | | | |
| Annual %age increase | | 2 | 5 | 7 | 40 | 30 | 15 | 24 |
| Cumulative | 100 | 102 | 107 | 115 | 160 | 208 | 239 | 297 |
| **COMPOUNDS** | | | | | | | | |
| Annual %age increase | | 10 | | 7 | 35 | 2 | 20 | 10 |
| Cumulative | 100 | 100 | 100 | 107 | 145 | 148 | 177 | 195 |
| **PACKAGING MATERIALS** | | | | | | | | |
| Annual %age increase | | 10 | 5 | 22 | 42 | 16 | 5 | 5 |
| Cumulative | 100 | 110 | 115 | 140 | 200 | 232 | 244 | 256 |
| **PALLETS** | | | | | | | | |
| Annual %age increase | | 8 | | 204 | 35 | | | 14 |
| Cumulative | 100 | 108 | 108 | 220 | 297 | 297 | 297 | 339 |

* Source : Reads Ltd.

It can be seen from Table IV that the trend in raw material costs since 1970 has been continually upward. It will be seen that the price of the principal component, tinplate, has risen particularly highly. This trend in raw material costs may be compared with the price of open-top cans.

TABLE V*

Wholesale Price Index for Open Top Cans 1970-1976

| 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|
| 100 | 110.9 | 117.1 | 125.1 | 162.4 | 201.9 | 236.2 |

* Source : Price Commission Report.

It is readily apparent that in the period 1970-1976 the can industry has maintained its price increases to a rate significantly lower than those of tinplate. If can-makers have performed to this standard in a period of criticism on prices, one can only conclude that in earlier years the can-making industry has done significantly better.

## 8. Conclusion

The two central and directly related questions concerning two-piece can manufacture are why has the innovation arisen and what are its implications. It has been observed that the original impetus came from the American aluminium industry which coveted the lucrative and fast expanding tinplate can market. The aluminium industry developed an extremely important complementary innovation in the easy-open end and put it on their new drawn container; this coupling constituted an extremely strong marketing edge and the American aluminium industry has subsequently well capitalised on its breakthrough. The steel industry in the United States responded by adopting the aluminium ring-pull end on their tinplate cans; within about twelve months they were also marketing TFS cans which permitted the same all-round lithography as on D & I containers. The steel industry and the can manufacturers, perhaps discouraged by the potential of TFS, set about modifying the two-piece container-making process to use tinplate. The inevitable achievement of this alteration, while it checked the growth in the use of aluminium, further strengthened the commitment to two-piece cans.

The large can-makers welcomed the two-piece can because they saw in it a competitive advantage over their smaller rivals. The high expense of the plant and its revolutionary nature made it more suitable to the expansive resources of the large corporation. The high outputs involved also limited the scope for use in self-manufacture which is an important area of competition.

In the UK Metal Box's position as the dominant can-maker and the store by which it sets in being at the forefront of new developments made it almost inconceivable that the company should not develop the two-piece technology. Although initially importing the expertise Metal Box is now among the world leaders in two-piece technology.

The UK brewers welcomed the two-piece can because Metal Box pegged the price at three-piece levels so as to promote its early establishment. At a comparable bought-in cost the two-piece offers operating economies for the filler.

The final link in the chain, the shopper, is probably not even aware of the change that has been taking place. He will continue to buy the can so long as it offers convenience and value.

The extremely marginal product advantages of the two piece can mean that the only real yardstick of its success should be its cost-reducing impact. The continued potential of the three-piece can for material saving innovation means that the two-piece is unlikely to constitute a case of a new technology increasingly undercutting the old as the novel process is further perfected. The spin-offs for three-piece technology from two-piece are significant and further undermine the capacity of the new technology to 'see-off' the old. The commitment which has been made to the new process by the various parties involved means that the two-piece can will continue to make ground and possibly monopolise the beer and soft drinks market. It may well be the case, however, that as long as someone is prepared to make the traditional beverage can there will always be those prepared to buy it. The future application of deep-drawing methods on the food can side is far less certain. Although a D & I food can has appeared on the UK market the fact is that it is not at the moment a sound commercial proposition. The willingness of can-makers to make a loss on the operation as an expensive way of buying into the new technology is the reason why the product has appeared.

The perfecting of the simpler DRD process may make a significant impact on the food can market if it proves to be commercial; if so it may well displace the D & I can.

Since the D & I can was introduced there has been a tremendous increase in the sales of beer and beverage containers. This has been accompanied by an increase in investment in the tinplate industry which has been compared to the boom years of the 1950s. To say however that D & I technology has led to this upturn would be inappropriate. The fundamental reason why it has been possible for D & I cans to become established has been the enormous potential in the beer and soft drinks market. This is not a chicken and egg situation if one accepts that the two-piece can is not a product innovation. The latent beer and soft drinks market has been tapped by the innovation of the easy-open end. Regardless of the propaganda of the can-makers to the contrary, the D & I can is rising to ascendancy on the back of the less fundamental development but real product innovation of the ring-pull end. Unless a similar type of innovation - perhaps even the apparently stillborn full aperture easy-open end - does for the food can what its cousin did for the beer and soft drinks market then the progress of the deep-drawn food can may well be painstaking. Since the development of DRD - where the potential for a food can appears to lie - was only made possible by the high-speed presses developed for D & I, then a strong case could be made out that, without the expanding beverage market created by the ring-pull end, the two-piece can in whatever variation would never have been a commercial success.

REFERENCES


1. Anon — 'A-Z of the Can' Tin International. Nineteen issues between January 1973 - June 1976. Tin Publications Limited, London.

2. Brown, GW — 'The Manufacture of Food Cans' Tin and its Uses, No. 60, 61, 62, 1963-64. Tin Research Institute.

3. Anon — 'The Evolution of the Sealed Tinplate Container' in 'Tinplate and Canning in Britain'. Bulletin of the International Tin Research and Development Council No. 1, February 1935, pp 40-56.

4. Langton, JW — '150 Years of Canning - Forming and Closing Machinery', Times Review of Industry, August 1960.

5. Van Fleet, HS — 'Engineering The Tin Can', Mechanical Engineering, April 1948 pp 315-320.

6. Anon — 'Can-Making', Packaging and Display Encyclopaedia 3rd Edition 1950.

7. Brighton, KW — 'Electrolytic Tin Plate from the Can-Makers Point of View' American Metal Market October 29, 1943 pp 6-7.

8. Brown, GW — Op Cit p 11.

9. Brown, GW — Op Cit p 12.

10. 'Report on the Supply of Metal Containers', Monopolies Commission H.M.S.O. 1970.

11. Sanders, RK — 'Food Cans 1927-1952' Food Manufacture June 1952.

12. Clay, GP — 'Developments in the Use of Tinplate and Tinplate Containers' Conference on Tin Consumption 1972.

13. Barry, BTK — 'Developments in Can-Making' Conference on Tin Consumption 1972.

14. Monopolies Commission Report Op Cit.

15. Stewart, JA; Pilcher, RW — 'Can-makers War-Time Problems' Chemical and Engineering News March 25, 1944 pp 422-34.

16. Rainbow, GH — 'Conveying and Division of Cans at High Speed'. Food Trade Review August 1968.

17. Anon — 'DR Tin Plate' SCOW Product Development Digest B.S.C. 1968 p 3.

18. Meyer, E — 'Handling Containers Made From New Steel Based Packaging Materials', Packaging Review August 1969.

19. Hoare, W.E — 'The Technology of Tinplate Manufacture', Publication No. 277, Tin Research Institute, 1964, p 12.

20. Kohn, EO — 'Tooling Aspects of High Speed Can Production' Sheet Metal Industries June 1976, pp 331-341.

21. Metal Box Limited, Reports on Accounts 1978 p 15.

22. Coonen, NM; Mason, SI — 'Recent Advances in Rigid Metal Containers' Proc. Int. Congress Food Science and Technology 3rd SOS/70. Washington D.C. August 9-14. 1970 pp 589-94.

23. Metal Box British Patent 661, 456, July 1950.

24. Pilley KP — 'Lacquers Varnishes and Coatings for Food Cans and for the Metal Decorating Industry'. Arthur Holden and Sons Ltd. Birmingham 1968.

25. Ball — 'Containers for Heat Processed Foods', Institute of Food Technology, 1943.

26. Flugge, SL; Brichata, JC — 'Can Linings' Modern Packaging, August 1952.

27. Anon — 'New Developments in the Protection and Decoration of Tinplate', Tin August 1964.

28. Sutton, CE — 'Production of Wide Steel Strip', Iron and Steel Institute Spec. Report 97, 1960 pp 3-8.

29. Morgan E; Short JFM — 'Future Pattern of the Tinplate Industry', Journal of the Iron and Steel Institute December 1967.

30. Evans CJ — 'Modern Tin Printing' Tin and Its Uses No. 101 1974.

31. Newbould AJ — 'Role of New Technologies in Coatings for the Packaging Industry' Journal Oil Colour Chemical Assoc. February 1977 Vol. 60 pp 53-7.

32. Campion DJ — 'Tooling for Deep Drawing and Ironing', Sheet Metal Industries July 1976.

33. American Can Company British Patent 1 140 258, 1966.

34. Kuhner JG — 'Captive Can-Making' MRAA Technical Quarterly Vol. 14 part 3 1977, pp 139-144.

35. Owen K — 'Closing the Performance Gap, London Times 9th January 1970.

## CHAPTER V

# STRUCTURE AND COMPETITION IN THE CAN-MAKING INDUSTRY

## 1. Introductions

This chapter is concerned with the changing structure of the domestic can industry, as it relates to technological innovation. There have been a number of academic studies of the connection between innovation and industrial structure, the findings of these having been summarised by Scherer.[1] Scherer concludes that the rapidity of innovation increases with the number of firms and that sellers with small market shares are more likely to trigger a rapid pace of innovation than dominant firms, though the latter may retaliate vigorously. Scherer further observes that where entry to an industry is difficult innovation is sluggish. The most favourable climate for rapid technological change seems to be a small amount of monopoly power in the form of structural concentration, very high concentration tending to dampen incentive from independent sources. Scherer believes that the evidence argues that barriers to entry should be kept at modest levels, a subtle blend of monopoly and competition is optimal with more emphasis, in general, on the latter.

The UK can-making industry would appear to offer a particularly instructive opportunity for the study of the implications for innovation of industrial structure. For thirteen years Metal Box maintained a total monopoly of the UK can-selling industry. This remained very much the case into the 1970s despite the presence of one competitor in all markets. Between 1969 and 1980 several further firms entered the industry. The post-war structure of the UK can industry up to 1969 was reviewed reasonably comprehensively by the Monopolies Commission,[2] and it is therefore the intention herein to deal with this period only very briefly and to focus on the changing nature of the industry and its pattern of innovation in the 1970s.

2. 1945-1969

i. Metal Box Ltd

Metal Box were the sde UK suppliers of open top cans from 1945 to 1958. In that period the business expanded continually; there were a number of reasons why the company maintained what must have been a unique monopoly situation. They negotiated a technical agreement with Continental Can Company (CCC) which gave them access to the American firm's technology, they entered into market sharing agreements with potential competitors, they operated a discount system on large orders, and they operated a subsidised leasing policy for closing machines. In spite of the importance of these practices the major reasons for Metal Box's unchallenged market dominance were their combination of all-round can-making and canning expertise, the role of its Machinery Building Group and Customer Technical Service departments in providing a comprehensive service to canners, the company's competitive pricing and, finally, the policy of passing on the benefits of increased efficiency to customers. These features of Metal Box are indicative of the paternalistic philosophy of the company to its customers. This philosophy has been cited as the cause of a fall in the rate of return earned on capital from 22% to 13% between 1954 and 1963.(3)

Throughout the 1945-69 period, as has been discussed, Metal Box continually developed and adopted minor process improvements which in aggregate made for continued and significant productivity improvements. Metal Box consolidated its monopoly position by building a network of factories to serve the main canning regions - it being uneconomic to transport cans full of fresh air over any distance.

TABLE 1*

Metal Box Expansion 1945-1962

| Location | Year |
|---|---|
| Acton .. .. .. .. | 1945 (pre-war) |
| Worcester .. .. .. | 1945 (pre-war) |
| Portadown .. .. .. | 1946 |
| Sutton-in-Ashfield .. .. | 1947 (closed for open top 1976) |
| Wisbech .. .. .. .. | 1953 |
| Leicester . .. .. .. | 1954 |
| Westhoughton .. .. .. | 1956 |
| Carlisle .. .. .. .. | 1957 (rebuilt) |
| Arbroath .. .. .. .. | 1961 |
| Rochester .. .. .. | 1962 |

* Source: Various.

ii. Reads Ltd.

Reads was a well known general line and drum manufacturer when they entered the open top market in 1958. From the outset the company had the benefit of a technical assistance agreement with the then world's largest can-maker, American Can Company (ACC). Reads originally intended to supply both open top and beer cans, but quickly withdrew from the latter option. Reads were particularly fortunate in having the patronage of the UK's leading pet food manufacturer, Pedigree Petfoods (Mars Ltd), who at the time used only two sizes of can. On Reads entry to the market, Metal Box reduced its prices, enforced restrictions on closing machines and extended its discount system. Reads, or rather its parent Courtaulds, was totally out-manouevred by Metal Box in the tactical skirmishes that ensued in the same way as ACC had been in 1930. During this period, Metal Box confirmed a well deserved reputation of ruthlessness. The result of this competitive barrage was that Reads was unable to compete; the continuance of open top trading was more an act of faith than anything else. Reads saw its way through the final ten years of open top trading by virtue of being subsidised from both its general line business and also by Pedigree Petfoods who were anxious to see a viable second supplier established. Throughout this early period, Reads, with only a token R & D effort, had little to offer in the way of technological innovation beyond adopting whatever techniques were unique to ACC, e.g. the roll-form body-maker. Reads most notable first was possibly in 1962 when they pipped Metal Box to be the first company to use differential tinplate. The entry of Reads to the can-making business appears to have had no discernible impact on the pattern of innovation in the UK can business.

iii) <u>Self-Manufacture</u>

Although Metal Box maintained a monopoly on the sales of cans until 1958, they have never had a monopoly on the manufacture of cans. One of the cornerstones of Metal Box's commercial policy has always been to try to persuade canners who 'self-manufacture' to leave can-making to the specialists. In 1946 there were at least eight of Metal Box's customers manufacturing some or all of their can requirement, among them Heinz and Nestle (two of Metal Box's largest customers), C.W.S., Chivers and Maconochies. Some customers have never been enticed to give up making cans entirely and while Heinz increased its can purchases from Metal Box from 13 million cans per annum (cpa) in 1946 to 693 million cpa in 1966[4], in the later years, at least, any increase only reflected a policy of buying 50% of an increasing can requirement. Metal Box has been successful in securing all the business of some of the 'captive can-makers', as self-manufacturers are also known. The C.W.S. and Chivers are two examples; in 1957 Chivers, one of the leading UK canners of fruit and vegetables, decided that after sixty years operation they would sell all their can-making equipment to Metal Box. In making this announcement, Oswald Chivers stated that the company no longer found it competitive to manufacture their own cans against the prices and services offered by Metal Box. The C.W.S. abandoned self-manufacture for the same reason in 1967.

In other instances Metal Box has been less successful. In 1966 the General Milk Products (Carnation Foods) announced a new four-line can-making plant at Dumfries to supply all their own can requirements. This particularly hit Metal Box whose Carlisle plant was heavily dependent upon Carnation's business. In the food can business self-manufacture, or the threat of it, has been a more potent form of competition than the second supplier. Metal Box consider it a great testimony to their efficiency that they have been able to persuade canners that they can buy cans cheaper than they can make them. In the case of Carnation there is evidence that the decision to self-manufacture was dictated from the American Head Office irrespective of local UK conditions.

## 3. 1969-80

### i. Introduction

There seems no reason to suppose that the trends from 1945 to the late 1960s of Metal Box dominance, dogged perseverance from Reads, significant but stable self-manufacture and continuous if innocuous innovation would not have continued to be the order of the day if not for a breakthrough in the small beer can business. The breakthrough was the potential created by the innovation in 1965 by Metal Box of the beer can tab pull end followed, in 1967, by the super ring-pull end. This innovation of the easy open end, or 'Touch 'N Go' (TNG) as it is sometimes called, has given a completely new dimension to the UK can industry. The impact on industrial structure of this innovation may best be illustrated by a review of the expansion of each canmaker in turn.

ii. Metal Box

With their countrywide base and established beer and beverage can capacity it took quite a few years before the growth in the beer and beverage market which followed the TNG innovation impacted itself on Metal Box as regards new plant locations. It was possible to take up large amounts of increased demand by increased efficiency on existing lines and by the laying down of new lines at existing locations. The Metal Box plant profile did not really alter until the adoption of the Drawn and Ironed (D & I) can innovation.

The first Metal Box plant to be built since 1962 was in 1969 at Winsford, Cheshire. This factory is well sited from the perspective of both Government location grants and also the large Bass Charrington brewery at Runcorn. It was at Winsford that Metal Box chose in 1972 to install their cemented Tin-Free Steel (TFS) 'A-Seam' beverage can. The first really positive manifestation of the importance of the up and coming beer and beverage market was the opening in 1970 of Metal Box's thirteenth open-top factory in Glasgow. Unlike Winsford this factory produces no sanitary cans. Scotland is especially significant as a stronghold of the beer can and the location of the plant in Glasgow was therefore predictable. The first two lines to be laid down at Glasgow were for the conventional '3-piece' can.

Metal Box's commitment to D & I beer and beverage cans has been the most significant feature of the company's policy since 1973. The first '2-piece' cans to be produced in the UK were on a semi-commercial basis at Metal Box's Acton plant. These were Metal Box's 12-oz tinplate 'Sheerwall' cans for supply to Coca-Cola.

This was followed in 1974 by the first UK D & I aluminium can line at Glasgow. In Scotland the half-pint drinker tends to be an object of ridicule, consequently the 16-oz beer can has always been the most popular type. In 1974 it was not technically possible for these tall cans to be made from tinplate.

Metal Box's third major investment in D & I technology was at their Westhoughton, Lancashire plant. Originally schedule for operation in Spring 1975, the four D & I tinplate lines did not in fact come on stream until 1976. The Westhoughton development was aimed at the 12-oz soft drinks can market. The 'four-leg' D & I line laid down has a 550 million cpa capacity, equivalent to ten conventional lines. The Westhoughton plant already had twelve 3-piece lines, including two for beverage cans. This addition represented an investment of £11 million, at the time the largest single outlay in the history of Metal Box.

The Westhoughton development was followed by a second aluminium D & I line at Glasgow, commissioned in 1977, for 16-oz beer cans at a cost of £2 million. In late 1977 the company also gave the go-ahead for a £1.8 million expansion scheme at their Carlisle plant to include two new 3-piece 16oz beer can lines. These two lines complemented Carlisle's 10 existing 3-piece lines.

Metal Box continued their expansion by opening a fourth location for 2-piece cans at Braunstone, Leicestershire. The plant has two D & I beer can and two D & I pet food lines. The company also announced its decision to build a further four D & I lines but did not specify the plant location. The displacement effect of this tremendous 2-piece investment manifested itself in 1979 when Metal Box announced the closure of their 3-piece can-making facilities at Acton, Glasgow and Westhoughton.

iii. Reads

Although Reads invested in beer and beverage production in 1965, their expansion programme to tap this market did not get under way until after ACC purchased a £1.2 million, 60% stake in the company in early 1967. At this time Reads was still a one-site, family-style operation, though their original complement of four can-making lines had been increased to six.

ACC's first move was to strengthen Reads' existing base as a sanitary can-maker. They consequently financed a second factory at Grantham, Lincolnshire, in 1969 and increased beer and beverage output from Liverpool. This was quickly followed in 1970 and 1971 by two plants aimed mainly at the beer and beverage market. In the first instance a can-end making facility was built at Rhymney, South Wales, followed by a £2 million plant at Milton Keynes, specially built to produce 10-oz and 12-oz 'MiraSeam' cans. The plant became operational in 1972 and in 1975 the two 10-oz TFS lines were changed to tinplate.

Reads continued incremental 3-piece investment until 1979 when they announced their entry to the 2-piece market with a £10 million scheme for D & I cans.

iv. Crown Cork

Crown Cork is the British subsidiary of Crown Cork and Seal of Philadelphia, USA. With the decline in the crown cork market, Crown Cork originally diversified into aerosols in the early 1960s. The logical extension of this policy was entry into the can market, which they effected in November 1969. Crown initially set up one 10-oz line at their Southall, London, location for tinplate cans. This was followed by a second double 10-oz line and a 16-oz double line, commissioned in 1974. In early 1976 the company increased its complement of 10-oz 'Y-lines' to three with a further facility at Southall. In July 1978 the company entered the 2-piece business with a £10 million plant at Livingston, West Lothian, for the manufacture of 16-oz D & I tinplate cans.

v. Nacanco

In 1967 National Can Corporation of the United States announced it was to take-over Clover Industries, a subsidiary of Metropole Industries of London, Clover was itself the holding company for three general line subsidiaries - J. Billig and Son of Norwich (primarily paint tins but also oil cans), Self Opening Tin Box Company of Barking, Essex, (primarily paint tins) and S. C. Lomax of Barking (wide range of general line containers). The Clover Can Company, as it was called, changed its name to Nacanco in 1974. Although the company have continued general line trading from Norwich, their base, and Barking, the company is orientated towards the beer and beverage can market.

Nacanco entered the beer and soft drinks can business in 1974 with a 350 million cpa D & I aluminium facility at Skelmersdale, Lancashire, for 12-oz cans. The Skelmersdale plant was followed in 1978 by the building of a second D & I aluminium line, this time at Milton Keynes, for 12-oz soft drinks cans. On the beer side the company has invested exclusively in the 16-oz can.

vi. Mardon Illingworth

Mardon Illingworth is a subsidiary of Mardon Packaging International, the second largest packaging firm in Europe; the latter is itself jointly owned by the Imperial Group and British American Tobacco. Mardon Illingworth had no history of can-making at all when it plunged straight into the 2-piece can business in July 1978 with a £4.5 million 200 million cpa beaded pet food can line at Sutton-in-Ashfield, Notts.

vii. Continental Group

In the wake of the severing of a reciprocal agreement with Metal Box in which CCC had agreed with the British can maker not to compete in each other's market, the Continental Group announced in 1978 its intention of investing in the UK 2-piece can industry with production due to commence in early 1980.

TABLE II*

UK Can-Making Expansion 1969-1980

| YEAR | COMPANY | LOCATION |
|---|---|---|
| 1969 | Crown Cork | Southall |
| 1969 | Reads | Grantham |
| 1969 | Metal Box | Winsford |
| 1970 | Metal Box | Glasgow |
| 1972 | Reads | Milton Keynes |
| 1974 | Nacanco | Skelmersdale |
| 1978 | Crown Cork | Livingston |
| 1978 | Nacanco | Milton Keynes |
| 1978 | Mardon Illingworth | Sutton-in-Ashfield |
| 1979 | Metal Box | Braunstone |
| 1980 | Reads | Runcorn |
| 1980 | Continental Group | Wrexham |

* Source : Various.

TABLE III*

Estimated UK 2-piece inventory 1980

| COMPANY | LOCATION | NO. OF LINES | CAN STOCK |
|---|---|---|---|
| Metal Box | Westhoughton | 4 x 12-oz soft drinks | tinplate |
| | Acton | 1 x 12-oz soft drinks | tinplate |
| | Springburn | 2 x 16-oz beer | aluminium |
| | Braunstone | 2 x 16-oz pet food | tinplate |
| | Braunstone | 2 x 16-oz beer | aluminium |
| | ? | 4 x | ? |
| Mardon Illingworth | Sutton-in-Ashfield | 1 x 16-oz pet food | tinplate |
| Nacanco | Skelmersdale | 1 x 12-oz soft drinks | aluminium |
| | Skelmersdale | 1 x 16-oz beer | aluminium |
| | Milton Keynes | 1 x 12-oz soft drinks | tinplate |
| | Milton Keynes | 1 x 16-oz beer | tinplate |
| Crown Cork | Livingston | 2 x 16-oz beer | tinplate |
| Reads | Runcorn | 1 x 12-oz soft drinks | tinplate |
| Continental Cans | Wrexham | 1 x 12-oz soft drinks | aluminium |

* Source : Tin International

TABLE IV*

UK 3-piece Can Inventory - 1979

| COMPANY | LOCATION | NO. of 3-piece lines |
|---|---|---|
| Metal Box* .. | Arbroath .. .. | 5 |
| | Carlisle .. .. | 13 |
| | Worcester .. .. | 18 |
| | Leicester .. .. | 11 |
| | Portadown .. .. | 5 |
| | Rochester .. .. | 12 |
| | Winsford .. .. | 5 |
| | Wisbech .. .. | 17 |
| Reads .. .. | Grantham .. .. | 8 |
| | Liverpool .. .. | 4 |
| | Milton Keynes .. | 5 |
| Heinz .. .. | Harlesden .. .. | 5 |
| | Kitt Green .. .. | 8 |
| Nestle .. .. | Ashbourne .. .. | 3 |
| | Dalston .. .. | 3 |
| | Staverton .. .. | 6 |
| | Omagh .. .. .. | 3 |
| Crown Cork .. | Southall .. .. | 5 |
| | Livingston .. .. | 2 |
| Carnation .. | Dumfries .. .. | 4 |

*Metal Box do not release details of their can-making inventory. Figures are based on industry estimates 1975, updated as and where possible.

* Source: Various

## 4 . Market Growth and Market Shares

### i. Introduction

The change in character of the UK can industry since 1969 has obsoleted the Monopolies Commission perspective of one market. The UK can market is split into two very distinct, non-competing sectors - the food can market and the drinks can market. To the can-maker these two categories represent totally different markets and a significantly different container. The two groups can be further sub-divided into human food and pet food, and beer and soft drinks. Although the differences are less marked within the two categories, from a marketing perspective they are extremely important.

The objective of this section is to consider the competitive development of the can market in the period since the Monopolies Commission Report. The actual growth in can-making is implicit in the figures of canned food production. For the record, annual production of cans for sale was 858 million in 1946 and 6,500 million in 1969. Production for canners' own use was probably at least an extra 20% in 1946 and 15% in 1969.

### ii. Human Food Can Market

The human food can market has been a straight two cornered fight between Metal Box and Reads since 1958, with both coveting the potential volume of the three large self-manufacturers Heinz, Nestle (Crosse and Blackwell, Libby McNeill and Libby) and Carnation.

To the can-maker, the human food market is the least attractive outlet. The mark-up on the can is relatively poor, reflecting demand and supply for this low technology product. There were, until recently, only two basic types of open top can - the straight sided and the beaded. The larger sizes, with the exception of the very big catering sizes, tend to be beaded. As a market the human food industry is static, conservative and unexciting - though there is some jostling between the canners. Of the thirty-one significant canners the top six or seven constitute the aggressive companies. These are the ones who have been installing new machinery.

TABLE V*

Human Food Can Market - 1977

| COMPANY | TOTAL CAN CONSUMPTION (MILLIONS) | OWN PRODUCTION |
|---|---|---|
| Heinz | 1200 | 650 |
| Nestle | 600 | 300-350 |
| Carnation | 300 | 300 |
| HP - Smedley | 300 | --- |
| Lockwoods | 260-280 | --- |
| C.W.S. | 200 | --- |
| Batchelors | 200 | --- |
| TKM | 260 | --- |
| Campbells | 150 | --- |
| Others (21) | 100 and below | --- |

* Source : Reads Ltd

Metal Box have always supplied over 95% of the human food can market. In 1968 Reads manufactured about 400 million cans, most of which went to one outlet - Pedigree Petfoods. The challenge facing the company in the 1970s was to expand on its firm foothold in the petfood business and to break into the Metal Box preserve of human food cans.

Beyond continuing to give a sound all round packaging service there was little in the way of additional restrictive practices which Metal Box could use in the wake of the Monopolies Commission Report. Reads' main problem in attacking the human food can market was their credibility as a sound second supplier. This question mark over the company was reinforced by reservations regarding the quality of some of the company's cans. It is a sign of the resilience of Reads that they have been successful in penetrating many major Metal Box accounts. The one company to reject Reads on quality grounds has been Heinz. Heinz are regarded as the 'Marks and Spencer' of the canning industry and it is indicative of the progress which Reads have made that they now appear to have satisfied Heinz requirements.

A major problem facing Reads is the unwillingness of some companies to undertake the extra work involved in maintaining two suppliers. Reads cannot compete at the margin on the large orders with the quantity discount offered by Metal Box. Large customers are sometimes unwilling to pay the necessary premium, even though they would in fact be buying insurance.

The nature of the human food can market and its nil potential growth have not been a stimulus to technical change, particulary the 2-piece can. The most suitable drawn food container would seem to be the draw-redraw (DRD) beaded can with a TFS end. Metal Box have not pioneered or pushed this possibility.

In the future in the human food can market Metal Box will very probably continue to lose part of their market share to Reads in a slightly declining market. Metal Box to some extent find themselves in a difficult position as regards Reads' encroachment; it would appear to suit the larger company to have Reads in evidence if, for no other reason, than to avoid the attention of various watchdog bodies. For this reason Metal Box are unlikely to ever try to force Reads under. This policy will always carry the very real threat, however, that the competitor will penetrate attractive accounts. This appears to be happening with Heinz and will no doubt happen elsewhere.

TABLE VI*

Human Food Can Market - Growth and Market Shares (excluding 1,300 million self-manufacture)

| | (Millions of cans) | | | | | |
|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
| Market size | 3,700 | 3,500 | 3,510 | 3,500 | 3,450 | 3,450 |
| Market Growth % | -- | 5.4 | 0.3 | 0.3 | 1.4 | -- |
| Metal Box % share | 96.4 | 96.0 | 95.2 | 94.2 | 93.6 | 93.1 |
| Reads % share | 3.6 | 4.0 | 4.8 | 5.8 | 6.4 | 6.9 |

* Source : Reads Ltd.

iii. Self-Manufacture

Whilst discussing the human food can market, it is appropriate to include the self-manufacturer, who is not to be found in the petfood or beer and beverage industry.

The increased concentration of the canning industry in the 1950s and 1960s made the supply of cans a more attractive proposition due to economies of scale from long production runs etc. These same economies also make self-manufacture (captive can-making) a more viable proposition. From Table V it can be seen that the most important self-manufacturer is H J Heinz. It is, principally, from the perspective of the relationship between Heinz and Metal Box that the captive can-making dimension will be discussed.

The key to the Heinz/Metal Box relationship has been the canned food market situation. The two companies are very similar in many respects - attitude, approach, etc., and the continued growth in the canned food market from 1945 until the late 1960s made for a close, cosy relationship. With the downturn in the progress of the canned human food market in the 1970s the relationship has suffered, In the growth days Metal Box were prepared to allow Heinz to concentrate on the easy, high volume can sizes on which there was the greatest profit. As business growth levelled out Metal Box became far less happy with this aspect of the relationship. When the canned baby food market collapsed in the 1970s, Heinz' sales of this product fell by two-thirds. Although Heinz were disgruntled by this turn of evets, Metal Box were not unduly perturbed because of the low profit margin on such cans. This volume drop did, however, lead Metal Box to feel that they should have more of Heinz' 8-oz and 16-oz can business to compensate.

Heinz for their part felt that Metal Box had been trading unfairly on the close relationship between the two companies, particularly as regards passing on cost increases. Heinz considered that the Monopolies Commission Report had failed to alter the realities of the can-making industry or the outlook of Metal Box, the results and recommendations of the Commission being watered down. It was with these feelings in mind that Heinz considered the Metal Box request for a greater share of the 8-oz and 16-oz can business. Metal Box and Heinz reached a compromise in 1976 whereby the canner should shut down its new 10-oz line at Harlesden in return for which Heinz would receive certain concessions such as suspension of rentals and increased discount. While this pleased Metal Box, what they did not realise and what Heinz were careful to conceal was that problems at Harlesden, in particular the loss of skilled labour, had in any case made the 10-oz line an unviable proposition. The deterioration in the Heinz/Metal Box relationship came to a head in January 1978 with further can-price increases which Metal Box refused to moderate. As a result, the canning company's purchasing department now take a very much harder line on all aspects of the relationship - prices, rentals, etc.

The role of the self-manufacturer as a competitor to, rather than a customer of, the specialist can manufacturer is more determined by the relative manufacturing realities rather than the final market situation. Basically, and somewhat glibly, it might be said that the specialist can-maker's advantage lies in economies of scale while the captive can-maker's lies in transport economies. In discussing this question the Monopolies Commission presented very much the Metal Box perspective emphasising, in particular, that canners' cost figures for can-making did not include many of their overheads. What might equally have been argued, however, was that the self-manufacturer must compete against his supplier in the face of problems which are peculiar to the former. Being both a can-maker and a can filler creates a number of problems, mainly related to labour. Making cans is noisier and hotter than filling them; overtime opportunities are not as frequent. The crux of the whole operation is the filling, the product has to be made ready, this creates a three-hour advance in preparation. There is no built-in early start in can-making, and no built-in late finish for washing down, etc. Special premiums for these early starts and late finishes are not available to the can-making employee. Further, discipline tends to be tighter on the can-making side, the actual work input per shift considerably higher. As a result of these differences, fitters are not very keen at all on can-making when can-filling lines are also present. Consequently, as soon as a vacancy arises for a fitter in the filling department, a transfer request will come from the can-making department. This means that the turnover of employees is much higher in the can-making areas and that the newer, less experienced employee, is found there. The effect of this problem with skilled labour on final unit costs does not accrue for the specialist can-maker.

In the tin-plate, can-making and canning chain it has traditionally been considered inadvisable to compete with one's suppliers and customers. For this reason, companies such as B.S.C., Metal Box and Heinz have rarely entered the fields of one another as sellers. Recently, however, Both Heinz and Carnation have supplied, but not sold, quantities of cans to other members of their own group. There seems to be no intention by either to do this on a permanent or regular basis. With the tightening of margins in the can-making business, however, this possibility cannot be ruled out entirely. There is evidence that Heinz, for one, have in the past underestimated the savings to be made by self-manufacture; if Reads do become well established as a strong second supplier then perhaps Heinz will feel that to make up the shortfall in their own can production, or to threaten to, would provide the additional leverage they want against Metal Box. (Metal Box's leasing agreements specifically outlaws the sale of cans to a third party).

### iv. Technical Change and Self-Manufacture

Can fillers in general take a very cautious view of technical developments not least because of the repercussions on sales of any mishap, e.g. the John West salmon case of 1978. This conservative attitude is maintained as regards the introduction or adoption of can-making changes. Heinz, for example, had still not used double-reduced tinplate or TFS on their own can-making lines by 1978. Heinz do all their own pack-tests and are currently evaluating TFS ends. They estimate that lacquered TFS ends would save them £500,000 but they want to be absolutely sure before they adopt them.

Despite their cautious innovative outlook the captive can-makers have welcomed the flurry of technical activity by the tinplate makers and specialist can-makers since the mid-1960s. They believe that all this development can only result in better equipment and improved manufacturing technique, and that they themselves will benefit from the spin-offs. 2-piece cans are a case in point. Heinz, who have evaluated the 2-piece food can, are not impressed by the economies of self-manufacture and at present have no intention of adopting this innovation. They do intend to buy all their baby food can requirements in 2-piece from Metal Box because of factors particular to this product, e.g. strict lead regulations. Heinz have also been able to purchase these cans at favourable cost at the tail end of a pilot project, as Metal Box seek to defray R&D expenses. By adopting the 2-piece Heinz enjoy the benefits of simpler final end-seaming in the cannery.

## 5. Pet Food Can Market

### i. Overview

Compared to the human food can market the pet food can market is an attractive outlet for the can-maker and offers more incentive for technological innovation. There are a number of differences between the two markets which help to explain the better price mark-up and greater scope for technical change.

One of the most important factors is that the pet food market uses only three sizes of can compared to the bewildering variety of human food cans. The three cans used are the 'Giant' can, the 'Tall' can and the 'Handican'. The respective consumption of each is 6.5 million cpa, 1.200 cpa and 130 million cpa.

A Second reason why the pet food market is an attractive outlet for the can-maker is potential growth - the pet food can business is expected to grow around 10% in the years 1979-1983.

TABLE VII*

Pet Food Market Growth

| | (Millions of cans) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
| Market size | 1300 | 1250 | 1260 | 1320 | 1345 | 1370 | 1400 | 1425 |
| Market growth % | nil | 3.8 | 0.1 | 4.6 | 2.0 | 2.0 | 2.0 | 2.0 |

* Source : Reads Ltd.

Within this overall growth, Handican volumes are declining significantly, and may suffer as much as a 40% fall by 1983. This is because the shopper is perceiving the Handican as poor value. Output of the Tall can will grow anytning between 17-29% and the Giant can 31% by 1983.

A further reason for the differences between the pet food can and the human food can is that, ironically, the former is a more sophisticated container. Reads us a TFS body for their cans, and both Reads and Metal Box use the very thin 0.17 mm double-reduced plate.

A final factor which must be mentioned is that the petfood market is highly concentrated whereas, in comparison, the food can market is comparatively fragmented.

TABLE VIII*

Canned Pet Food Market Shares 1978 (%)

| | |
|---|---|
| Pedigree Petfoods .. .. | 60 |
| Spillers .. .. .. .. | 27 |
| Quaker .. .. .. .. | 8 |
| Others .. .. .. .. | 5 |
| | 100 |

* Source : Various.

ii. The Pet Food D & I Can

The history of competition in the canned pet food market is a success story for Reads since their entry in 1958. It was the keenness of Pedigree Petfoods to obtain a second supplier, and their willingness to pay for it, that was responsible for getting Reads' open top venture off the ground and to which the can-maker owes its present position as an established supplier. Reads are the main suppliers of Pedigree Petfoods' 800-850 million cpa requirements and in 1976 their pentration of the pet food can market reached a peak of 41.3%.

The Pedigree Petfoods contract is the Reads account most coveted by Metal Box. It will have come as a blow to both companies, then, when Mardon Illingworth, somewhat sensationally, plunged into this market in 1978 with the first UK D & I food can. This turn of events has completely upset the equilibrium in the pet food can business.

Pedigree Petfoods, no doubt concerned that it should not be upstaged by Spillers, were very anxious to adopt the 2-piece, Tall, pet food can which had already been on the United States market for four years. Reads and Metal Box both considered supplying Pedigree Petfoods with this container; they will both have evaluated the alternative options and will have carried out financial evaluations. The two companies independently concluded that the return on investment (ROI) was inadequate without at least a 10% price premium, an amount which Pedigree Petfoods - who traditionally negotiated a tight standard variable margin - were unwilling to pay. Although a premium would have been available, both can-makers concluded that it could not be guaranteed as permanent.

There were additional considerations, also, which led Metal Box and Reads to decline to supply. Metal Box and Reads, in particular, were very content with the traditional Tall can which they saw as sophisticated - being made as it was from the thinnest body and end available. Further, Metal Box and Reads both had at the time excess 3-piece food can capacity and realised that to go to 2-piece would only obsolete existing conventional equipment.

Pedigree were not content to let matters lie for they believed that the technology of 2-piece can-making was bound to improve and would quickly produce a thinner and cheaper D & I food can. Whilst this would seem a reasonable assumption it does not mean that the cost advantage of the 3-

piece can would necessarily be reduced over time. Undeterred, however, Pedigree approached the Imperial Group who already owned the general line box-making company of Mardon Illingworth. Although Mardon Illingworth had no history of open-top can-making, Imperial agreed to fund their entry to this market to supply Pedigree with the 2-piece cans they wanted. It was ironic, then, that the reason why Metal Box had pioneered 2-piece can-making - to strengthen their monopoly and make entry more difficult by upgrading the technology and financial threshold of the industry - should backfire in that the sophisticated but 'artless' new technology was a gateway for the new entrant so long as large resources were available. Mardon Illingworth negotiated the supply of Krupp 2-piece machinery from Germany. Krupp's system had the distinct advantage for the new entrant in that it can be built up incrementally over time, i.e. all the capital costs do not have to be incurred at the outset and a large market need not be immediately available.

The positive response by Imperial encouraged Metal Box and Reads to re-examine the D & I food can option. They knew that Pedigree had offered Imperial a premium, though not the exact amount except that it was considerably below 10%. At the time of these re-appraisals the base material cost advantage of the 2-piece can was in fact declining. Both Metal Box and Reads were well aware that the cost advantage of the 2-piece lay in its thinner sidewall. They were also aware that the Mardon Illingworth can was made of plate comparable to conventionally available gauges. Not surprisingly, therefore, Reads for one again rejected any D & I food can investment. No other decision was possible on commercial criteria. Metal Box, however, decided that as market leads who boasted of their innovative record, it was not conceivable that they should be seen to be outside the main stream of a new can-making technology. They therefore made the emotional decision to produce their own D & I pet food can although they admitted to not seeing any likelihood of it being profitable, at least in the short term. They rationalised their decision to some extent by arguing that with the possibility of using thinner materials, and also non-lacquered steel, the situation might change to the advantage of the 2-piece can.

As regards market shares, the emergence of the D & I food can into Reads' most lucrative account will obviously most affect the Liverpool company. Reads expect both their volume output and market share to suffer.

TABLE IX*

Pet Food Can Market (millions of cans)

| | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|
| Reads output .. .. | 380 | 278 | 169 | 140 |
| Reads market share % .. | 28.3 | 20.3 | 12.1 | 9.8 |

* Source: Reads Ltd.

Unless Reads can find an alternative outlet for their Tall can displaced by the D & I container, then, without any line closures, they will most likely be faced with a total surplus capacity on all food cans of 344 million cpa. Metal Box, similarly, have already felt the displacement effect of their 2-piece investment. It is mainly, however, on the Open Top Group's cash flow that the D & I investment will show the biggest impact.

It is clear, therefore, that the decision by Pedigree Petfoods and Mardon Illingworth to go ahead with the 2-piece can, and Metal Box's response, were not normal business investment decisions. Pedigree were not taking a calculable risk, but were gambling that the technology of the D & I food can must improve. For Pedigree this gamble was understandable because they had the least to lose if the technology did not prove viable. Mardon Illingworth's decision cannot be viewed in exclusivity but must be seen in the context of the connections of the Imperial Group with Courage in the brewing industry. Metal Box, again, did not take a normal business decision based on the expected rate of return, but decided to subsidise a loss-making venture for image purposes. In the long run, the D & I pet food can investment will probably result in a dearer pet food can, which is the opposite result from that intended; if so it will be a negative contribution to économic progress.

## 6. Beer and Soft Drinks Can Market

### i. Overview

It can be seen from Tables I-III how the UK can industry has changed dramatically in structure since 1968. With the exception of Mardon Illingworth, all the new entrants have entered the beer and beverage market exclusively. In the case of Mardon Illingworth, as previously intimated, there is evidence that they see their long term future in the same drinks market. The impact on market shares of this drinks can bias is clearly seen in the case of Metal Box. Between 1968 and 1976 their share of the food can market fell from 76-71% whereas their share of the drinks can market fell from 94% to 69% in the same period. The relative attractiveness of the two markets is indicated by Metal Box's own performance.

TABLE X*

Indexed Return on Capital Employed for Certain Products Within the Metal Box Open-Top Group

| RETURN ON GROSS CAPITAL EMPLOYED YEAR ENDED | TOTAL OPEN TOP GROUP | FOOD | **CONVENTIONAL BEVERAGE |
|---|---|---|---|
| 30.9.72 | 100 | 100 | 100 |
| 31.3.73 | 96 | 94 | 106 |
| 31.3.74 | 113 | 95 | 184 |
| 31.3.75 | 75 | 69 | 106 |
| 31.3.76 | N/A | N/A | N/A |
| 31.3.77 | 166 | 152 | 296 |

** Substantial losses have been made on D & I operations.

* Source : Price Commission Report.

The salient feature of the beer and beverage can market in the 1970s has been the 2-piece can. This is such an overriding aspect that it is more logical to discuss the two markets within the framework of the D & I dimension than vice versa.

For technical reasons the 2-piece technology is more suitable for carbonated than non-carbonated packs. Equally important, however, the 2-piece can needs the longer production runs associated with the beer and soft drinks can if it is to be economic. Once a sufficient volume of output can be maintained there are cost advantages for the drawn container over the conventional can. These manufacturing considerations are, needless to say, academic if one cannot sell that output, i.e. the success of the 2-piece drinks can rests on the market size and potential of take-home beer and soft drinks. It is for this reason that it is argued that the success of the D & I can has been made possible by the marketing advantage of the ring-pull-end can over other forms of packaging.

TABLE XI*

Total Canned Beer and Soft Drinks Production 1964-1982 (millions of cans)

| YEAR | | | OUTPUT | YEAR | | | OUTPUT |
|---|---|---|---|---|---|---|---|
| 1964 | .. | .. | 395 | 1977 | .. | .. | 2850 |
| 1970 | .. | .. | 950 | 1978 | .. | .. | 3250 |
| 1971 | .. | .. | 1220 | 1979 | .. | .. | 3832 |
| 1972 | .. | .. | 1412 | 1980 | .. | .. | 4313 |
| 1973 | .. | .. | 1874 | 1981 | .. | .. | 4823 |
| 1974 | .. | .. | 2193 | 1982 | .. | .. | 5300 |
| 1975 | .. | .. | 2539 | | | | |
| 1976 | .. | .. | 2778 | | | | |

* Source: Various.

It has been the proven ability of the canned beer and beverage market to expand, on a world-wide basis, since the ring-pull-end was introduced in the UK (1964), the perceived future market growth, the opportunity to compete against established can-makers offered by D & I, and the determination of aggressive beer and beverage manufacturers to have the 2-piece can, that has led to the influx of new entrants to this sector of the UK market since 1968.

In spite of these advantages in the beer and beverage market the 2-piece can is by no means a fail-safe option. The burden of high investment and consequent risk falls on the can-maker much greater than on the can-filler; the final markets for canned beer and, particularly, beverages are very volatile, not least because of their vulnerability to short, wet summers. This introduces a large element of uncertainty. For these reasons firms such as Reads and Crown Cork, while attracted to the beer and beverage market, would probably have been happier confining their operations to conventional can-making if it were not for the pressures from competitors and customers, and the implications of both on the ability of the 3-piece can to compete in the 1980s.

In discussing the beer and beverage market one is essentially dealing with only three types of can: the 16-oz and 10-oz beer can, and the 12-oz soft drinks can. A small quantity of smaller soft drinks cans is produced for specialist outlets, e.g. British Rail, and up to 20 million cpa party cans of beer are produced. In the beer and beverage industry it is usual to refer simply to the '10-oz', '12-oz' and '16-oz' cans. For can-makers other than Metal Box, whose interests lay in a broad front approach, the question in the early mid-1970s was whether to go 2-piece and, if so, in which of the three drinks can markets to effect one's entry. The most instructive example of this 2-piece dilemna is very probably the one which faced Reads in 1975-76.

### ii. <u>The Northfield Project</u>

In 1974 the Coca-Cola Export Corporation decided, for the first time in Britain, to operate its own filling plant rather than to rely exclusively on contract canners. At the same time, the company also wanted to reduce its dependence on Metal Box for can supplies. Coca-Cola were adamant in requiring 2-piece cans for which the obvious supplier was, in fact, Metal Box.

For the smaller can-maker a most important consideration before going 2-piece is whether volume guarantees can be obtained. Strictly speaking the Monopolies Commission Report debarred any can manufacturer from seeking forward orders for any more than a two-year period. This clause was aimed at restricting the monopoly power of Metal Box. The 2-piece innovation, however, meant that it had the opposite effect because it reduced the ability of the smaller can-maker to break into the 2-piece market. To circumvent this clause, Reads proposed to enter into a seven-year obligation to supply cans - which is entirely legal - and, initially, a seven-year agreement from Coca-Cola to purchase. If the latter were challenged by the Government it was still conceivable to retreat to a two-year renewable agreement provided this was covered by a side letter from Coca-Cola agreeing to continuance of trading within the spirit of the original agreement.

Reads proposed to Coca-Cola that the two should build and operate independent but adjacent can filling and can-making plants on Reads' site at Northfield, Milton Keynes. The advantage to Coca-Cola was that it would receive an on-site source of D & I cans which it insisted be supplied; in addition it would reduce dependence on Beecham (Table XII) who at the time filled 76% of Coca-Cola's cans and, further, it would facilitate the development of a strong second supplier to Metal Box (as had happened with Pedigree Petfoods). Reads would gain the advantage of serving an on-site market leading customer. In addition, the 'through-the-wall' type of operation involved offered security in itself, this all meant a relatively low risk way of entering the D & I can market.

Reads knew in early 1974 that Nacanco had already ordered D & I equipment; they therefore reasoned that without the Northfield Project they would be unable to maintain their 15% share of the beverage can market and would eventually suffer from lower margins as 3-piece cans became more difficult to sell. In proposing the project to American Can Company (ACC) in 1974, Reads argued that without the investment in D & I can-making its growth could be expected to platequ in 1976. Most importantly, Reads' future in the beer and beverage industry could be seriously affected as customers turned to Nacanco and, eventually, Crown-Cork as a second supplier of the preferred D & I cans.

For Reads the Northfield project appeared to mark the crossroads in their development; after going a long way to establishing themselves as a viable second supplier in the past five years, they had to decide whether they were to make the considerable D & I capital investment needed to secure and maintain their desired 20-25% stake in the burgeoning beer and beverage market. Reads manufacturing cost data showed that the 12-oz D & I can for Coca-Cola offered a very significant variable cost saving over the two alternatives - the 'Mira Seam' cemented TFS can and the soldered electrolytic tinplate can. Given the availability of volume guarantees, this variable margin was sufficient to justify the high capital outlay involved.

TABLE XII*

Coca-Cola Canners - UK Market (Millions of cans)

| | | |
|---|---|---|
| 1973 | Beecham .. .. .. | 320 (76%) |
| | Own Filling .. .. | 0 |
| | Solent .. .. .. | 50 |
| | T.W. Beach .. .. .. | 20 |
| | C.W.S. .. .. .. | 15 |
| | Batchelors .. .. | 15 |
| | S. Bottles .. .. .. | -- |
| | | 420 - Approximately 42% of Total Beverage Market. |
| 1980 | Beecham .. .. .. | 765 (60%) |
| | Own Filling .. .. | 250 |
| | Solent .. .. .. | 80 |
| | T.W. Beach .. .. .. | 30 |
| | C.W.S. .. .. .. | 30 |
| | S. Bottles .. .. .. | 120 |
| | | 1,275 - Approximately 45% of Total Beverage Market. |

* Source: Coca-Cola Export Group

The alternative to the D & I project was to hold a 'steady state' investing current cash flow in replacement facilities and defensive investments and eventually suffering a loss in margins as the 3-piece can became slowly obsoleted. Reads estimated the financial impact of the alternatives as Table XIII.

TABLE XIII*

| | SALES ($) | OPERATING INCOME ($) | % SALES | NET PROFIT* AFTER TAX ($) | % SALES |
|---|---|---|---|---|---|
| **STEADY STATE** | | | | | |
| 1975 .. .. .. .. | 56,800 | 2,635 | 4.6 | 2,251 | 4.0 |
| 1976 .. .. .. .. | 62,880 | 3,691 | 5.9 | 3.451 | 5.5 |
| 1977-80 Avg. .. .. | 62,880 | 3.691 | 5.9 | 3.452 | 5.6 |
| **D & I COCA-COLA PROJECT** | | | | | |
| 1975 .. .. .. .. | --- | (500) | --- | (1.250) | --- |
| 1976 .. .. .. .. | 14,440 | 4,263 | 29.5 | 3.073 | 21.3 |
| 1977-80 .. .. .. | 20,160 | 7,247 | 35.9 | 4.471 | 22.2 |
| **COMBINED STEADY STATE & COCA-COLA PROJECT** | | | | | |
| 1975 .. .. .. .. | 56,800 | 2,135 | 3.8 | 1,001 | 1.8 |
| 1976 .. .. .. .. | 77,320 | 7,954 | 10.3 | 6,524 | 8.4 |
| 1977-80 .. .. .. | 83.040 | 10.938 | 13.2 | 8,013 | 9.6 |

*Assuming 'steady state' Reads would not pay taxes during this period due to tax loss carryover; if D & I went through Reads would begin income tax payments in 1978.

* Source: Reads Ltd.

It can be seen from Table XIII that the economics of the Northfield Project vis-a-vis a steady state strategy were attractive. This was against the background of a canned soft drinks market which had grown at an annual compound rate of 20% between 1965 and 1973, and at an average growth figure of 30% between 1971 and 1973.

As regards the soft drinks manufacturers, a venture with Coca-Cola seemed gilt-edged security in terms of final sales.

It was Reads' intention to secure their minimum volume guarantee of 240 million cpa from Coca-Cola and to supplement this with additional custom from the other soft drinks fillers.

A major advantage to Reads of their entry to the D & I beverage market was that it would reassure the beer can buyers of Reads' viability as a 2-piece can supplier, thereby strengthening the company's position regarding entry to the beer can market, the equal potential of which was an important consideration in going 2-piece in the beverage market, Table XV.

TABLE XIV*

Canned Beverages - Production, Market Share and Market Growth

| LABEL | 1974 MILLIONS OF CANS | 1974 % SHARE | 1980 MILLIONS OF CANS | 1980 % SHARE | ANNUAL % |
|---|---|---|---|---|---|
| Coca-Cola .. .. .. | 450 | 37.5 | 1,300 | 46.4 | 19.3 |
| Pepsi-Cola .. .. .. | 190 | 15.8 | 500 | 17.9 | 17.5 |
| Stotherts 'Strike' .. | 150 | 12.5 | 350 | 12.5 | 15.2 |
| Others .. .. .. .. | 410 | 34.2 | 650 | 23.2 | 8.0 |
| | 1,200 | 100.0 | 2,800 | 100.0 | 15.1 |

* Source: Reads Ltd.

TABLE XV*

UK Beer and Beverage Can Market

(All sizes in millions of cans)

| | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|
| BEER | | | | | | | |
| Metal Box .. | 730 | 790 | 920 | 1,015 | 1,185 | 1,408 | 1,635 |
| Reads .. .. | 170 | 210 | 240 | 280 | 315 | 362 | 415 |
| Crown .. .. | 150 | 200 | 240 | 280 | 300 | 330 | 350 |
| | 1,050 | 1,200 | 1,400 | 1,575 | 1,800 | 2,100 | 2,400 |
| BEVERAGE | | | | | | | |
| Metal Box .. | 1,010 | 1,125 | 1,300 | 1,609 | 1,735 | 1,762 | 1,935 |
| Reads .. .. | 170 | 215 | 250 | 250 | 290 | 338 | 415 |
| Nacanco .. | 20 | 100 | 150 | 150 | 225 | 300 | 300 |
| Other .. .. | --- | --- | --- | --- | 50 | 150 | 150 |
| | 1,200 | 1,440 | 1,700 | 2,000 | 2,300 | 2,550 | 2,800 |

* SOURCE: Reads Ltd.

Reads financial analysis of the D & I option, and the market implications of remaining wedded exclusively to 3-piece cans, appeared to offer a conclusive case in favour of the Northfield project. However, after considering the proposal at length, ACC refused to back the venture. It was not until 1976 that the final decision to pull out of the scheme was made. During this period of deliberation Coca-Cola had been acting on the premise that Reads, who after all proposed the project, would go through with it. The ACC decision, which probably set Coca-Cola back two years, did not endear Reads to the canner. The reason for ACC's decision is of considerable interest as regards a strategy for innovation. The rejection by ACC of the Reads' proposal was essentially a corporate problem created by a difference in perspective between the parent company and its subsidiary. A basic difference in philosophy between ACC and Reads explains why an apparently golden opportunity was turned down: Reads is almost wholly an open top and general line manufacturer and has long seen its future in the can-making business. The company therefore evaluated the D & I investment on its economic and commercial viability. ACC, on the other hand, despite their past dominance of the American can market, no longer saw themselves primarily as can-makers. The company is strongly committed to diversification and only about 30% of its interests is now in the can-making business. Further, as a multi-national company with a diverse investment portfolio, ACC examined the Reads proposal in terms of their overall investment strategy. Of crucial importance will have been the ROI from the Coca-Cola venture, having regard to local conditions, e.g. taxation and labour relations. The Northfield project had to compete against alternative locations where the ROI is traditionally higher; in particular in the mid-1970s ACC was involved in an investment proposal for can-making in South Africa.

There is also evidence that there was a lack of confidence by ACC in the then Reads management team and that, given the dominance of Metal Box, ACC did not feel that Reads had the credibility or indeed the technical expertise required. The decision by ACC, whether sound or otherwise, denied Reads the opportunity to secure an early and a strong foothold in the UK D & I can market. It has made the entry of other American can-makers to the UK market that much easier, not least because of the desire for a second supplier. The decision has also cost Reads a significant portion of its beer and beverage can market share. However, given the problems which Metal Box have faced in the D & I can market, particularly as regards labour co-operation, one cannot say with confidence that Reads, with its Liverpool base, would not have been taking too much on with the Northfield project.

### iii. Northfield Project - Postscript

Coca-Cola were eventually supplied with the cans they wanted at Milton Keynes by Nacanco in 1978. Reads re-kindled their interest in the D & I option after the 1976 disappointment, but before they could seriously contemplate entry to this market they still required the type of volume guarantees which had been available from Coca-Cola. Key customers identified in this regard were Pepsi-Cola (Cadbury Schweppes), Allied Breweries and Whitbread.

Reads' evaluation of respective costs still in 1977, showed a variable cost advantage for the 2-piece over the 3-piece. Of the three options, 10-oz, 12-oz and 16-oz, the last two were the most attractive. These were the only two seriously considered by Reads in 1977/78. Although detailed figures are not available, the prelimary economics of the

12-oz and 16-oz were estimated as Table XVI.

TABLE XVI*

D & I economics (1978)

| | 12-oz | 16-oz |
|---|---|---|
| Annual Capacity .. .. | 300 | 195 |
| Investment (£ million) | | |
| Fixed .. .. .. | 9,153 | 8,045 |
| Working ... .. | 795 | 650 |
| TOTAL .. | 9,948 | 8,695 |
| Net Income (pre-tax) pa | 3,200 | 2,722 |
| Return on investment after tax .. .. | 15.4% | 1.50% |

(An important point to emphasise in respect of UK investment is that the whole of fixed capital investment in plant and machinery can be written off for tax purposes in the first year giving a major boost to cash flow).

* Source: Reads Ltd.

In 1978, Reads announced a 12-oz D & I line for Runcorn which will be using tinplate as can stock. There were a number of factors which had changed by 1978 to influence ACC to support a D & I operation in the UK. Most importantly, perhaps, the impending entry of the Continental Group to the UK can market will have compounded the fear that, without a D & I investment, Reads would be totally eclipsed in the beer and beverage market. Also of considerable importance will have been the stronger, more confident, management team at Reads in 1978; further, Reads implemented important administrative changes in 1978 to increase the company's market effectiveness. Both of these last two factors will have helped to reassure ACC of Reads credibility.

iv. Beer and Beverage Can Market round-up

In the wake of ACC's decision on the Northfield project, Reads concentrated on incremental 3-piece innovation in the beer and beverage can market, as also did Crown Cork. Metal Box, Nacanco and subsequent entrants went exclusively for the 2-piece market.

a. Beer Can Market

In the early 1970s the future of the beer can was thought to be in the 10-oz size. It was considered that the half-pint size was convenient, it being unnecessary to keep topping up the glass as with the 16-oz. The can-makers were not inclined to discourage this thought because the 10-oz can offered a greater variable margin than the 16-oz. This is probably because the aluminium end, on which a significant profit is made, makes up a greater proportion of the material input; this mark-up may reflect an under-capacity in aluminium easy-open ends. Demand for the 10-oz can grew well up to the mid-1970s but has started to plateau since. This down-turn has been accompanied by increased preference for the 16-oz. This change is difficult to explain: reasons offered are that the 16-oz is better value than the 10-oz, that the former is nearer the traditional British measure and, indeed, that the larger size can may be perceived as a pint by many customers. Further, lager is claiming an increasing proportion of all beer sales and, as this is marketed as a 'long cool' drink, it may fortuitously have benefited the 16-oz. Metal Box, Reads and Crown Cork all invested in 10-oz capacity in line with original expected growth.

The swing in the market in favour of the 16-oz beer can at a time when decisions were being made on 2-piece investment resulted in a concentration of D & I can investment exclusively in the 16-oz size. Of the UK can-makers Nacanco were the most astute in anticipating this swing; the company has no 10-oz capacity.

b. <u>The Soft Drinks Can</u>

The very healthy growth in the 12-oz can market has made the container an attractive outlet for the can-maker. The variable margin on the soft drinks can is not as favourable to the can-maker even though there are fewer brand labels per filler and more concentration of canning at a limited number of sites. The explanation of the different mark-up would seem to lie in the disparity in the price of the finished can of beer compared to the can of soft drink.

Although the 12-oz size is the only beverage can of note, this is possibly too large a measure. There would appear to be scope for a 'thirst quencher' in the 6-10-oz range though as yet there appears to be no recognition of this in the industry, which is surprising given the dynamic nature of the leading companies.

TABLE XVII*

Soft Drinks Manufacturers in Order of Can Usage

1. Beecham
2. Schweppes
3. Coca-Cola
4. CWS
5. Barr
6. Lockwood
7. Suncharm
8. Whites
9. Solent
10. RHM
11. Silver Spring

* Source : Various.

TABLE XVIII*

Estimated Beer and Beverage Product Line Split 1982

| | (000 millions of cans) |
|---|---|
| 10-oz .. .. | 1.0 |
| 12-oz .. .. | 2.6 |
| 16-oz .. .. | 1.7 |
| TOTAL | 5.3 |

* Source : Reads Ltd.

### c. Future Trends

In an area as dynamic and volatile as the beer and beverage market, any statistics tend to need regular updating. The additional investment in 2-piece capacity by Metal Box and Nacanco, the entry to the market by Reads, Crown Cork and Continental, will all influence the market shares as detailed in Table XIX. As mentioned earlier, Mardon Illingworth may also enter this market, further subdividing the shares albeit of a larger cake. Given the tremendous potential of the beer and beverage market it seems that the expected growth will be sufficient to support six can-makers. It seems unlikely that Metal Box will be able to command any more than 25% of the beer and beverage market in the second half of the 1980s, an almost inconceivable situation before the development of the 2-piece can.

The UK manufacturing capacity for beer and beverage cans, set out in Table XIX, is based on the key assumptions of Table XX.

## 7. Summary and Conclusions

The salient observation to arise from this chapter is the remarkable change in the structure of the UK beer and beverage can industry which has accompanied the progressive introduction of the 2-piece can. From a condition of almost total Metal Box monopoly in the late 1960s has emerged a situation wherein Metal Box are but the dominant firm in a very competitive market with little prospect of the company maintaining their present market share. The prima facie case for asserting a cause and effect relationship between technological innovation and industrial structure can rarely have been stronger. To examine the evidence for such an assertion each of the can markets involved should be examined. Before embarking on this review it is appropriate to recap on the

TABLE XIX* (Millions of cans)

Beer and Beverage Manufacturing Capacity and Demand Patterns

| | | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|
| 12-oz 2-piece | Metal Box .. | 550 | 650 | 650 | 650 | 650 |
| | Nacanco .. | 150 | 400 | 450 | 450 | 450 |
| | TOTAL .. .. | 700 | 1050 | 1100 | 1100 | 1100 |
| 3-piece | Metal Box .. | 800 | 800 | 800 | 800 | 800 |
| | Reads .. .. | 200 | 200 | 200 | 200 | 200 |
| | 12-oz TOTAL .. | 1700 | 2050 | 2100 | 2100 | 2100 |
| | Market Demand | 1390 | 1491 | 1660 | 1844 | 2019 |
| | SURPLUS CAPACITY | 310 | 559 | 440 | 256 | 81 |
| 16-oz 2-piece | Metal Box .. | 150 | 200 | 200 | 200 | 200 |
| | Nacanco .. .. | 80 | 100 | 100 | 100 | 100 |
| | TOTAL .. .. | 230 | 300 | 300 | 300 | 300 |
| 3-piece | Metal Box .. | 600 | 600 | 600 | 600 | 600 |
| | Crown .. .. | 120 | 180 | 200 | 200 | 200 |
| | Reads .. .. | 160 | 160 | 160 | 160 | 160 |
| | 16-oz TOTAL .. | 1110 | 1240 | 1260 | 1260 | 1260 |
| | Market demand | 819 | 925 | 1045 | 1181 | 1347 |
| | SURPLUS CAPACITY | 291 | 315 | 215 | 79 | (87) |
| 10-oz 3-piece | Metal Box .. | 500 | 500 | 500 | 500 | 500 |
| | Crown .. .. | 360 | 400 | 400 | 400 | 400 |
| | Reads .. .. | 260 | 270 | 360 | 360 | 360 |
| | 10-oz TOTAL .. | 1120 | 1170 | 1260 | 1260 | 1260 |
| | Market Demand | 864 | 976 | 1127 | 1288 | 1457 |
| | SURPLUS CAPACITY | 256 | 194 | 133 | (28) | (197) |

* Source : Reads Ltd.

TABLE XX*

Manufacturing Capacities

METAL BOX, TWO-PIECE 12-oz (millions of cans)

| | |
|---|---|
| Acton .. .. .. .. | 50 |
| Westhoughton .. .. .. | 600 capacity<br>400 produced in 1977 through industrial relations problems |

NACANCO, TWO-PIECE 12-oz

| | |
|---|---|
| Skelmersdale .. .. .. | 150 capacity |
| Milton Keynes .. .. | 250 produced in 1978<br>300 thereafter |

METAL BOX, TWO-PIECE 16-oz

| | Capacity | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|
| Glasgow (line 1) | 120 | 100 | 110 | 120 | 120 | 120 | 120 |
| Glasgow (line 2) | 120 | 30 | 90 | 120 | 120 | 120 | 120 |
| Leicester (line 1) | 150 | | | 40 | 120 | 150 | 150 |
| Leicester (line 2) | 150 | | | | 40 | 120 | 150 |
| TOTALS .. | | 130 | 200 | 280 | 400 | 510 | 540 |

NACANCO, TWO-PIECE 16-oz

| | |
|---|---|
| Skelmersdale .. .. .. | 120 capacity |

CROWN CORK, THREE-PIECE 16-oz

| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|
| Southall .. .. | 75 | 85 | 85 | 90 | 90 | 90 |
| Livingston .. .. | 30 | 85 | 85 | 100 | 110 | 110 |
| TOTALS .. | 105 | 170 | 170 | 190 | 200 | 200 |

TABLE XX Cont'd.....

READS

Three piece, 16-oz beer can capacity assumes third three-piece line added during 1978.

CROWN CORK, 16-oz ADDITIONAL INVESTMENT

| | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Livingston, three-piece .. | 30 | 85 | 100 | 110 | 100 |
| Livingston, two-piece .. | | | 50 | 175 | 200 |
| TOTALS .. | 30 | 85 | 150 | 285 | 310 |

* Source: Reads Ltd.

situation in the late 1960s.

The human food can market was one of near complete monopoly by Metal Box, but with a significant contribution to production from the self-manufacturers. Reads were well established as the second, and only other, manufacturer of pet food cans after Metal Box. The beer and beverage can market was showing evidence of latent potential but at the time was still supplied almost exclusively by Metal Box. One of the obvious explanations for the change in the structure of the UK can industry in the 1970s is the influence of the Monopolies Commission Report and, in particular, its recommendations to curb some of Metal Box's monopoly power. On this subject the tinplate, can-making and canning industry seem agreed that the Monopolies Commission Report changed virtually nothing of real importance. Crown Cork had already decided to enter the UK can industry prior to MB's referral to the Commission and, moreover, there is widespread consensus that the trading realities of the UK can industry have remained unaltered by the Report. Conditions relating to the supply of cans to the human food industry have not changed significantly in the 1970s. This suggests that a crucial variable in the relationship between technological innovation and industrial structure is market potential; the lesson seems to be that a static market is an infertile one where technical change is concerned. In the pet food can market it has been shown that the 2-piece innovation directly impacted an industrial structure when Mardon Illingworth entered the arena. One of the most significant pointers from this episode is the importance of the nature of the technology. The mystique which surrounds conventional can-making affords its own barrier to entry. The only two UK firms to enter this market - Reads and Crown Cork - both did so with the confidence gained from a history in metal container fabrication and also with the technical support of experienced American can-makers. The evidence of Metal Box superiority in conventional can-making suggests that the 3-piece can-making art is not easily learnt. The second important factor in the exploitation of innovation to arise from the analysis of the pet food industry is the role of the customer. Without the determination and commercial muscle of Pedigree Petfoods there would have been no D & I pet food can in the UK. The role of Pedigree indicates the importance of the structure of the consuming as well as the manufacturing industry where technological innovation is concerned.

The case of the beer and beverage can reinforces many of the conclusions about the nature of technical change and its relationship with industrial structure drawn from the instance of the food can. Most obvious are the importance of the final market situation and future growth potential and, secondly, the role of the customer, as evidenced by Coca-Cola, in forcing the pace of technological innovation in the supply industry. The observation that the ability of the 2-piece can to take an increasing share of the packaged drink market was due to the marketing advantage of the ring-pull-end, would suggest that innovation begets innovation. The Northfield project confirmed some of the classic variables in technological innovation such as the role of risk, uncertainty and commitment; it also highlighted problems regarding investment decisions which may be peculiar to multi-national corporations.

As regards industrial structure, the different paths of the human food and beer and beverage cans would seem to make it indisputable that the new entrants to the industry since 1968 invested in a market rather than a technology. The nature of the new technology, while it suited the expansive resources of Metal Box, was an encouragement to completely new entrants. Given the profits to be made in the conventional beer and beverage can market (Table XI) it would seem probable that the large American can manufacturers such as Nacanco would have invested in the UK market even without the 2-piece innovation, as evidently the case with Crown Cork.

It would seem that the UK can industry bears out a fundamental tenet of classical economics, namely that profit acts as a magnet for competition. The innovation of the ring-pull-end is in the process of transforming the beer and beverage can from the minor to the major partner in the UK can industry. The considerably greater standard variable margin on the drinks container relative to the food can has attracted the investment of the new entrants. The fact that the higher single can outputs involved in the beer and beverage industry give the 2-piece container an opportunity to exploit material cost savings has resulted in a concentration of investment in this new type of can.

The transformation in the structure of the UK can industry in the 1970s encourages the belief that it is now a more innovative industry and that the bustling competition in the dynamic beer and beverage sector is a contributory factor. Such assertions need to be examined carefully. With so much investment and unprecedented competitive activity in the can industry it is all too easy to become subsumed in what can only be described as the 'razamataz' of 2-piece technology. In fact the industry in many ways retains its traditional characteristics. Although there has been the radical process developments of D & I and DRD and hybrid drawn container processes, within this technology the pattern of innovation remains much the same. The industry is still over-whelmingly concerned - particularly within the 2-piece development - with minor, incremental material saving and process improving innovations. Indeed, if we look beyond the 2-piece technology it would appear that there is in fact a reduced variety of innovation. Can-makers have become so preoccupied with the drawn container that the pace of technical change within the industry as a whole - and it must be remembered that the conventional can accounts for by far the greater share of the UK can market - seems to have slackened, though admittedly this may be an erroneous impression created by the publicity surrounding the 2-piece can. The extent of the innovation which has been catalogued throughout the post-war period makes for one conclusion that is well nigh indisputable, i.e. that the UK can industry has been a hot-bed of innovation, albeit for most part incremental, irrespective of the structure of the industry. From the analysis of the economic impact of conventional can-making innovations and from the evaluation of the financial implications of the 2-piece technology, it is the case that the accumulated, minor, incremental innovation in conventional can-making technology has made a consistently significant contribution to economic progress, whereas the technical progress of the 2-piece can has made a dubious contribution - to date at least - and in some cases a negative one, to human welfare in the only meaningful way in which the can-maker can measure it, namely the price of the can.

The case of the UK can industry posits the question why should a company pursue a policy of technological innovation so vigorously when for nearly twenty years it enjoyed a unique monopoly on the sale of open top cans? The answer from a single industry perspective would seem to be that the case of the UK can industry supports the argument that monopoly power provides the environment best suited to technological innovation. If this is correct, where does it leave the role of competition? It has been shown that competition in the 1970s has been responsible for innovations, sometimes even for premature and uneconomic innovations. This apparent paradox can be reconciled, indeed its solution is contained within and has been suggested by the inter-industry approach adopted. Whether Metal Box is one alone or one among many in the UK can-making industry is not the important consideration. The analysis of the post-war development of the UK can industry has shown that Metal Box has always been acting under the pressure of competition irrespective of the structure of the UK can industry. The pressures involved have been indicated at numerous points in the study and nearly all of them lie outside the strict parameters of the can-making industry. Pressure from within the manufacturing chain of tinplate maker and can maker, pressures from alternative forms of packaging material such as aluminium and plastics, pressures from alternative containers such as bottles and jars, pressures from alternative food processing systems such as freezing and dehydration, pressures from customers threatened by alternative packaging and processing developments, pressures from customers threatened by direct competition and, finally, the ultimate pressure, the need to ensure that the canned product - as a non-essential good - continues to compete for the disposable income of the consumer.

It is in view of the crucial role of these outside forces in determining the pattern of innovation in the can-making industry that one must extend the analytical framework to incorporate them in a study of the nature of innovation from an inter-industry perspective.

## REFERENCES

The material in this chapter has been compiled primarily from primary sources. Additional keyed references as follows:


1. Scherer S.M. '*Industrial Market Structure and Economic Performance.*' Rand, McNally & Co. Chicago 1971.

2. '*Report on the Supply of Metal Containers*'. H.M.S.O. London 1970.

3. '*Metal Box Company Profile', 'Times Review of Industry*'. London, February 1964.

4. Reader W.J. '*Metal Box: A History*'. Heinemann, London 1976.

## CHAPTER VI

# WIDER INTER-INDUSTRY ASPECTS

## 1. Introduction

This chapter seeks to explore those areas outside the focal industries which the foregoing analysis has suggested have an important bearing on the course and nature of technological developments in the can industry. The analysis is predominently at the technological level. The degree of technical exposition is the minimum necessary for a basic understanding of the technologies concerned. After brief mention of the canning industry, the chapter examines the role of alternative packaging developments influencing the nature and pattern of can-making developments. The chapter concludes by considering the role of the complementary development of secondary packaging in the course of tinplate and can-making innovations.

## 2. Canning Developments

In formulating a conceptual framework for examining innovation from an inter-industry perspective it was originally considered that examination of the focal industry - can-making - would be complemented by an almost equally in-depth investigation of the technological relationship with the tinplate and the canning industry. These three industries, it was considered, would form the core of the system. Other elements were perceived of as in the second or subsequent strata of this innovation system. The analytical usefulness of this perspective was reinforced in the research on the historical background which suggested a close and strong relationship between tinplate and can-making and canning. While this perspective was subsequently borne out in the case of the tinplate and the can-making industries, the same cannot be said of the canning industry. The intricate interplay of technological forces which was such a feature of the tinplate/can-making relationship was not a characteristic of the canning industry. While innovations in tinplate manufacture and can-making were observed to have important implications for the canner, and vice versa, the meaningful instances which could be cited as having important implications for an understanding of the nature of technological innovation were not numerous. In view of this finding it has not been considered either justifiable or necessary to present a review of the canning process*.

It would appear that although the can-making and canning industries are totally inter-dependent, the canning industry has not played an important role in shaping the pattern of can-making developments at the technology to technology level (we have already observed its development of the D & I food can). The peculiar nature of the UK industry with the historically dominating and pioneering role of Metal Box in the can-making/canning relationship may be responsible for this. It could well be the case that in the United States the canning industry played a more active role in can-making development where no firm, perhaps, embodied the greatest expertise in both can-making and canning developments. It may be the case that Metal Box's all round technical competence meant that the customer role in shaping technical change has been largely unnecessary.

## 3. Competitive Packaging

### i. Overview

The hypothesis underlying this section is that to understand the innovation system within the tinplate and can-making industries one

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* For those wishing to explore this technology in greater depth additional bibliographical sources are given at the end of the chapter.

has to be aware of competitive forces that operate at the intermediate stage of the production process.

Tinplate comsumption in containers, at over 1 million tonnes a year, is the main packaging medium used in the UK.

TABLE I*

UK Market for Packaging Materials by Value - 1979 (£ Million)

| | |
|---|---|
| Tinplate | 650 |
| Fibreboard | 585 |
| Plastics | 746 |
| Glass | 354 |
| Paper | 226 |
| Board | 275 |
| Paper Sacks | 116 |
| Aluminium Foil | 108 |
| Steel Drums | 105 |
| Aerosols | 76 |
| Cellulose | 57 |
| Wooden Containers | 130 |
| Collapsible Tubes | 22 |
| Fibreboard Drums | 14 |
| Miscellaneous | 110 |
| | £3,574 Million |

* Source: Packaging Review January 1980

Tinplate has been so successful in the food and beverage sector that from a competitive perspective innovation has not been designed primarily at breaking into the traditional markets of alternative materials - in the classical sense of aggressive innovation - but more at consolidating and extending its use within its existing framework. This has meant that in the UK food and beverage markets, alternative container materials have been engaged in either trying to penetrate tinplate's markets or in repulsing its encroachment from their own markets.

ii. Aluminium

Aluminium was first made in 1827, six years after the discovery of bauxite. As such it is a comparatively new metal. Most of the commercially produced aluminium is obtained by converting bauxite to aluminium and then converting the aluminium into pure aluminium in an electrolytic oven. This process was invented by Charles Martin Hall and first patented by Karl Bayer in 1888, when aluminium was first successfully produced in large quantities. The primary production of aluminium is one of the most energy-intensive processes in the metals business; smelters require huge amounts of electricity to operate the chemical process which separates white aluminium from bauxite and as a result energy is the aluminium industry's major overhead expense, and one that can vary enormously. In a world of escalating energy costs and restrictive legislation on energy-intensive process, the competitive position of the aluminium industry is likely to depend increasingly on recycling. Some 90% of the energy used in aluminium production can, in effect, be used again if the metal is saved, remelted and reused. Aluminium suffers in recycling because it is not magnetic, although it is no problem to induce magnetism electrically.

Aluminium has many attributes as a packaging material including strength, lightness, hygiene, attractive appearance, versatility of forming, adaptability to printing, rapid heat transfer, resistance to light and vapour transmission and to odour. These qualities have made the metal a suitable medium for many types of food packaging. Aluminium foil has a wide variety of uses for flexible packaging; aluminium has long been used as a closure, particularly on glass, and formed foil containers have been adopted for modern catering systems. As a rigid container, however, aluminium's only long or widely established use has been for shallow drawn fish containers - until the development of the D & I can in 1963. It is in the market for rigid containers, particularly the open top can, that the aluminium industry sees the real potential growth of its own container. This does not represent a threat to the can-maker, but is constitutes the most serious competitive challenge for the steel industry and the tin industry.

The first attempts to produce shallow aluminium processed food cans took place in Norway in 1919 (countries with cheap hydro-electric power offer greater potential for aluminium). These attempts were unsuccessful due to permanent deformation during sterilisation. In 1930 the introduction of the super-pressure autoclave overcame this problem. The first commercial production of these cans did not take place until the late 1930s. The introduction in 1947 of lacquers based on phenolic resins - which have the ability to be rapidly stoved at high temperatures - opened the way for the development of a continuous aluminium strip lacquering process based on the already developed continuous anodising process. The application of aluminium to deep-drawn cans began in 1942 in Switzerland, due to the war-time shortage of tinplate, when Kellver produced a deep-drawn aluminium can in a single pressing operation. Anodising was used as a means of protecting the surface of the can. In the UK aluminium processed food cans had not been used in commercial quantities before 1949. Again due to tinplate shortages, several British packers began investigating aluminium. When lower priced tinplate became increasingly available these shallow-drawn aluminium cans were quickly discarded.

The tall aluminium can may, theoretically at least, be made by any one of five different processes. The first is the conventional three-piece can-making method, the other four are variations of the same basic die stamping technique used by Kellver. In the traditional three-piece process problems arise in closing the side-seam. Soldering aluminium is slow and difficult and welding though possible, considerably slows down the manufacturing operation. The only satisfactory method as far as economy and efficiency are concerned is the use of thermoplastic cement but, as with TFS cans, such joining limits the cans to use for non-sterilised products. Double seaming of this can is also difficult without tearing the aluminium.

The four die stamping methods all have the advantage that they eliminate the side-seam. The can may be made by placing a round aluminium slug in a shallow die cavity where, under tremendous pressure from the descending punch, it is extruded or forced upward between the cavity wall and the side of the punch, thereby attaining a cylindrical shape. This is the method used to make collapsible tubes such as contain toothpaste. Secondly, forward impact extrusion may be used in which a ring-shaped aluminium slug is forced through a tube shaped die by the punch and thereby formed into a long open-ended cylinder from which several can bodies may be cut. (This technique draws to mind 'multi-high' conventional can-making). Thirdly, the aluminium disc may be drawn by a powerful steel punch into a cylindrical shell, then redrawn on a smaller diameter die to give it the desired height. The fourth method is one in which the disc shaped slug is drawn first into a shallow cylinder by the descending punch, which continues through a bottomless die and drags the aluminium cylinder through a lower die, slightly smaller in diameter, which spreads the metal thinner and extends it upward into a taller can ('drawing and ironing').

Commercial quantities of tall aluminium cans appeared for sale in the US for the first time in October 1957. These cans were supplied by Continental Can Company. It was this innovation from which sprang the frenzied competitive activity at the technological level which has been characteristic of the can industry in the 1960s and the 1970s. The first large scale try-out of aluminium cans in 1960 heralded the start of a twenty year competitive battle between steel and aluminium to undercut each other by introducing material-saving innovations. In 1960 aluminium broke into the frozen citrus juice market, a traditional tinplate outlet; this breakthrough speeded up the development and marketing of the new light-weight or 'thin' tinplate which was generally perceived as the steel industry's answer to the challenge of aluminium. Thus thinner, double-reduced, tinplate was rushed on the American market in 1960, twelve months ahead of schedule. With the production of aluminium 'Zip-Top' cans at the pilot stage it was prophetically stated at the time that:

"Curiously enough as long ago as April 1956 a patent was taken out in the US for a tinplate can with a 'peel-off' top. It might be useful for the can-makers research departments to examine this new development afresh".

Although the metallurgical differences between aluminium and tinplate mean that the two metals have somewhat differing implications for can manufacture, since the time of the successful commercial exploitation of the aluminium can the technical propoganda of the steel and aluminium producers has become increasingly less relevant. The case for adoption will in the future rest principally on commercial rather than technological criteria. The major barrier to the diffusion of the aluminium can innovation has been its price premium over tinplate. For this reason the D & I aluminium can failed to establish itself in the early 1960s. In 1964 two commercial factors combined to launch the aluminium can onto a spectacular growth path. The first was the reduction in price of aluminium sheets by several manufacturers, the second was the role of Reynolds Metals. Determined to establish its product in a steel preserve, Reynolds set down about half a dozen aluminium can plants of its own and found outlets for their container in the beer and soft drinks market. Somewhat ironically, the innovation of coiled tinplate stock handling gave an added impetus to the aluminium offensive. Coiled aluminium is very attractive to the can-maker using high-speed equipment, the efficient operation of which is very dependent upon the consistency of the material being worked. Steel coil processing is not as consistent as that of aluminium. The growth in the use of lithographed cans highlighted the importance of this difference, good print quality on tinplate often requires an undercoat to hide coil processing marks. This problem comes from faster tool wear and die build-up when working steel. These factors increased the pressure on tinplate manufacturers to reduce the incidence of pin holes and surface defects.

iii. Easy-Open Ends

The second area in which aluminium played a significant role in shaping the can industry in the 1960s and 1970s was in the easy-open end. Ideas on easy-open ends date back to the 1930s; most were regarded as either too costly or not suited to the required production speed. In the late 1950s the leading American brewers introduced one plain aluminium end to their cans. This innovation met with immediate consumer success because of the ease with which the can opener penetrated the end. An additional advantage which accrued to the brewers using an aluminium end was a reduction in iron pick-up in the beer, thus adding to shelf life. At this time Alcoa were searching for a can end which could be opened without an opener and which would be attractive to the consumer and, also, economical to manufacture. In 1961 the first satisfactory solution was found and experimental ends were made using a variety of techniques such as cold welding, ultrasonic welding and riveting to attach the opening tab. Further work by Alcoa in conjunction with a machine tool manufacturer led to the development of the integral-rivet easy-open end, and to many improvements in the design of the tab and the score configuration.

Two basic alloy systems were developed for use in the manufacture of can ends, an aluminium manganese and, increasingly later, an aluminium magnesium alloy. This product was produced in finished thickness on special multi-stand cold mills. The metal was characterised by high strength and better flatness and gauge control than is usually possible with strain-hardened sheet produced by conventional rolling methods on all-purpose cold mills. The alloy, temper and gauge produced by this method are variable; a strong alloy in a super hard temper is used for easy-open beer and beverage ends because of internal pressures encountered in packaging.

The end is produced by feeding a completely formed but unscored end into an easy-open end-making press and, in a series of progressive dies, the end is converted into an integral rivet easy-open end.

When the first easy-open end appeared on the market the tab was flat and somewhat crescent shaped. From this early tab configuration to the advanced ring pull, many designs were tried and test-marketed. Apart from the tab in the shape of a ring, the score-line of the ends had undergone a great many variations. One note-worthy characteristic is the location of the rivet; the strongest influence here is the use of the can. Beer and beverage cans, with their partial aperture opening, tend to have a central rivet where-as full aperture cans have the rivet off-centre.

In the US, Alcoa's integral rivet can was first introduced for a full aperture citrus can in 1961, but its main marketing impact has been on the partial aperture beer and beverage can.

Although the aluminium end eliminated a very significant area of potential tinplate usage, its introduction did not bring about the 'life and death' type struggle between aluminium and steel to be found in the rigid container market. The reason for this was because the innovation could be applied equally successfully on a can body of either metal. The major implication of the development from a competitive perspective is that is seems to have reinforced the determination of the aluminium industry to capture the can market, and it thereby fuelled the development of the aluminium two-piece can, and the competitive response of the steel D & I can.

iv. UK Developments

In the UK aluminium has played a different role than in the US. The considerably greater price difference between steel and aluminium in the UK than in the US meant that the all-aluminium can was not a viable proposition except for 'quality' packs such as salmon where the cost of the container is a less significant proportion of the final selling price. Further, even if they had thought it viable, no aluminium manufacturer would have been too keen to challenge Metal Box's dominance in the way Reynolds Metals had pioneered the aluminium can.

The convenience aspects of the easy-open end were so great, however, that they outweighed the cost factors. As a result, in the UK the easy-open end was introduced over six years before the tall aluminium can, and the latter has to date shown little sign of displacing tinplate to anywhere near the extent that has taken place in the US. (The plain aluminium end does not appear to have been used at all in the UK).

Probably because of its proven suitability for use as a drawn container, and initial reservations about the suitability of tinplate for the tall 16oz beer can, aluminium has made a significant breakthrough into the UK two-piece market. In the late 1960s moreover, aluminium was rising in price considerably less steeply than tinplate (about a 5% difference in the crucial 1968-70 period when Metal Box were on the threshold of their two-piece venture). The most significant UK aluminium development has been the £35m rigid container sheet rolling mill at Swansea, which came into full production in 1977. This plant is aimed directly at the European can markets. Alcoa, who have made this investment, see a big future for aluminium in baby foods, pet foods, steamed puddings and dry products as well, of course, as a beer and beverage can.

In the future however, the success or otherwise of aluminium in securing an increased share of the UK tinplate can market will depend very much on the relative cost-competitiveness of the two metals. In the past, aluminium producers have been prepared to peg the price of their product, sometimes to cost levels, in order to capture new markets. This is unlikely to be the case in the future, as the chief concern of the aluminium industry will be to recoup an acceptable return on investment. If it were not for the enormous value of the European can market, the aluminium manufacturers would most probably concentrate their attentions only on those outlets where aluminium has clear product advantages over alternative packaging media and where, therefore, there would be scope for significant price premiums. This is clearly not so in the case of the can industry; the aluminium industry must therefore concentrate its efforts within this area on technological innovation aimed at minimizing the cost disadvantages and maximizing the product advantages, such as they are, of aluminium over tinplate. We are, therefore, likely to see more innovations such as the 'featherlite' aluminium can (a container introduced in 1972 which was

20% lighter than the standard aluminium can) and also the polypropylene adhesive film lamination which allows wider use of aluminium ends on steel cans, particularly for food uses. It is these types of developments which will shape the nature of competition between aluminium and tinplate for the UK can market, and which will influence the nature of tinplate's technological response.

v. Glass

Glass differs from aluminium in that it has a long established and large share in the food and beverage rigid container markets. While aluminium has been trying to displace the tinplate can in these areas, the glass bottle and jar have been very much on the defensive from tinplate. The tinplate and can manufacturers have tended to regard glass as a material with certain crucial inadequacies as a modern packaging medium and thereby ripe for replacement. The nature of the post-war tinplate-glass relationship has been one of continual encroachment by tinplate with the glass manufacturers apparently only recently responding with the required urgency at the technological and marketing level, to the threat to their outlets. The principal arena for this competitive struggle has been the take-home beer and soft drinks markets. The two paramount disadvantages of glass - its weight and its fragility - have been the weaknesses which the tinplate can (and other packaging media also) have sought to capitalise upon.

Glass Container History

Although an ancient medium for packaging food and drink, it was not until the invention of the internal screw stopper (1872) and the crown cork (1892) that the incentive to mechanize glass container manufacture and filling was provided. After considerable and diverse pioneering developments in the late 1800s and early 1900s particularly by the Owens Company in the US, the Hartford single feed glass container-making machine was perfected in 1922. This 'gravity' or 'gob' feed method accounts for around 90% of contemporary glass container production.

## The Modern Glass Container-Making Process

The raw materials for glass are all indigenous and inexpensive. A typical bottle consists of 50% sand, 20% cullet (clean, broken, recycled glass), 15% soda ash, 11% limestone and 4% of minor additives. To manufacture glass containers these raw materials are mixed and fed into the glass melting furnace where they are fused at over 1500° C. The molten glass is then cooled slightly in a forehearth (a long, covered trough). As the glass leaves the forehearth it is transformed into a seres of 'gobs', each separated by the stroke of a shear. Scoops collect the gobs and transfer them to moulds wherein the body is roughly shaped into a 'parison'. The parison is then inverted and placed in a second mould in which compressed air is employed to blow the nearly formed glass against the mould surrounding it, thus producing the final container configuration. An important variation in this method, as regards the technological challenge of tinplate, is in the 'press and blow' and 'blow-blow' processes. Widemouth containers are made by the press and blow method in which a plunger forms the mouth of a jar in the parison mould before transfer to the second mould. In the blow-blow process two puffs of compressed air are used, one in the parison (blank) mould and the second after the gob has been swung into the blow mould.

As the containers leave the forming machines they travel on a conveyor through a hood in which they are strengthened by chemical process. This treatment is generally referred to as the 'hot-end' treatment because it is carried out soon after the bottles are made. The process usually consists in the application of a compound of a metal either in sprayed liquid or vapour form, causing decomposition to take place on the surface of the glass, giving a film of metal oxide. The coating produced in this way becomes part of the glass and cannot be removed by normal washing.

After forming, the containers are re-heated and cooled at controlled rates in an annealing oven. (This lehr performs a similarly crucial purpose as the tinplate annealing lehr). This process releases the stresses caused during forming without which the containers would be useless.

The containers next receive a second surface treatment, generally referred to as the 'cold end' treatment because it is carried out when the bottles are close to or emerging from the annealing lehr. A combination of hot and cold end treatments imparts not only strength to the container but also lubricity. This increases its resistance to shock and abrasion.

Glass as a Packaging Medium

The purpose of food and beverage packaging has been defined by the American Food Protection Committee as to "protect the contents during storage - both before sale and in the home - from contamination by dirt and other micro-organisms; and loss or gain of moisture, odours or flavours. Frequently deterioration is controlled by preventing contact with air, contaminating glases or light. Because the packages are closely associated with food they must contribute little, if any, acceptable, harmless, incidental additives which orginate in the packaging and are transferred to the food mechanically or by solution, extraction or decomposition".

When confined to this definition of the technical requirements of packaging, glass containers are arguably the natural medium for food and drink. Among its characteristics, glass is chemically inert, i.e. it does not react with the contents and, secondly, it is impermeable to gases and liquids. On commercial criteria, too, the fact that the raw material is cheap and readily available strongly favour glass. It is, however, when one considers the marketing merits of glass vis-a-vis other containers that the disadvantages arise. While glass scores over cans on being reusable, resalable, distinctive and attractive, it loses out to the can, principally, on being heavy and breakable. The glass and can manufacturers frequently produce almost interminable lists of the merits of their container and cite contradictory evidence on consumer preferences. Essentially the situation is that glass and cans enjoy unique characteristics which ensure each a permanent stake in the market place, but that the share monopolised by glass would be considerably greater if a lightweight, 'unbreakable' bottle could be devised. It is the reconciliation of these two opposing criteria that is really the kernel of glass container innovation.

<u>Innovations In Glass Containers</u>

As initially formed glass is probably some twenty times stronger than steel, but it soon acquires flaws which reduce that strength to 1% of its original. To produce a glass with only 10% of its primal strength would thus give a container ten times stronger than that currently in use. Present technological developments would realistically aim to raise the strength to 5% of its original. The emergence of the modern can, which is very light but strong, was originally responsible for highlighting this drawback of glass (a disadvantage further exploited by plastic).

A dramatic contribution to strength and abrasion-resistance has been made by surface treatments. Since 1945 a tin oxide coating, somewhat ironically, has been steadily developed which strengthens glass appreciably. The tin coating applied (as a 'hot end' treatment) becomes part of the glass and cannot be removed by normal washing. Lightweighting has had the greatest physical impact on the milk bottle (from 20oz in the 1930s to 8¼oz in 1970s). The assult by the can on the take-home beer and soft drinks market made the application of this process to this area a matter of urgency in the 1960s. The large weight reductions made possible by the tin oxide coating have effected significant savings in the material and transportation of glass containers. It was this cost-saving which made possible the introduction of the lightweight 'one trip' soft drinks bottle in 1966 and, subsequently, the disposable beer bottle. Somewhat paradoxically, lightweight bottles are often less prone to breakage than the heavier types because their surfaces have not become scratched and weakened by handling as with multi-trip bottles.

Despite their considerable progress in lightweighting, the glass container manufacturers seem to accept that the can enjoys decisive advantages in the take-home beer trade (cidar excluded); while continuing to defend their declining share of this market, the glass container manufacturers seem to feel that developments in lightweighting have far greater potential for repulsing the can in the soft drinks market.

Lightweight one-trip bottles have been introduced with considerable success in this sector. A variation on the usual lightweighting theme, and an innovation with the technical and marketing appeal to counter the can, is the "Plastishield" bottle. This is a lightweight glass bottle shrink-wrapped in a pre-printed plastic sleeve. Introduced in the US in 1972, over 50% of all large sized carbonated soft-drinks are now packed in this way. Developed by Owens Illinois, the bottle was launched in the UK by United Glass in 1978. A host of advantages can be cited for the "Plastishield" bottle including the insulating properties of the sleeve. Of decisive importance may be its eye-catching appeal.

Apart from lightweighting, beer bottle innovations have sought to counter the can by mimicking its easy-to-open facility. When the one-trip beer bottle allied to the twist-off closure (in place of the traditional crown closure) failed to succeed, the glass container manufacturers turned to more visible technical novelty. A variety of new types of closures have been tested, four of which have been introduced. The "Rip-Cap" ring pull opener, an American innovation of the 1960s by American Flange, has been adopted by Rockware Glass for their widemouth beer bottle (another innovation). The "Maxi-Cap" supplied by Metal Closures is a similar tear-off device obviously aimed at offering the "intrinsic satisfactions" of the easy-open can. A somewhat different easy opening device is the "Seidel Seal" developed in Germany in 1978. This has the advantage over the "Rip-Cap" and "Maxi-Cap" of no sharp continuous edge caused by the scoring. Being a side-opening closure, it has the advantage over the can of not squirting the contents upwards (into the face) if opened after shaking. Another closure innovation has been the "Twist-Off Crown Closure", while in addition to the wide-mouth bottle a variety of other bottle shapes have been tried, such as the 'dumpy'.

Costs

Not only must the glass manufacturers devise a container to capture the imagination of the beer and soft drinks producers, but must also demonstrate the cost-competitiveness of their product against the can. Although there is considerable disagreement on the relative cost positions of the bottle and the can there is general consensus that the bottle offers a significant bought-in economy for the filler, some or all of which is subsequently lost due to slower filling speeds in particular and higher handling costs in general. The following analysis, although commissioned by the glass container manufacturers, appears to be the most objective available.

TABLE II*

## A. Material Costs

Breakdown of Typical Glass Bottle Price

| | | per '000 |
|---|---|---|
| Bottle: | 10oz No Deposit | £19.00 |
| Crown: | | 1.20 |
| Label: | 4 Colour | 0.60 |
| | | £20.80 |

Outer packaging 24 bottles in six pack multi-wrap (neck through) with shrinkwrap; multi-wraps @ £18.00 per '000.

Total Unit Cost 2.44p

Breakdown of Typical Can Price

| | | per '000 |
|---|---|---|
| Can: | Standard 2 Piece Tinplate | £25.50 |
| | Printed 4 Colours | |
| | Aluminium Ring-Pull End | 4.60 |
| | LESS 4% Rebate | 1.20 |
| | | £28.90 |
| | | Equals 2.89p each |

Outer packaging 24 cans in six pack "Hi-Cone", shrink wrapped in shallow tray; trays @ £32.40 per '000.

Total Unit Cost 3.16p

## B. Cost Calculations

Data used to produce 'Typical Answer'.

| | Bottle | Can |
|---|---|---|
| Capital Cost of Line | £348.5K | £444.25K |
| Depreciation & Interest | 20% p.a. | 20% p.a. |
| Line Speed | 600 p.m. | 1000 p.m. |
| Manning Levels | 16 | 12 |
| Operating Line Efficiency | 55% | 60% |
| Maintenance Costs p.a. | £80.0K | £60.0K |
| Container Losses | 1.85% | 2.0% |
| Product Losses | 0.35% | negligible |
| Distribution Distance | 100 miles | 100 miles |

| In-Brewery Costs | Bottle p. each | Can p. each |
|---|---|---|
| Goods Inward | 0.020 | 0.015 |
| Packing Line | 0.586 | 0.417 |
| Finished Goods Handling | 0.031 | 0.023 |
| Distribution | 0.145 | 0.105 |
| Overheads | 0.280 | 0.275 |
| | 1.062 | 0.835 |

* P.E.'s Typical Packaging Cost

| | Bottle p. each | Can p. each |
|---|---|---|
| Material | 2.440 (70%) | 3.160 (79%) |
| In-Brewery Cost | 1.062 (30%) | 0.835 (21%) |
| | 3.502 | 3.995 |

* Source: P.E. Management Consultants

These figures would possibly be broadly accepted by the filling industry. There are a number of reasons why the economics indicated by the figures have not been decisive in influencing investment decisions. One of the most potent reasons will be the proven efficiency of UK canning lines when operating at very high speeds, whereas UK bottle filling lines do not measure up well by international standards.

The different performance of the UK canning and bottling industries reinforces the importance of the relationship between industrial structure and technical change. Glass container production depends for economy, like the can, on continuous production in large quantities. The fragmentation of the bottling industry has militated against long runs on one bottle and flexible filling lines, at the expense of speed, have been the order of the day. In recent years, rationalisation has given more scope for automated high output lines.

Similarly, unlike the can-manufacturing industry, the glass container industry is traditionally fragmented; severe internal competition has made for low margins without the concentrated surplus available for investment as in the case of Metal Box. Since about 1960 mergers have significantly reduced the number of firms and the glass container industry is now dominated by United Glass, Rockware and Redfearn National Glass. This has improved the scope for large scale investment and innovation. These factors should make for keener price competitiveness against the can, reinforcing the trend in raw material prices in favour of glass.

## Food

The role of the glass jar in the food area is worthy of note even though in the UK the can virtually monopolises the thermally processed food market. Only about 1% of processed fruit and vegetables is packed in glass in the UK, compared to more than 30% in some European countries. Further, Britain is unique in having a strained baby food market which is not dominated by glass. Not surprisingly, therefore, the glass industry feels that the processed fruit and vegetable market is an area where the glass jar could go on the offensive against the can.

One of the major differences between glass and tinplate is that one is transparent (usually) and the other opaque. This may be viewed either positively or negatively. The glass container industry would emphasise the opportunity glass offers for eye-catching appeal, but a major drawback is that the higher standard of presentation required increases food processing costs.

There are two major obstacles to a successful penetration of the processed food market by glass. The first is the inadequacy of packaging and processing technology in the UK as regards glass containers for food. The second is the declining state of the market anyway, with tight margins, cut-throat competition and very little advertising of the end product. The glass manufacturers would no doubt argue that a glass container might be the development to stimulate this market by replacing the 'anonymity' of the can.

## Conclusion

The role of glass container developments on the nature and course of technological progress in the can industry has not been anywhere near as influential as that of aluminium. The glass container industry has, like the can industry, been steadily improving the speed and efficiency of their machines. The industry has, however, been either unwilling or unable to marshal its resources to counter the assault on its markets by Metal Box. Given the relative shares of the can and the jar, glass can only increase its market share, though there is no evidence that the can manufacturers view this prospect with any alarm.

In the beer and soft drinks market the major influence of glass on the can industry is in cost-consciousness. There is little if anything the can manufacturers are able to do to counter the product advantages of the glass container as regards visual appeal, and the emergence of a very strong but light bottle seems only a matter of time. The strategy of the can-makers in fending off a successful reprisal from glass will be in exploiting the superior canning technology vis-a-vis bottling technology.

vi. Other Competitive Packages

Aluminium and glass are not the only alternatives to the tinplate can. Plastic and fibreboard may both be formed to offer a similar rigid construction as a can.

Plastic

Plastic has been the object of the greatest speculation as regards its potential to replace the open-top can. However, despite perennial predictions of a plastic take-over in packaging, the material's main impact has been in creating its own markets and, also, in displacing glass. A plastic can suitable for carbonated drinks was introduced in the UK by Plastona (John Waddington Ltd.) in 1973 but seems to have disappeared without making any impression. This container combined a single-piece body and a spun-on metal end. Cadbury Schweppes were first to adopt the can for their product 'Zing'. Although the fears regarding plastics' ability to replace the can have proved unfounded, the material is so versatile that it cannot be underestimated. If an economic alternative to the tinplate can were to be developed in plastic, its impact would undoubtedly be significant. The world's major packaging companies recognized the potential threat of plastics by diversifying into the material.

Fibreboard

Fibreboard and composite cans have been another area of speculation but, like plastic, have tended to create their own markets rather than to replace other packaging.

Aerosol

The aerosol differs from other containers examined in this section in that it is usually made of tinplate. The aerosol has principally attacked the markets of the glass container, notably in toiletries, whilst the aerosol has also been used in the US as a food dispenser (mainly for whipped cream, desserts, sauces and the like) but does not appear to have been so employed in the UK.

Retortable Pouch

Although the retortable pouch is usually made of either aluminium or plastic, this type of container is worthy of a mention in its own right. Interest in the retortable pouch has been increasing in the UK, particularly since the introduction of aseptic canning. The pouch does offer several advantages over the tinplate can; it requires less cooking time than the can and this improves the flavour and reduces processing costs. The pouch has the disadvantage of somewhat slower filling speeds and requires more secondary packaging. It is, however, easier for the packer to store and it provides transport economies. It scores heavily regarding energy costs in its production; the energy needed to produce a 16oz pouch, including the outer carton, is 3,015 kilo joules (KJ) per container. By comparison, the 16oz three piece tinplate can is 5,276 KJ. While the retortable pouch will never replace the can, it will find increasing uses in areas where the can is an alternative.

4. Complementary Developments

i. Overview

In considering the role of technological change from an inter-industry perspective the question of complementary developments arises.

The study of the impact or repercussions of innovation beyond the focal industry is usually associated with very major developments such as the railways, electrification or computerisation. Such investigations often take the form of 'multiplier' or 'accelerator' type analyses and seek to explore the labyrinth of industries which build up around major innovation in the form of firms supplying or serving the focal industry, or using its waste products, or simply living off the income which is earned in the focal industry but re-spent on other goods and services. Schumpeter and Kuznets both drew attention to what might be termed non-apparent complementary production; it is simple, for example, to relate the production of records to record players but often more difficult to causally relate less connected activities. Electrification, for example, contributed to the house-building boom of the early twentieth centry as people sought to go 'all electric' in their houses. Similarly, another major innovation, the motor car, also contributed to house building as people desired garages adjoining their homes.

In dealing with developments at the level of can-making such grandiose connections do not arise; in this sector the concern is with only one type of production which directly complements the open-top can and which is therefore a contributory factor in the success of can-making innovations. The specific complementary production involved is that of secondary packaging.

ii. Secondary Packaging

Secondary packaging that is used on the can may be split into two categories; in the first instance there are those types of outer packaging intended principally to protect and transport the can prior to sale, eg. palletisation, and secondly there is the secondary packaging employed for marketing purposes eg. 'multipacks'.

Palletisation

Palletisation was essentially an American development to overcome the mammoth transportation problems of the second World War. The innovation which made palletisation possible was the fork-lift truck. Prior tothis development units which could be man-handled were needed. Initially can-makers used the box pallet but this was replaced in the 1950s by the now familar Busse pack in which the cans are stood vertically on a wooden pallet base and overwrapped.

The contribution of the Busse pallet has been in fast, reliable, adaptable packing and in reduced handling costs. The innovation of palletised cans is not of great interest in this study because it is not inter-dependent with other can-making innovations.

Packing Filled Cans

The packing of filled cans has changed considerably during the post-war period, partly due to the requirements of can-making developments. The traditional way of packing cans is in a fibreboard or corrugated case, of which there are three main types:

a. Top Loaded Casers: the original top-loading system was the 'rolling can caser'. This system created a certain amount of seam-to-seam damage resulting in denting of the can near the end seam. The introduction of lighter thickness tinplate and aluminium cans highlighted this limitation. These innovations consequently stimulated the development of casers in which the cans are fed on end and not rolling. These vertical can casers feed the cans into rows onto assembly platforms from which they are loaded directly into cases. This has the advantage of being quieter but it is more expensive.

b. End Loading Casers: in the 1960s end loading casers were developed because they require up to 30% less board for a given size and therefore offer a price advantage.

c. Wrap-around Casers: this development of the late 1960s assembles cans in pre-arranged loads and wraps them round with fibreboard or corrugated scored blanks, which are automatically tightened or sealed. This method saves cost and also makes for slightly smaller cartons.

Shrinkwrapping

Shrinkwrapping was not initially suited to cans because it still allowed movement within the pack. The invention in 1969 of a special round-cornered tray as a base for assembling containers prior to shrinkwrapping overcame this problem, allowing the polythene shrink films to form a snug fit. The round-cornered tray with shrinkwrapping has a number of advantages over the alternative shrinkwrapped fibreboard case:

a. The pack greatly facilitates handling particularly at the retail stage because:-
    1. the shrinkwrapped tray forms a convenient display and sale unit.
    2. the case is easy to open.
    3. the complete trayload can be put directly onto the supermarket shelf after removal of the shrinkwrap.
    4. the tray is easy to dispose of.
b. A substantial cost-reduction in the outer material is possible.
c. The transparency of the pack allows easy identification without the need for labelling or external printing.
d. Can damage and pilferage is reduced.
e. The weight reduction is substantial.
f. A degree of space-saving through the closer bulk stacking which is possible.

As regards the inter-dependence of can-making innovations, shrinkwrapping was not only facilitated by lighter tinplate but also by the necked-in can which does not have the protuding chime at each end.

Multipacks

Multipacks, often shrinkwrapped, have made a significant contribution to the success of the easy open can in penetrating the beer and soft drinks market. This is of more marketing than technological significance and discussion is consequently deferred until the following chapter.

5. Summary

The canning industry, the final link in the manufacturing chain of tinplate, can-making and canning, does not exhibit the same intricate interplay of technological forces as was found in the case of the preceding two industries. There is a lack of the technological stimulus - response type relationship so in evidence at the tinplate and can-making stage. The canning industry does not appear to force the pace or set the tone of technological developments on a manufacturing-to-manufacturing level as has been found in other areas of the study, most notably the tinplate/can-maker relationship. The reason why the canning industry has not conformed to the role found in other 'user industries' elsewhere in the study lies in the historical development of the industry catalogued in earlier chapters and, in particular, the dominant role of Metal Box in that development. To secure its own can-making business, it will be recalled, it was necessary for Metal Box to take the lead and itself diffuse the art of canning technology, a role which it still performs through its Customer Technical Services with many canners today. This burden which Metal Box took upon itself created a situation where the UK can-making industry, in the form of Metal Box, did not require the sort of customer input found elsewhere. It is probably because Metal Box has been so well grounded in all areas of canning technology that the usual supplier-user interplay at the manufacturing level has not been a pre-requisite of can-making innovations. One feels that Metal Box has been able to follow a technological development through without recourse to customer knowledge and experience because they themselves are in many cases the accepted authority on can usage as well as can-making. The case of the aluminium industry is the most striking example of the impact of a new technology on established industries. Since 1960 aluminium has been making a sustained attack on the American can at the expense both of the tin and the steel industry. The competitive challenge by aluminium has been a primary, and in America perhaps the primary, factor in determining the rate and, in particular, the nature of technological developments in the tinplate and can-making industry. Whilst the goal of a light-weight steel can has existed since Appert's times, it has been the threat of aluminium which has given the search for 'thin tin' its overriding urgency since 1960. The steel industry has been anxious to prove that tinplate is not lacking in areas in which it was originally considered that aluminium enjoyed inherent advantages. In addition to reducing the weight of the conventional can, the steel industry has demonstrated that traditional can stock is compatible with the most demanding of drawing technologies. It is interesting to note that the one area where aluminium has eclipsed tinplate is in the easy-open feature. Although steel easy-open ends have been made they do not appear to enjoy any widespread commercial use. One feels that the explanation why aluminium has not been technologically countered in this area by tinplate, as it has in every other can usage, is that the aluminium end of itself does not pose any threat to the existence of the tinplate can, as the aluminium two-piece appeared to do. Whilst the tinplate makers would no doubt like to see aluminium repulsed in this area also, the success of the bi-metallic can of steel body and aluminium end removed the urgency which has been such a feature of the struggle for dominance in drawn container technology.

In the UK aluminium was not perceived as an immediate threat to tinplate because the price differential between the two metals was considerably greater than in the US. This potential threat produced the same quest for thinner steel and lighter tin coatings in the tinplate industry to try to ensure that technological advances by the aluminium manufacturers did not erode this differential. The actual competitive struggle to establish aluminium as can stock is only a recent feature of the UK situation. With no home-based aluminium interest to contend with Metal Box was under no pressure to pioneer aluminium can stock. Consequently there is a consistent pattern in the UK of delayed adoption concerning aluminium. The development work for the aluminium can and ring-pull end was undertaken in North America. Metal Box did not adopt the aluminium easy-open end until the evolutionary phase of the development cycle had been completed and the now familiar integral rivet type perfected. A similar 'wait and see' strategy was adopted with the two-piece can. It is interesting to note that the conditions which gave rise to the aluminium can were absent from the UK. Although the aluminium can has been adopted it is difficult to perceive of it ever having emerged from the UK.

One of the most interesting questions now facing the domestic can industry is whether to use tinplate or aluminium as can stock. The respective interests are both able to cite technical and product considerations, but nowadays their importance is probably exaggerated. The drawn container technology is now at the point where one can say that the future ability of aluminium to replace tinplate in the can market will depend almost exclusively on the price and availability of both metals.

The glass industry contrasts markedly with the aluminium industry in that the former has been forced onto the defensive by tinplate. It has been seen that the UK glass container industry has differed from the can industry for most of the post-war period as regards industrial structure; the experience of each tends to strongly suggest that competition between the major glass manufacturers and the low profit margins obtained have restricted their willingness or ability to devote their resources to a strategy of innovation, as in the case of Metal Box. The glass container industry influences the pattern of innovation in can-making by creating cost-consciousness and also by offering product competition, though in both instances the initiative has rested with the can industry for most of the post-war period. While it is a natural competitive response for the glass industry to try to imitate the success of the ring-pull can end, the crucial technological requirement from a competitive perspective is the development of a very lightweight but 'unbreakable' bottle. A decisive factor in the ascendancy of canning over bottling has been the all-round technical superiroity of the former in the UK. Consumer evidence on container preferences is unreliable and unconvincing. Unless consumer preferences are voiced more loudly in the market place the food and drinks manufacturers will continue to decide whether we eat and drink from glass or metal containers. So long as this is the case the superiority of canning technology is likely to be decisive.

While glass and, in particular, aluminium are examples of real competitive pressures which lie outside the parameters of the can-making industry, they are not what we understand, in the Schumpeterian sense, of 'new men' and new firms arising out of new technologies. When Schumpeter argued that the real threat came from completely 'new combinations' he probably did not have in mind innovations from within traditional industries, but new products and processes which threaten the very existence of whole industries and do not strike only at the margins, as in the case of competition in the traditionally accepted sense.

No new technology has actually materialized to threaten the existence of the can, but the metal container industry has always been aware of the possibility, some would say overly conscious of it. It has been mentioned earlier that tinplate has been written off as a packaging material with monotonous regularity; the international packaging companies have protected themselves against the threat of new packaging technologies by diversifying into the new areas. This to some extent has undermined the Schumpeterian concept of the 'new thing' as the most potent form of competition, but it has not invalidated it. Within the international, diversified packaging company each section, such as the Open Top Group in the case of Metal Box, stands or falls by the success of its own particular product, irrespective of the investment portfolio of the Company as a whole. For this reason the 'new thing', or the threat of it, exerts the same commercial pressures in the market place even though it is not accompanied by the emergence of new firms in the traditional idea of capitalistic evolution. It has been plastic which has been the subject of the greatest speculation in packaging during the post-war period, not least from within Metal Box, and although the regular predictions that plastics will take over have never come to pass, the predictions themselves are evidence enough that the threat of plastics, and the other new packaging materials mentioned, has to some extent served the 'competitive' function of which Schumpeter wrote. The new technology has had precisely the effect that Schumpeter predicted in other areas of the innovation system. The tin producers and the tinplate makers are not in a position to protect themselves from a new material by diversification. For this reason the threat of TFS and aluminium, for example, exerts on the tin and steel producers - despite their monopolistic situation - a pressure to perform to the highest technical and commercial standards which we associate with the traditional idea of competition.

The success of the open-top can has been enhanced by complementary developments in secondary packaging. Secondary packaging is, of course, a distinct area and its development has not been dependent on the progress of the can. The can makers and users have, however, adopted secondary packaging wherever it has been advantageous to do so. Somewhat fortuitously a number of tinplate and can-making innovations such as thinner tinplate and necked-in cans have enhanced the compatibility of the can with some forms of secondary packaging.

## 6. Conclusion

It is clear from this chapter that the rate and direction of technical change within can-making is to a considerable extent determined by forces outside of the can makers' control. These are primarily competitive pressures at the technological level, initially, to which the can-maker must offer a technological response; while competition in the traditional neo-classical sense rarely has a cataclysmic effect on established industry, new technologies do have this potential. The knowledge that one's very existence is at stake from new alternatives and not just the margin, which is prey to every transient commercial breeze, is why technical advance is the lynchpin in the industrial strategy of established industries. It is an awareness of the possible repercussions of an alternative technology which fuels technical change in traditional technologies, in an attempt to pre-empt any such breakthrough.

REFERENCES

The background information to this Chapter has been compiled from a review of the relevant technical and commercial periodicals (see references Chapter II). Information on the aluminium industry has been supplemented by in-house material provided by Alcoa. Information on glass container developments has been drawn from discussions with the management of United Glass Ltd., and from in-house material supplied by United Glass, Redfearn National Glass and by Rockware Glass.

REFERENCES - CANNING TECHNOLOGY


1. Voiril, F. et al "Fruit and Vegetable Processing", Food Processing Industry, August 1962, pp 27-43.

2. Slade, F. H. "Food Plant Layout", Food Processing & Marketing, February, March and April 1968.

3. Anon "Canning Equipment", Food Manufacture, February 1958, pp 49-61.

4. Anon "Canning Machinery", Food Manufacture, August 1960, pp 334-350.

5. Dickson, D. "Canning and Freezing", Food Manufacture, April 1960.

6. Dickson, D. "Fruit Vegetable Canning and Quick Freezing", Food Manufacture, March 1956.

7. Anon "Cans for the Canning Industry", Tin and its Uses, Nos. 63 and 64, 1964.

8. Masterson, D. C. "Canning and Quick Freezing Machinery", Food Manufacture, November 1966.

9. Uthwatt, T. A. "Equipment and Production Lines - 150 Years of Canning", Times Review of Industry, August 1960.

10. Anon Food Industries Manual, 20th Edition 1969.

11. Anon "A-Z of the Tinplate Can", Tin International October 1974.

12. Adam, W. B. "Research and Horticulture - 150 Years of Canning", Times Review of Industry, September 1960.

13. Tattersall, G. "Quality Control - 150 Years of Canning", Times Review of Industry, September 1960.

14. Holdsworth, S. D. "Dehydration and Canning", Food Manufacture, November 1969.

15. Bonnet, Ch. et al "Proceedings of the Fifth Int. Congress on Canned Foods", Vienna 1967, C.I.P.C. Pass.

16. Cuthbert, T. J. L. "Food Sterilisation", Food Trade Review, 1957.

17. Uthwatt, T. A. "Recent Developments in Canning Machinery", Food Manufacture, August 1962, Vol. 37, Part 8, pp 365-370.

# CHAPTER VII

# THE ROLE OF THE MARKET

## 1. Introduction

This study has attempted to gain a deeper understanding of the nature and role of technological change by examining it within an industrial framework. The factors which give rise to innovation and the way in which these changes impact on the economy have been viewed at the manufacturing level from an inter-industry perspective. In examining the competitive aspects of the innovation system the role of the market as the mechanism through which competitive pressures operate has been largely by-passed. One has to be aware, in examining innovation within an industrial context, of the role of external pressures in shaping the rate and direction of innovative activity. The purpose of this chapter is not to extend the analytical framework to include these 'exogenous' factors, but to briefly introduce them in the way of qualification. Without such qualification there is the very real danger of asserting cause and effect relationships between technical change and market performance which seriously misinterpret the role of 'technological push'.

In this section it is sought to illustrate the role of market forces in the progress of canned food, not by a thorough examination of the growth and change in canned food consumption*, but by a general look at the post-war trends and, secondly, by highlighting a number of specific areas where both technological and market forces may be seen to combine in determining the commercial success of a particular canned product.

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* For those interested, official Government Statistics may be used to chart the progress of virtually each and every canned product from almost every conceivable angle.

## 2. Socio-Economic Factors

The increased demand for canned food is part of a trend to pre-packaged and convenience foods in general throughout the post-war era. Convenience foods are defined by the National Food Survey Committee "as those processed foods for which the degree of preparation has been carried out to an advanced state by the manufacturers and which may be used as labour-saving alternatives to less highly processed products". A number of socio-economic factors have combined to produce the growth in convenience foods.

The Second World War accelerated the already growing acceptance of prepared foods by increasing the penetration of this form of food across a broader strata of society. In some instances this exposure retarded consumer acceptability, as in the case of dried eggs, but the concept of prepared food in general benefited greatly.

There is a mild social stigma attached to convenience foods, in particular an implication that their use for anything but snacks suggests an inadequacy in traditional domestic skills. Similarly, convenience food, and canned food in particular, is associated with inferior and less nutritious produce. Heavy and effective promotion of convenience foods in the media have succeeded in overcoming, to a large degree, these prejudices against canned food; of importance also, and it is impossible to quantify the contribution of each, has been the technological advances in cans, particularly lacquers, which have virtually eliminated some of the harmless but unsightly problems with certain canned produce.

Increasing post-war affluence has reduced the dependence on staple foodstuffs and increased the variety of foods consumed. Again, however, technical progress in food processing and manufacture has reduced the real cost of canned food. The increase in the number of working wives, due partly to earlier marriages, has helped to make convenience foods a necessity in many households as the time that is available to spend in the kitchen is greatly reduced. The increasing emphasis on leisure has also reduced the inclination of people to prepare elaborate meals; television watching in the home has also favoured the growth in quickly preparable meals and snacks in particular. The trend to compact high-rise flats in the 1950s and 1960s created domestic conditions suitable for convenience foods.

In addition to domestic circumstances, the changing pattern of wholesale distribution and retail selling have favoured the growth of prepared foods. The increasing cost of labour generally means that distributors can afford less and less handling, particularly at the point of sale. Goods must be packed for sale by mass production methods wherever possible. This packaging makes self service at the wholesale stage through 'Cash and Carry' possible for most goods. The enormous growth of 'multiples' since the war and the domination of the grocery trade by the 'big five' would have been impossible without growth in packaging; the two are now mutually reinforcing. The growth in concentrated, high choice retailing which allows economies in purchasing and management was itself dependent on socio-economic changes, primarily car ownership.

3. <u>The Market for Canned Goods</u>

i. <u>Human Foods</u>

After consistent post-war growth in nearly all areas, demand for many canned foods is now static or actually declining.

a. Fruit and Vegetables: the major canned products are beans in tomato sauce and processed peas, followed by garden peas. The rest of the processed vegetables sector is made up of an increasingly wide range of produce. To combat the levelling off of demand in some traditional canned produce, manufacturers have introduced new packs such as French beans, butter beans and various pasta products. The introduction of new potatoes has revived a failing canned product and certain small volume products, such as mushrooms, have shown high growth in the 1970s. The majority of canned fruit is imported to the UK from South Africa and Australia, with relatively small amounts of home-grown fruits such as strawberries accounting for UK output.

b. Milk: the market for traditional condensed and evaporated milk is a relatively static area. The success of certain other milk-based products, particularly puddings, has somewhat compensated. Rice pudding must be the product most suited to canning; it takes only a few minutes to prepare compared to the hours of preparation required for home-made rice pudding. The food manufacturers have introduced aseptic canning for milk-based products in order to gain a significant marketing advantage; this does not appear to have materialised.

c. Soup: soup is another instance of rapid early growth thanks to large scale advertising by the major companies. This growth has now levelled off partly due to the introduction of dehydrated packet soups.

d. Meat: canned meat has not traditionally offered a large outlet for the domestic industry, and is not considered to be a potential growth area. The food processors have turned to 'ready meals' to revitalise this area; these include traditional

English meals such as 'grills' but also exotic dishes such as curries, bolognaise and Chinese foods. Vesta are the market leaders in this field with a variety of dehydrated foods. Harveys (Cadbury/Schweppes) attempted to incease their share of this market with the innovation of the divided can "Duo Can" in 1968, particularly suitable for curries and spaghetti bolognese. The major barrier to establishing these products as large can users is the conservative eating habits of the British, though the food companies have had considerable success in this area in the last ten years.

e. Fish: fish makes up only a very small part of the UK canned food output, demand is mainly seasonal.

f. Baby Food: the baby food market is a very interesting area in the context of this chapter because its development has been surrounded by a variety of socio-economic and market forces in addition to the technological input of Metal Box, discussed earlier.

A major influence on the baby market in general is the birth rate. The 'baby boom' of post-war years reached a peak in 1964 with 876,000 babies born in England and Wales; by 1976 there were only 583,502 or 11.9 births per thousand, this was well below the previous lowest level of 14.4 per thousand in 1933.

The canned baby food market comprises strained and junior foods. Heinz introduced imported strained foods in 1937, but UK production did not start until 1947. The market grew quickly to 7,500 tons by 1953 with Heinz accounting for over 90% of sales; other firms in the field on a smaller scale were Trufoods (with glass jars), Brands and Robinsons. Heinz introduced junior foods in early 1958.

Baby feeding habits are an emotive area; to maximize the market potential it was necessary for Heinz, by subtle promotion, to influence pediatric theory and traditional domestic ideas on baby care.

Heinz apparently believe that the key to success in the baby food market is variety on the premise, no doubt, that mothers equate this with a balanced diet. The 1947 range originally consisted of six varieties; when Heinz introduced three types of junior food ten years later the strained range had increased to twenty-one. By 1964 Heinz offered sixty-one varieties; by 1977 this had increased to 102.

Nestle, Libby's, Batchelors and Scotts all attempted at various times to gain a foothold in the strained baby food sector only to subsequently withdraw. Trufoods remained into the early sixties as Heinz' only real competitor, offering a range of thirty-five varieties packed in jars but at a significantly higher price. Robinsons persevered with their lever lid cans, and Cow and Gate entered the market in tins. In 1962, obviously having gained advanced warning of the impending entry of the Gerber Corporation to the UK baby food market using glass jars, Heinz introduced a range of twenty-four strained and junior foods in glass jars. Heinz' commercial thinking at this time was that it was inevitable that their 95% share of a market worth £7½ m. p.a. would attract the entry of a rival large firm. They also reasoned that a determined challenge from Gerber, who at the time accounted for 55% of the US baby food market, could conceivably halve Heinz market share if each Company were to offer an alternative container. Heinz believed it made more commercial sense to accept the inevitability of effective competition but to try and contain it by also offering baby food in jars rather than be drawn into price competition with Gerber. Within two years Gerber held 13% of the market, though Heinz retaliated vigorously with a resulting drop in Gerber's share to around 9%.

TABLE I*

Canned Baby Food Market %

| 1962 | | 1966 | | 1975 | |
|---|---|---|---|---|---|
| Heinz | 95 | Heinz | 83 | Heinz | 75 |
| Others | 5 | Gerber | 13 | Gerber | 18 |
| | | Others | 4 | Cow & Gate (Unigate) | 7 |
| | 100 | | 100 | | 100 |

* Source: Retail Business

With the decline in the birth rate from the second half of the 1960s Heinz sought to counteract a decline in sales by extending the age range of babies using canned food and, secondly, by the Company's policy of increased varieties. As a result, the market continued to grown from £15.7 m. in 1966 to £28.3 m. in 1974, though by 1974 the market was declining slightly in volume terms - partly because of the then current medical fashion of advising mothers to keep their babies on milk for a longer period.

Whilst Gerber have remained wedded exclusively to glass, Heinz continue to favour cans, their filling lines for jars are, in fact, worked substantially below capacity. Some of the disadvantages claimed for jars are that exposure to light causes the vitamin content to diminish, jars are breakable, fragments of glass can get into the jar on the production line (to offset this manufacturers have to ensure that the jars undergo a technically advanced process which ensures that no foreign body or piece of glass is in the jar). To overcome criticisms that it was difficult to lever off the lid on glass jars, Gerber introduced the twist-off cap. The perceived disadvantages of the can are essentially emotive and suggest anachronistic prejudices against the metal food container die hardest in the area of the baby food. Evidence has shown that 60% of mothers have a strong preference for glass; reasons offered are safety, cleanliness and aesthetic appeal. In addition a jar of baby food does not have to be consumed in one go, but can be stored opened in the 'fridge' for up to two days.

A critical area in the success of baby food is in the retail outlet. In the early 1950s more than two-thirds of strained and junior baby food was sold through chemists; by the mid 1960s the situation had completely reversed with sales through grocers amounting to 70% and those through chemists only 30%. This trend was again turned round due primarily to the efforts of Boots, the most successful retailer in the baby products market.

TABLE II*

Sales of Strained and Junior Baby Foods 1977

| | % |
|---|---|
| Boots | 32 |
| Other Chemists | 15 |
| Grocery Outlets | 53 |

* Source: Retail Business

The grocery trade, faced by a falling birth rate, has tended to devote less and less space to baby products, principally resulting in less variety in baby foods. This has been counter-productive because of the pre-occupation of mothers with a balanced diet for the infant. Secondly, young mothers are very time conscious, not least due to the constraints placed upon them by the child. They are therefore increasingly opting to buy all their baby's requirements at one time in the same retail outlet; Boots identified, responded to, and capitalised on this need. A second problem with grocers has been that, despite the good mark-up on baby foods, retailers consider it to be a labour-intensive commodity. To overcome these merchandising problems both Heinz and Gerber have a colour-coding system. Heinz' varieties are labelled blue (for strained) and red (for junior). The labelling also ties in with the two-tier price structure - white is used for cheaper varieties and yellow for the more expensive. Thus individual cans do not have to be marked. The colour key used by Gerber distinguishes between strained and junior varieties and separates the Gerber range into three meal-time segments: dinners, tea-time savouries and desserts.

The growth of the baby food market is a testament to the ability of a Company to influence social thinking by subtle, some would say subliminal, advertising. The recent sharp decline in the baby food market is evidence of an inability to continue to offset the effects of a falling birth rate. The canned baby food market appears to be a case of successful market growth for many years without a single innovation of the type discussed in earlier chapters to promote that growth. It must be remembered, however, that in the forty years since the introduction of canned baby food in 1937 the price of the final product increased to only about three times that of pre-war days. This is probably the lowest rate of price increase of any household food item. Innovations in tinplate and can-making and food processing are partly responsible.

In the future the increased use of the innovation of the domestic food mixer will contribute to what will probably be a continuing decline in the prepared baby food market. The two-piece baby food can, when Metal Box finally overcome their considerable development problems, may affect the respective market shares of Heinz and Gerber but is unlikely to have the marketing appeal necessary to bolster a flagging market.

ii. Pet Food

Pet food, first introduced in the inter-war years, has risen from a small base in the early 1950s to become the biggest single type of canned product. Pedigree Petfoods, who reintroduced canned pet food to the UK after the war, is the biggest single user of cans. In 1954, the first year in which figures were recorded separately, output of canned pet food was 56,000 tons, by 1976 this figure had risen to 603,000 tons. Pet ownership in the UK is about 5½ million dogs and 5 million cats.

The alternative to prepared dog and cat food is fresh food, scraps or milk. Whilst consumption of prepared pet foods has been rising dramatically, consumption of the alternatives has hardly changed.

## TABLE III*

Consumption of Pet Foods ('000 tons)

| | 1960 | 1975 | % Incr. |
|---|---|---|---|
| Prepared | 227 | 631 | 177 |
| Fresh | 153 | 156 | 2 |
| Scraps & Milk | 533 | 568 | 7 |

* Source: Retail Business

The reasons for the preference for prepared pet food is that prices have increased much less markedly than those of fresh, and that the increase in use of convenience foods in general has reduced the availability of scraps, i.e. canned pet foods success is to some extent a spin-off of prepared human foods. From a marketing perspective, two important factors have been T.V. advertising, which is ideally suited to pet food, and the introduction of varieties, which now account for more than 30% of all canned dog food sales. Pet owners, like mothers, appear to equate diversity of flavours with a balanced diet. The growth of multiples has also suited the retailing of pet food; 85% of pet foods are sold in grocers against 7% in pet shops. Over half the sales through grocers is accounted for by multiples, principally Tesco, Cavenham, Sainsbury and International Stores.

The only hiccup in the growth of canned pet food was the imposition of a 20% purchase tax in 1969. The prepared cat food market remains substantially canned, whilst dry and semi-moist alternatives packed in paper bags and boxes have had some limited success in the dog food sector since their introduction in the 1970s. These products are likely to pose an increasing challenge in the future because they contain a higher proportion of cheaper, plant-based proteins and also because the trend in packaging and processing costs is likely to disadvantage cans and canning against the dry and semi-moist alternatives. However, as long as the pet food canners continue to offer a nutritious and competitively priced product, there is every prospect that their growth will continue to be amongst the highest of any canned food.

iii. Beer

A small Welsh enterprise, Felinfoel, reserved itself a place in brewing history when it became the first Company to introduce canned beer to the UK in 1936. Production ceased during the war and the wax-lined, cone-top beer can did not make a reappearance until 1952. In 1954 the cone-top can was replaced by the now familiar 'flat-top' but the serious introduction of domestically canned beer to the UK market did not start until 1956 when the beer can was adopted by some of the leading UK brewers.

The perceived success of the beer can in the early years depends to some extent on how the figures are interpreted; beer can sales, including imports, rose from 42 million in 1956 to 147 million in 1960; whilst this represents a large increase, it is from a very small base. During this period total beer sales were rising significantly and canned sales as a percentage of total sales remained between 1-2%. In terms of the forecasts of canned beer sales made in 1956 this performance was very disappointing.

There were a number of reasons why early beer can sales failed to match expectation. The post-war trend in beer consumption up until 1958 had seen a swing towards bottled beer. The brewers had predicted this trend and expected it to continue as affluence increased. However, in the late 1950s the British drinker confirmed his traditional price consciousness by a revived preference for draught. Canned beer was at the time about three old pence dearer than bottled, a premium which the beer drinker was reluctant to pay. A second reason why canned beer did not 'take off' from the outset is that promotion was aimed at the upper income groups of the middle aged, one of the most conservative segments of society.

From early experience it became clear that there were two distinct beer markets - the public house and the take-home trade. It was also increasingly clear that the can could not compete in the public house against the bottle because the return and reuse of the glass container was virtually 100%, making the throw-away can hopelessly uncompetitive. It was therefore evident that the success of the can depended on its ability to create new demand in the take-home trade and, secondly, to displace the bottle as far as possible in the same market.

A key factor in the success of the beer can was its rate of adoption, or diffusion, amongst the breweries. The mass production of cans for beer could not even be considered until post-war restrictions on the use of tinplate were lifted, which came about in 1952. By this time many brewers had invested large sums of money in bottling equipment. There was a natural reluctance to write-off this investment unless there was strong evidence from the market of a preference for the can over the bottle; this was not the case in the early years of canned beer. Further, each can sold represented up to two pence less profit to the brewer than a bottle so there needed to be good reasons for the brewers to co-operate in the advance of canned sales if it meant the loss of bottle sales. The canning of beer spread quite widely in the early years but, with it accounting for such a small precentage of total sales, production at each individual brewery must have been somewhat nominal.

TABLE IV*

Diffusion of Beer Canning 1956-60

| Year | No. of Brewers | Types of Canned Beer |
|---|---|---|
| 1956 | 14 | 32 |
| 1957 | 19 | 32 |
| 1958 | 36 | 100 |
| 1960 | 43 | 120 |

* Source: Retail Business

In the 1960s the beer can continued its steady but unspectacular growth. It has been since the widespread adoption of the super ring-pull end between 1967 and 1970 that the beer can (along with soft drinks) has become the major growth area in canning.

## TABLE V*

### Trends in UK Beer Consumption 1960-1972

(mn barrels)

| Vol. | | Index | % Lager | % by Package Draught | Bottled | Canned |
|---|---|---|---|---|---|---|
| 1960 | 27.5 | 100 | 2 | 64 | 34 | 2 |
| 1961 | 28.6 | 104 | 3 | 64 | 33 | 3 |
| 1962 | 28.3 | 103 | 3 | 66 | 31 | 3 |
| 1963 | 29.5 | 107 | 2 | 67 | 31 | 2 |
| 1964 | 29.9 | 109 | 2 | 68 | 30 | 2 |
| 1965 | 30.4 | 111 | 3 | 68 | 30 | 2 |
| 1966 | 31.3 | 114 | 3 | 69 | 29 | 2 |
| 1967 | 31.5 | 115 | 3 | 70 | 28 | 2 |
| 1968 | 32.2 | 117 | 4 | 71 | 26 | 3 |
| 1969 | 33.5 | 122 | 4 | 71 | 26 | 3 |
| 1970 | 34.9 | 127 | 5 | 73 | 23 | 4 |
| 1971 | 36.1 | 131 | 8 | 73 | 22 | 5 |
| 1972 | 36.6 | 133 | 9 | 73 | 21 | 6 |

* Source: Retail Business

This trend is more clearly illustrated if sales of draught beer are excluded.

TABLE VI*

UK Market for Packaged Beer (Million Gallons)

| | Bottled | Canned | % Canned |
|---|---|---|---|
| 1964 | 332.6 | 19.2 | 5 |
| 1965 | 329.3 | 22.5 | 6 |
| 1966 | 324.1 | 23.9 | 7 |
| 1967 | 314.7 | 27.6 | 8 |
| 1968 | 293.2 | 34.8 | 11 |
| 1969 | 275.3 | 43.3 | 14 |

* Source: Retail Business

The impact of the easy-open end is further illustrated if we take the case of the 10oz can, which was the growth area in beer cans at the time.

TABLE VII*

Annual Percentage Increase of 10oz Beer Can Sales

| Year | % |
|---|---|
| 1964 | 8 |
| 1965 | 55 - introduction of tab pull opener |
| 1966 | 14 |
| 1967 | 45 - introduction of super ring-pull |
| 1968 | 45 |
| 1969 | 28 |
| 1970 | 30 |

* Source: Retail Business

From the analytical perspective of this chapter, the central question is to what extent socio-economic and market forces may be identified as alternative explanations for the rise of the beer can since the innovation of the ring-pull end.

Most of the socio-economic factors mentioned earlier such as increased leisure time and home entertainment (T.V. watching) may be discounted because they are a general post-war influence. This is largely so with the ownership of 'fridges, which has been cited as a contributory factor in favour of the can. The trend to lager consumption, particularly amongst the less conservative younger drinker, has favoured the easy-to-cool can. The relaxing of UK licensing laws in 1961 may seem somewhat dated to be significant, but it is the case that the new law was applied sparingly for many years. It is irrefutable that the increased sales of beers by licensed supermarkets have contributed to the growth of packaged beer since the mid 1960s. The total number of supermarkets grew from 3,500 to 4,000 whilst those with off licenses increased from 295 to 650. A further complication is the introduction in 1967 of the breathalyser law which, if it stimulated drinking at all, will have done so in the take-home sector.

In addition to the socio-economic variables there are the more market-orientated pressures; these seem to offer the credible alternatives to the stimulus of the easy-open end. In earlier chapters when considering the interaction of technological relationships at the manufacturing level the role of complementary and competitive forces was discussed; these are further factors to be taken into consideration at the market level.

As regards complementary developments the complication of note is the innovation of multi-packing. These have been introduced in two main alternatives, the Hi-Cone plastic shrink-wrapped hoops which secure a number, usually four, of cans together and, secondly, the paper-board containers such as "Cluster-Pak" and "Jak-et-Pak" which are used for bottles as well as cans. Multi-packing is an inducement to buy in bulk; for this reason it suits supermarket merchandising. It has decorative and display advantages in the case of paper board, is convenient for carrying and, inevitably, leads to a higher turnover of canned drink.

Watney Mann introduced the "Jak-et-Pak" in 1966 but is is impossible to isolate its effects from other factors.

TABLE VIII*

Index of Sales of Canned Beers by Watney Mann

| | |
|---|---|
| 1965/66 | 100 |
| 1966/67 | 130 - "Jak-et-Pak", plus price cut |
| 1967/68 | 189 - Introduction of ring pull |
| 1968/69 | 340 |
| 1969/70 | 406 |

* Source: Retail Business

A price reduction can never be discounted, so the only guide is to rely on the opinion of Watney Mann who believe the impetus to sales in the above years was due significantly to the multi-pack.

The success of the can in displacing the bottle in the take-home beer market brought a competitive response from the glass container manufacturers in the form of lightweight, one-trip bottles, new closures and, somewhat later, new bottle designs. Such repercussions are different from the other forces discussed in the chapter in that they counteract rather than complement can-making innovations. Herein consideration is restricted to the one-trip bottle. This offers similar mechandising and consumer convenience as the can, but was dependent upon the development of lightweight bottles to make it economic. In challenging the convenience aspects of the can the one-trip bottle sacrifices the traditional advantage of glass as returnable and re-usable. Again, socio-economic factors such as high-rise flats had been reducing the 'trippage' of returnable bottles throughout the post-war era (particularly noticeable with milk bottles). Further, people were increasingly feeling that it was not worth the trouble or embarrassment, in many cases, of reclaiming the deposit. The first one-trip beer bottle was introduced by Whitbread in 1961 but was withdrawn without success two years later. When re-introduced in 1966 the one-trip bottle met with some success and by 1971 it accounted for 2.1% of packaged beer sales. It is a matter for speculation whether this success was at the expense of the can or the returnable bottle; what is sure, however, is that it failed to check the growth in beer can sales in the 1970s. By 1978 the take-home market accounted for 9.5% of all beer sales with cans dominant; 'one-trips' accounted for 10% of sales.

## 4. Conclusion

This chapter, in stepping outside the central focus of the study at the industrial level, has identified a variety of socio-economic and market forces which have all influenced the development of canned food. This chapter has demonstrated that in studying the impact of an innovation on the growth of an industry it is not possible to isolate the effects of the innovation from those of other casual phenomena. The question therefore arises of whether the innovations in tinplate, can-making and canning were indeed crucial in the post-war development of canned foods, or were they merely a necessary response to the pull of demand? The analysis seems to argue that the innovations were crucial because most of the socio-economic forces uncovered favoured concenience foods in general and not canned foods in particular. It was the competitive role of technical change in deciding to which form of packaging would go the spoils that one must attribute its vital function. It must be remembered that some of the socio-economic changes, such as 'fridges, favoured convenience foods other than canned. Clearly, market forces and technical change both had their role to play and it will never be possible to quantify the contribution of each because, as we have observed, it is not possible to disentangle the effects of each. Measurability is not, however, always important or even necessary; the evidence still allows one to present a case for the dominant role of technical change. In the effect of the ring-pull for example, one could cite international comparisons to show its global impact. Similarly, one can to some extent discount many of the market complications in assessing the value of the ring-pull end by reference to the soft drinks market where it was also accompanied by dramatic sales results.

Perhaps the main value of the chapter, however, has been that it has illustrated the difficulties that face the researcher in general, if he tries to establish cause and effect relationships in any conclusive sense. The lesson from this study would seem to be that before such relationships can be safely identified one must be sure that all the relevant phenomena have been considered in the study of most things of importance. It is probably the case that the analytical frameworks required would be so panoramic as to be unmanageable.

# REFERENCES

The marketing information in this chapter has been pieced together from various primary sources, from official Government Statistics, and from the editions of Retail Business over a twenty-five year period. Additional bibliographical sources are as follows:


1. "Packaging and Industry", Financial Times Supplement, January 21, 1957.
2. "International Drinking Habits", Discussion Paper No. 7, Incpen., 1978.
3. "Baby Market 1977", The Grocer, July 23, 1977.
4. "The Nursery Market", E.I.U. Special Report No. 50, 1978.
5. Mills, R. "Price Trends in Packaging Materials", The Brewer, February 1978.
6. Dudley, K. "The UK Market for Cans", Packaging Review, May 1971.
7. "UK Food Industries Review 1975-1976", Gower Economic Publications, 1977.

# CHAPTER VIII

# SUMMARY AND CONCLUSIONS

## 1. The Theoretical Perspective

This study has attempted to contribute to the burgeoning literature on a 'theory of innovation' by probing the nature and role of technical change from an inter-industry perspective. Understanding of the character of innovation, the factors which give rise to it, and the consequences or effects of innovative behaviour, is at present still very much superficial and impressionistic. The level of understanding of technical change reflects the way in which economists have treated the subject; despite a general recognition of the importance of technical change to economic progress, economists have tended to either treat the subject on a piecemeal basis - often subsumed within a number of different theories - or, more recently, considered it as an 'exogenous' or 'residual' factor. The way in which innovation has been dealt with in post-war Growth Theory, in particular, has been increasingly criticised. It has been argued that the lack of any distinct theory of technological change restricts the development of our understanding of the process of industrial development. Critics of growth economics have argued that a theory of technological change can only be developed from case studies of the history of inventions and innovations in different industries.

In the past two decades such studies have been forthcoming and they have been the foundation of, and contributed immensely to, the development of a theory of innovation. Whilst the case study methodology has been invaluable in providing an empirical base for the formulation of abstract hypotheses, it is important to recognize that the methodology which they have employed and the types of innovations which have been chosen for study may bias the perception of the nature of technical change.

Case study material has tended to focus on the salient innovations (such as the float glass process) and, particularly so with US studies, concentrated on what might be termed 'glamorous' or high technology type industries such as scientific instruments and aerospace. Other studies which have been undertaken in more traditional industries have tended to focus on innovations with an obvious or drametic product dimension such as the case of Porvair in the footwear industry. Studies of process changes in traditional industries have similarly been biased toward the revolutionary development, such as in the case of tufted carpets.

This understandable, and perhaps inevitable, bias in the selection of innovations to be studied, and the typical case study approach which focuses on an innovation in isolation, has encouraged the perception of technical change as a dramatic and disruptive force in industrial development. This study has argued that such innovations are the exception rather than the rule and that technical change is predominantly a process, a stream of minor and incremental changes, with only occasional radical upheavals. Given this hypotheses, it is argued that the case study 'snapshot' approach is inadequate; to understand technical change one must examine the process over time for an industry by detailed enquiry. It is important, however, that within the industry approach the investigation is not restricted by conventional industrial classifications. It is necessary to recognize that change in one area affects another, and may produce a competitive or complementary response; for this reason an inter-industry or systems perspective is required.

It is further believed that innovation per se, i.e. the commercial exploitation of something new, may not be particularly relevant from the view of economic progress. It is a fact that the overwhelming majority of 'new' products and processes are commercial failures, hence the very high risk factor in enterprise business. Innovation, it is argued, owes its real significance in the extent to which it is adopted or imitated. It is important, therefore, for an understanding of the nature of technical change that the inter-industry perspective should include the diffusion process. Studies of innovation which restrict themselves to the innovating firm only tell a small part of the story of an innovation.

To test these hypotheses this study has attempted, by detailed historical enquiry, to trace the development of a traditional industry - can-making - through the medium of the technical change which has taken place therein. It has sought to relate this innovation, in terms of the reasons which brought it about and the effects which it generated, to developments in associated industries, principally being the tinplate and canning industries but also the competitive industries of alternative packaging. It has sought to relate the role of innovation in can-making to that in complementary activities and, finally, to qualify the part played by technical change in industrial development by reference to wider economic and socio-economic factors.

The essential methodology of the study has been to "follow the innovations". To identify and examine technical change at the very minor and incremental level of process developments a thorough understanding and exposition of the technologies involved has been necessary. The source of this information has been a month by month review of the technical and commercial publications of the steel processing, metal manufacturing, food processing and food packaging industries covering a thirty year period. Such a review has also served to develop a historical perspective of the development of an industry at the technological and manufacturing level.

## 2. Technological Change As An Evolutionary Process

In testing the hypotheses that innovation is essentially an on-going, evolutionary process this study has been inconclusive. Such a characteristic of technical change has undoubtedly been found to be so in the case of the can-making industry. The development of can-making from a craft through to a mechanized and, finally, a largely automated industry has been so incremental and continuous as to be almost imperceptible. The analysis has demonstrated that the humble art of can-making has been a hot-bed of innovation, albeit for the most part minor, since the birth of the industry in 1810.

In the case of the tinplate industry, however, a stream of minor changes did not appear to be a characteristic of technical change, particularly since the development of hot-strip rolling in the 1930s. Technological change in the tinplate industry (and also the steel industry) is typically associated with periodic, large scale changes in the methods of production. These changes are accompanied by large capital outlays on new equipment, the installation of which tends to be disruptive by nature. The development of the industry can be traced using the adoption of major innovations as the reference point. In the days when steel production was a growth industry these major technical changes were often accompanied by the opening of entirely new plants, or major expansion to existing ones. The evidence of the tinplate trade is such that one cannot claim that all industries support the hypothesis that technical change is essentially an on-going evolutionary process. In the case of tinplate the opposite is, superficially at least, true.

Despite this, the detailed examination of the post-war development of tinplate making suggested that the major innovations which had been adopted were the manifestation, or exploitation, of a host of continual minor advances in the engineering industries; progress in mechanical, electrical, chemical, electro-chemical, and electronic engineering underlay the changes in tinplate technology. Electrolytic tinplating is an example of a major innovation which drew heavily on all the branches of engineering so as to overcome a problem unique to the tinplate industry. It is perhaps precisely because some industries such as tinplate are characterized by enormous items of plant that it is not commercially viable to modify processes on an on-going basis. It is, however, interesting to note that subsequent diffusion of each innovation was characterized by increased performance as reflected in physical measures of line speeds etc. This indicates the improvement of processes on an on-going basis but which cannot be realized until the major capital outlay necessary for a new piece of equipment is justifiable.

In summary, then, the study has not proved that technical change is essentially evolutionary, but it has demonstrated that minor, incremental change is certainly a large element of the innovation process and as such warrants serious academic consideration.

In attempting to analyse the contribution of minor innovation to economic welfare it is not realistic or possible to attempt a comparison of the effects of large scale change in the tinplate industry against small scale change in the can-making sector. However, the comparatively major and supposedly cost-saving innovation of the two-piece can does lend itself to comparison with the benefits of the on-going development of the three piece. The detailed physical measures, and also the operating data of Metal Box, would seem to prove conclusively that the continuous, minor, incremental innovation in conventional can-making technology has made a consistently significant contribution to economic progress, whereas the technical progress of the two-piece can has made a dubious contribution - to date at least - and in some cases a negative one, to human welfare in the only meaningful way in which the can-maker can measure it, namely the price of the can. Given the claims of the innovating firms, this is a most important and illuminating finding; it would provide an interesting exercise to examine the benefits of accumulated minor change against radical change in a number of industries. This is perhaps a subject which warrants further academic investigation.

## 3. Innovation As A Complex And Diverse Phenomenon

The hypothesis that innovation is a complex and diverse process whose causes and consequences cut across traditional ideas of industrial groupings was the basis of the inter-industry perspective adopted. Technical change in can-making has been examined as part of an innovation 'system' which included the supplying and using industry, complementary and competitive activity, and also wider economic and socio-economic factors. At the technological level the tinplate and can-making relationship was very useful in understanding the interactive role of the two industries in technical change. Indeed, the course of technical progress in one industry cannot be understood without an appreciation of its effect on the other. In a somewhat different context, the role of innovation in generating change across industrial boundaries was also seen in the case of steel technology where a chain reaction or 'ripple effect' was seen to go right through the steel-making industry to the ore carriers, deep sea terminals, and sources of supply.

It was at the commercial level, though, that the value of the inter-industry approach was most apparent. In the case of the tinplate industry this manifested itself, primarily, as a competitive struggle to defend its markets against the encroachment of the aluminium industry. The continual trend to thinner steel plate and to lighter tin coatings was an attempt to keep the cost of the base material the same in proportion to the overall cost of the can. Although the tinplate industry is in a monopoly situation, its whole technical and commercial strategy was aimed at maintaining the competitiveness of its product. The role of technical change in the tinplate industry and the pressures which exist to remain competitive cannot be understood without an appreciation of the relationship with can-making, and the options open to the can-maker to substitute steel or tin, or both.

In the case of the can-making industry the inter-industry dimension is important from both a competitive and a complementary view point. In the historical analysis of the development of the industry in the nineteenth and first half of the twentieth centuries commercial relationships were not apparent. In the post-war analysis however, which was based mainly on primary sources, it was these commercial factors, and the way in which they were related to technical change, which was paramount. The examination of can-making and related activities had served to illustrate the interdependence and 'action-reaction' nature of industrial innovation at the technological and manufacturing level. The examination at the commercial level, focusing as it did particularly on the changing industrial structure, served to illustrate the interactive nature of technical change in terms of the stimuli to innovation and the effects which it generated; these effects were primarily seen to be 'defensive' technical change or, to a lesser extent, supporting complementary developments. The course of technical change in can-making is determined by the commercial relationships which underlie the industry. These relationships, or pressures to innovate, came primarily from outside what is traditionally understood to be the source of competition. The competitive relationships which affect commercial, and therefore technical, behaviour in the can-making industry were seen to include the steel industry, aluminium industry, glass container industry, plastics industry, tin industry, and also the food processing industry. These pressures exist irrespective of the structure of the can-making industry; for this reason, whilst it was demonstrated that industrial structure has an influence on innovative performance, any analysis which seeks to explain innovative behaviour by reference to the presence or absence of 'competition' must not restrict the perspective to the popular or traditional notion of competition as a function of the number of firms supplying a particular product. Alternative suppliers are important to innovative behaviour in that they are one of many sources of competitive or commercial pressure acting upon the firm which ensure that it strives to improve the quality of its product and to maintain constant cost proportions. Technological innovation is one of the ways in which the firm attempts to improve the competitiveness of its product by reducing the physical unit of input per unit of output, and by making the finished article more attractive to the customer.

The inter industry, or systems, perspective was also valuable in attempting to assess the role of technical change in industrial development. This analysis has posited the question of what was the contribution of a particular innovation to the development of an industry and, secondly, what was the role of technical change in general, in the longer term, in industrial development? The examination has shown that, at any one time, there are so many factors to be considered that it is extremely difficult to establish the contribution of a particular innovation to some subsequent change. In the case of the ring-pull can adoption with Watney-Mann, for example, which was followed by market growth, it was not possible to isolate the role of this change from that of complementary developments and from other commercial changes. At the general level, by including within the analytical framework wider socio-economic factors, it was apparent that it was not possible to establish, in any definitive cause and effect way, the role of technical change in the development of the can-making industry. This finding was reinforced by the analysis of the 'role of the market' which introduced further complicating factors in the development of canned food. It is possible to conceive of this quandary as personified in a round-table discussion of the various functional departments of an innovating firm debating the reasons for some recent commercial success; the marketing man might well cite the role of his salesmen as being crucial, the production man the role of his team in meeting output and delivery targets, and the technical man, perhaps, the cost-reducing effect of some innovation. In one corner might be the 'fly in the ointment', possibly an Accountant, qualifying his colleague's claims by reference to fortuitous or external factors outside of the Company's control which had a bearing on the success of the product.

It would appear then, that the innovation system is complex and diverse and that to understand the nature of technical change a broad analytical framework is necessary. The difficulty in citing cause and effect relationships in any definitive way may be applicable to academic research in a more general context, perhaps the best that can be achieved is an identification of 'association' between cause and effect.

## 4. The Significance Of Diffusion In The Innovation Process

This study has attempted to show that innovation owes its significance to diffusion, that the rate and extent of diffusion is determined by the attractiveness of an innovation and, secondly, by the extent of the capital outlay required to adopt it and, further, that the diffusion process will encourage defensive innovation in the product or process being replaced.

To say that an innovation owes its significance to the extent to which it is adopted may seem so self evident as to be considered a truism. In terms of the long term development of industry or the workings of the business cycle it is, however, fundamental. By being the source of the increased supply of the innovatory product, the reduction in its real price and, in aggregate, the creation of the consumer bonanza associated with that phase of the business cycle where further investment opportunities are temporarily exhausted, the diffusion process is the mechanism by which innovative effort generates an improvement in human welfare. However, it is not in this grandiose role that diffusion is examined in this study; here the concern has been primarily with minor, incremental innovation on an on-going basis and not the major technical changes which are argued to generate the business cycle. The extent to which an innovation is diffused is important in this context, too, precisely because one is dealing with minor developments. Even though a small process change, for example, may not in isolation contribute dramatically to the cost of the final good, it may be considered an important innovation, within the context of the industry, if it is widely diffused.

The simplest measure of diffusion is the number of firms within an industry who adopt an innovation; this is of limited use in the context of the tinplate and can-making industries because of their monopolistic and oligopolistic structures. A more applicable measure is the percentage of output accounted for by an innovatory product or process. However, when one is dealing with minor changes this information is not usually available simply because it is not recorded within the industry. In the case of a major innovation, such as electrolytic tinning, it was possible to monitor, year by year, the percentage of electrolytic tinplate to total production. However, it remains the case that many, if not the majority, of the minor changes to the method of can manufacture have achieved total diffusion throughout the industry; this is particularly evident when taking the long term perspective and comparing the heavy, unwieldy, "open with a hammer and chisel" can of the nineteenth century with the super-light, easy-to-open can of today. Even comparing the cone-topped, wax-lined, paper labelled, three-piece, chimed, beer can of thirty years ago with the flat-top, lacquered, lithographed, two-piece, necked-in can of today reveals the same universal diffusion. Alternatively, there have been many minor innovations introduced with a view to providing particular properties for specific end-use; this accounts for the co-existence of a wide selection of tinplate and can-types. These innovationary products, such as double-reduced or differential tinplate, were never intended to replace all other tinplate finishes, and for this reason it is unrealistic to measure their success in terms of their production as a percentage of total output.

The hypothesis that diffusion will encourage defensive innovations in the product or process being displaced and thus serve to prolong, perhaps indefinitely, the latter's life was found to be the case in a number of instances. The clearest example was that of hot-dipped tinplate which managed to "hold-out" against electrolytic tinplate for over thirty years by virtue of process innovations of its own. Various tin-less steels, and TFS in particular, are a classic illustration of the response from the traditional product being stronger than the challenge of the new; tinplate has, in commercial terms, "seen-off" a variety of alternative materials which when introduced appeared to have decisive advantages. A variation on this theme is the competitive struggle of the three-piece can against the two-piece. The three-piece has remained competitive by unashamedly imitating many of the features of the two-piece such as all-round lithography. The three-piece has also benefited from the technical advances, particularly in the quality and composition of the steel plate, which were developed with a view to their application to two-piece technology only.

The hypotheses that the rate of diffusion would be determined by the attractiveness of the innovation to potential imitators and, secondly, by the extent of the capital outlay required to adopt it was, again, open to limited verification by the monopolistic and oligopolistic nature of the principal industries. However, in the case of the tinplate industry it has already been seen that, because of the large capital outlays required, it was necessary to accumulate, in abeyance as it were, potential innovations until new plant and equipment was justified. In the case of the can-making industry it has been argued that Metal Box perceived the large capital outlays necessary for two-piece technology as a barrier to entry to the industry and that, indeed, in the case of Reads Ltd. and their Northfield Project, the large capital outlay involved dissuaded the Company from taking the risk of investing in two-piece technology. The two-piece can is the only innovation on which it is possible to draw conclusions as to the 'attractiveness' of a new product or process as perceived by a potential imitator. In this instance it has been argued that, while the new technology was attractive in itself in that it removed the art and mystique from can-making, the only relevant consideration was the commercial one, i.e. is it a source of profit?

## 5. Physical Measures As An Indicator Of The Impact Of Innovation

This study has postulated that the best measure of the effect of an innovation is the physical changes which it is intended to bring about. Consequently, the study has attempted to reflect the impact of innovations by recourse to physical measures; the material reducing effect, the speed of output, the relationship between physical units of input and physical units of output are examples of such measures. These are considered much more acceptable than monetary measures. It has fortunately been possible to indicate throughout the study the effect of technical change in terms of physical measures; this has been particularly valuable as an indicator of the effect of minor, incremental innovation when accumulated over time. The benefit of tinplate innovations in terms of the steel plate, the level of tin coating and the speed of output have variously been used to illustrate the dramatic success of the industry in reducing material input while increasing the rate of output consistently throughout the post-war years. By showing a cross-section of tinplate prices for particular types of tinplate product the economic impact of these innovations is clearly visible in the sliding scale of charges which is used.

In the case of the can-making industry the underlying effect of can-making innovations is reflected in a continual reduction in the cost of producing a can in terms of physical inputs per unit of physical output. This is due to a reduction in both the labour and capital input per unit of output, due to material saving innovations, and to constant increases in the speed and efficiency of production. In terms of economic impact, the container has lost none of its properties as a method of food preservation and in respect of price, the can has managed to absorb many of the increases in material cost to which it has been subjected.

## 6. Summary

This study has attempted to contribute to an understanding of the nature of technical change by examining it from an inter-industry or 'systems' perspective. Mainstream economics has failed to give serious consideration to the role of technical change in industrial development and contemporary studies of innovation as a separate theory have been based on the case study approach. Case studies are an insufficient empirical base for the development of a theory of innovation because, by their nature, they are biased toward the revolutionary or radical change and, to a lesser extent, are concentrated in the 'glamorous' or high technology industries. This study argues that innovation is essentially a process, a stream of minor and incremental changes, and that in order to fully understand it one must adopt a historical perspective and observe the phenomenon by detailed enquiry over an extended period. To understand the on-going nature of technical change it is appropriate to examine it within a traditional, staid, industrial setting. The choice of subject - the UK can-making industry - reflects this hypothesis.

This study has found that the superficially unexciting activity of can-making has in fact been a hot-bed of innovation, albeit for the most part minor and incremental, since its inception in 1810. It has also been found that although the tinplate industry is apparently characterized by major innovations, the nature of the industry is such that on-going changes to processes is not possible; the important finding is that it is the on-going advances in engineering in general upon which these occasional, radical changes are based. The evidence from the study indicates that accumulated, minor innovation has made a consistently significant contribution to human welfare in terms of the can's true purpose as a safe and inexpensive medium for food and drink.

The inter-industry perspective adopted, incorporating firms supplying the can industry or using its output, and those engaged in competitive or complementary activities, has shown that for an understanding of the nature of innovation, the factors which give rise to it and the effects that it generates, a broad analytical framework is necessary. This has been found to be the case at both the technical and the commercial level. Investigation of the stimuli to, and effect of, innovation has concentrated on the interdependence of industrial processes and the role of commercial pressures on the firm. The most important conclusion from this analysis is that it is competition in its widest sense, and not the immediate industrial structure in which one is operating, which is the main stimulus to innovation. The inter-industry perspective has also shown the complexity of factors surrounding innovation and industrial development and suggests that claims of definitive cause and effect relationships between innovation and industrial development should be avoided.

The study has argued that innovation owes its significance to diffusion and that the best measure of the success of an innovation is the extent to which it is adopted. It has been found, however, that whilst this may be true and applicable in terms of industrial evolution in general, it must be qualified when dealing with specific innovations. Whereas widespread adoption of a minor process change indicates a valuable innovation in the context of the industry, the industrial structure may be such as to devalue this measure. Further, many important innovations, again in the context of a detailed industrial analysis, may not be intended to be widely adopted or to displace alternative processes.

Finally, the research has shown that physical measures as opposed to monetary ones, are best suited to assess the significance of technical change, particularly so when one is trying to convey the importance of accumulated, minor changes.

## 7. The Limitations Of The Research

Whereas the can-making industry may be considered to be a typical, traditional British industry it is necessary to evaluate the findings with regard to that industry's peculiarities. It is obviously important to consider its unusual, and perhaps unique, position in being dominated for so long by one firm. This monopolistic feature has limited the usefulness of the analysis of diffusion, this being compounded by the concentration of tinplate production in the post-war period under the umbrella of the British Steel Corporation. Similarly, the domination of tinplate and can-making by two firms has restricted the boundaries of the inter-industry framework; whilst this has served to make the system more manageable, it may be that in a more complicated industrial labyrinth the observed causes and consequences of innovation may appear significantly different.

A further limitation, from an inter-industry perspective, is that the food and beverage can has proved itself to be such a self-contained entity that the concept of complementary production as an important variable has proved somewhat fruitless. Again this has helped to keep the system manageable, but it may mean that what is possibly a very important factor in innovation in most industries appears peripheral in the case of can-making.

Finally, the ubiquitous role of Metal Box in general and the Company's omnipotent role in the development of the UK food canning industry in particular must surely be unique. The all-round expertise of Metal Box in the technology of tinplate manufacture, can-making, and food processing must inevitably have distorted the relationship which might normally be expected to exist between suppliers and users. In the case of the food processing industry it has completely undermined the role of the consuming industry in influencing technical change in the supplying industry.

## 8. The Need For Further Research

It follows from the above that to put the findings of this research into perspective it would be useful to have similar hypotheses examined within a different industrial framework. Such study would need to be within a traditional industrial setting but contain an assortment of firms in the focal industry, with a wide range of suppliers and with an aggressive consuming industry.

To establish the respective roles of radical and minor innovations there is a need for further historical analysis of industrial development over time or, at least, the compilation of registers of the innovative record of industries. Further study is needed to establish the differences in innovative behaviour between highly capitalised industries and those with a low financial threshold with a view to assessing whether in fact capital intensity restricts on-going change.

The relationship between industrial structure and innovative behaviour, although relatively well researched, offers scope for continued study, particularly the hypothesis that competitive pressures to innovate will exist irrespective of the immediate industrial structure.

In subsequent research there would seem to be a strong case for testing the appropriateness of physical measures as the best indicators of the impact of innovation; a specific study of the role of technical change in affecting the relationship of physical inputs to physical outputs would seem particularly appropriate.

It must be remembered, however, that suggestions on the need for research in particular areas should not distract from the need for industrial studies in general into the process of technological innovation.

APPENDIX

INNOVATION IN THE FOOD PACKAGING AND PROCESSING INDUSTRIES.

RESULTS OF A POSTAL QUESTIONNAIRE

## INTRODUCTION

The data collection exercise in which you have participated is part of a three year study into technical change in the processed food and beverage can industry. The study aims to contribute to the theoretical understanding of the nature and inter-industry implications of technological innovation. The base of any such investigation must be a register of the new products and processes which have been introduced.

## METHODOLOGY

Compiling such a register has been a fundamental problem in similar past investigations. One important conclusion from foregoing studies has been the need to eliminate bias as far as possible by approaching independent sources. This was the methodology successfully adopted by the Science Policy Research Unit, University of Sussex in their "Report On The Role of Small Firms Innovation in The United Kingdom Since 1945".

The SPRU study attempted to compile data on innovations in industries comprising 66 3-digit Standard Industrial Classification 'Minimum List' Headings. The investigation did not include the industries probed in this exercise. SPRU adopted a two pronged approach to their problem; they initially contacted non-manufacturing organizations and individuals with special knowledge of each relevant branch of industry, this source included technical journals, research associations, trade federations and academic institutions. When the responses from these groups were collated the Unit then endeavoured to check the factual content by writing to each firm listed as responsible for an innovation and asking them to confirm whether they had in fact made the innovations, to check the date, and also to provide some supplementary information such as number of employees which was related to the Unit's specific objectives. The response rate for both phases of the exercise was good, but particularly so in the second instance when over 90% of queries were answered. This response rate is phenomenally high for such a postal data collection exercise, it was on the basis of this success that the SPRU methodology was adopted as a blue-print for this particular study.

The food processing and packaging trade directories, which appeared to cover all those classes of organizations approached by SPRU, were initially consulted so as to identify potential sources. A pilot study was undertaken consisting of what was considered the ideal independent sources, based on the description of their interests given in the directories. This pilot included in particular consultancy firms and research establishments. The response rate of over 50% from this selection was considered very satisfactory - but the information provided was inadequate. A number of consultants who replied stated that the specific area of interest in question lay outside their own particular specialisation; in most cases these respondents suggested a more appropriate source. The major problem with the quality of the response from the pilot was in the high degree of repetition; the sources tended to supply details of what were evidently the salient innovations in the industries.

It would seem to be the case that SPRU methodology, while suitable for eliciting the major developments, was far less appropriate for an in-depth study of any one particular industrial grouping. It was decided, therefore - on the basis of the evidence from the pilot - to abandon the two tier approach and to contact the manufacturing organizations, again listed in the directories, from the outset. It was fully realized that this would introduce bias in that each respondent would be most familiar with his own company's innovations. It an attempt to offset this problem to some extent, an equal number of small and large firms - determined on subjective criteria - were selected for approach.

The second major problem in relying solely on these manufacturing units was that it was envisaged that the response rate would drop dramatically. It is far more agreeable to confirm or contradict information than it is to go to the greater effort of preparing it. Further, it was considered that the exceptionally high response rate to the SPRU enquiry from these types of organizations was due to the fact that the exercise carried the authority of the "Bolton Committee of Enquiry on Small Firms" behind it. It was the belief that when writing to manufacturing companies - who receive large amounts of unsolicited mail - it was important to the response rate to identify a particular individual in the organization. A certain amount of effort, mainly telephone enquiries, was expended to identify an individual with a technical background. The point of enquiry was usually director level in the hope that, if initially unsuccessful, the letter would be 'passed down' rather than discarded.

Having regard to the extent of duplication in the pilot survey it was decided to reduce the total size of the investigation from 100 to 50 contacts: as the pilot had initially been based on 1/5th of the sample i.e. 20 contacts, a further 30 manufacturing organizations were broached. It was somewhat surprising that as many as 17 organizations actually acknowledged receipt of the enquiry; of these 17 responses 11 declined to provide information for a variety of reasons, the most usual of which was confidentiality.

In using the one contact method it was not considered realistic to re-approach firms, some of whom had already declined to co-operate, to verify the information about them supplied by another source; this meant that the information provided had to be accepted as correct without any in-built system of clarification. It was possible, however, to check some of the information by subsequent re-course to personal contacts who were involved in other aspects of the overall study. Where this was not possible and two companies have been identified as responsible for the same innovation, a rule of thumb policy has been adopted whereby the earlier accreditation is given preference.

RESULTS

The innovations compiled have been split into three categories, and each listed in chronological order. Category three - miscellaneous packaging and processing innovations - include developments which under a strict definition of the industrial categories initially specified would have been excluded. It is felt that these may be of interest to respondents and are therefore included.

It has not been possible to provide an analysis of the results within the parameters of the exercise but one or two interesting points have been made in covering letters returned with the completed form.

One respondent observed that even those closely concerned with developments cannot usually be definitive as to whether they are 'Innovators'; only when there is close co-operation between the processor and the manufacturer in developing an innovation is it usually possible to be sure that one is involved in the first commercial introduction of something new.

In the context of the can industry - and a feature of innovation which may well be true in a more general context - it was observed that post-war progress has been very much the result of incremental development; this is more often than not a process of applying the wider advances in mechanical, electrical, chemical and electronic engineering to solve the particular problems of the can-maker and, as a result, are difficult to identify as innovations.

A final point on innovation made by a respondent which might be mentioned is that although many of the UK innovations were first applied abroad, these developments are rarely adopted 'verbatim'. Modifications and refinements are such an integral part of the adoption process that a large grey area is created in which it is a matter of opinion whether or not each successive application of a development is worthy of consideration as an innovation. This observation perhaps suggests that a clearer definition of 'innovation' would be helpful.

## INDUSTRIAL INNOVATIONS SINCE 1945 IN UK

| Name or Description of Innovation<br>1(a) Metal Food Container/Machinery/<br>Materials Supplier | Firms First Using or Making: UK | | WORLD (if Prior to UK) | |
|---|---|---|---|---|
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 1. Electrolytic tinplate | 1947 | Richard Thomas & Baldwins (RTB) | 1937 | United States Steel Corp. (USSC) |
| 2. Flat top beer can | 1956 | Metal Box (MB) | | N/A (USA) |
| 3. Decorated processed food can | 1957 | MB | | N/A (USA) |
| 4. 'Differential double seamer' | 1957 | MB | | World 1st |
| 5. Continuous annealing | 1957 | Steel Co. of Wales (SCOW) | 1936 | Crown cork & Seal (USA) |
| 6. Roll-form bodymaker | 1958 | Reads Ltd | c.1910 | American Can Co. (ACC) |
| 7. Self heating can | 1959 | Heinz & I.C.I. | | Possible world 1st |
| 8. Caged can palletization | 1958 | MB | | Possible world 1st |
| 9. 'Two-up' can making | 1959 | MB | 1957 | Continental Can Co. (CCC) |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name or Description of Innovation | Firm First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD (if Prior to UK) | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 10. 7-pint beer can | 1959 | MB | | World 1st |
| 11. Tinplate shipped in coils (export) | 1959 | SCOW | 1957 | N/A |
| 12. LD Steel-making | 1960 | RTB | 1952 | N/A (Austria) |
| 13. Differential tinplate | 1961 | RTB | 1951 | N/A (USA) |
| 14. Differential tinplate can-end | 1962 | Reads Ltd | 1951 | N/A (USA) |
| 15. Tinplate received in coils | 1964 | MB | 1957 | ACC |
| 16. Beer can tab-pull end (aluminium) | 1965 | MB | 1964 | Cantop Inc. (USA) |
| 17. Open coil annealing | 1966 | RTB | 1960 | Lee Wilson Co. (USA) |
| 18. Super ring-pull can end (aluminium) | 1967 | MB | | N/A |
| 19. Double reduced tinplate | 1968 | BSC | 1960 | USSC |
| 20. 'Tin Free Steel' | 1968 | BSC | 1959 | Toyo Kohan Fuji Steel (Japan) |
| 21. Duo-can | 1968 | MB | 1964 | N/A (Italy) |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name or Description of Innovation | Firm First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD (if Prior to UK) | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 22. Jet soldering | 1970 | MB | 1966 | N/A (USA) |
| 23. Tinplate ring-pull | 1970 | MB | | N/A |
| 24. Plug-in can | 1970 | Eisler Consultants | | Possible world 1st |
| 25. Cemented 'Nylon A-Seam' can | 1971 | Metal box | | N/A (Japan) |
| 26. Cemented 'Miraseam' can | 1971 | Reads Ltd | 1965 | ACC |
| 27. Drawn & Ironed tinplate can | 1972 | MB | 1971 | Crown cork & seal |
| 28. Drawn & Ironed aluminium can | 1972 | MB | 1958 | Kaiser Industries (USA) |
| 29. Ultra violet lacquer curing | 1973 | MB | 1973 | N/A (USA) |
| 30. Full aperture easy open can end | 1973 | MB | | N/A (USA) |
| 31. 'Necked-in' can | 1973 | MB | 1965 | N/A (USA) |
| 32. Press-button can end | 1976 | MB | 1975 | N/A (Australia) |
| 33. Draw re-draw can | 1978 | MB | 1971 | N/A (USA) |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK

| Name or Description of Innovation<br>1(b) As 1(a) but no UK details known | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 1. Organic thermoplastic cement first used in place of solder in a can | | | 1947 | (USA) |
| 2. Beaded can | | | 1955 | CCC |
| 3. Aluminium can (oil) | | | 1955 | ACC |
| 4. Aluminium coated tin-free steel | | | 1956 | (USA) |
| 5. 'Margin plating' in can making | | | 1956 | ACC |
| 6. Soudronic welded can | | | 1958 | A.G. Zurich |
| 7. Aluminium coated steel can | | | 1962 | (USA) |
| 8. 'Universal' lacquer - Budium | | | 1962 | Dupont |
| 9. 'High tin fillet' can | | | 1964 | ACC |
| 10. Austenitized steel | | | 1964 | Inland steel Co. (USA) |
| 11. Aluminium coated can by vacuum evaporation | | | 1965 | USSC |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK

| Name or Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| 2. Processors of canned foods & beverages; food & beverage processing machinery manufacturers | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 1. Agitating vacuum process | | | 1946 | (USA) |
| 2. Pneumatic handling of dry matter eg. salt, flour | 1946 | | | |
| 3. Electronic sorting of dry goods eg. pulses | 1947 | | | |
| 4. Canned baby food (strained) | 1947 | Heinz | | |
| 5. Canned hamburgers with gravy | 1947 | Simpson Ready Foods (SRF) | | |
| 6. Anderson Barngrover spiral type continuous cooker | 1948 | | | |
| 7. Hydrostatic sterilisers | | | 1949 | (USA) |
| 8. Metal detection | 1950 | | | |
| 9. Martin Aseptic canning | | | 1950 | (USA) |
| 10. Ultra-high-temperature-short time milk processing | 1950 | Midland Counties Dairy | | |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name or Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 11. Canned pork burgers with gravy | 1950 | SRF | | |
| 12. Concentration with volatile recovery | 1950 | | | |
| 13. Steam peeling of vegetables | c.1950 | | | |
| 14. Treatment of factory wastes - various methods | c.1950 | | | |
| 15. Steak & kidney pie - (flat can) | 1951 | SRF | | |
| 16. Canned macaroni, tapicoa, semolina, sago, ground rice porridge | 1952 | Lemar Foods | | |
| 17. Canning of white rice | | | 1953 | (USA) |
| 18. Cola in cans (screw cone type) | 1953 | | | (USA) |
| 19. Canned custard | 1954 | Lemar Foods | | |
| 20. Canned mince beef with onions/ gravy | 1954 | Lemar Foods | | |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name or Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 21. 'Hydron' hydrostatic cooker | 1955 | | | (USA) |
| 22. 'Flash 18' aseptic canning (liquids) | 1955 | | | (USA) |
| 23. Hot air can sterilisation | 1956 | | | (USA) |
| 24. Simulated meat production by spinning of vegetable protein | 1957 | Pedigree Petfoods | 1942 | Anson Patents (USA) |
| 25. Canned baby food (junior) | 1957 | Heinz | | |
| 26. Canned soft drink - "Suncharm" | 1959 | Benjamin Shaw | | |
| 27. Steam flow closures in seaming techniques | 1960 | | | |
| 28. Use of magnets in can handling | 1962 | | | |
| 29. Sterilising by direct heat ('Steriflamme') | | | 1962 | (France) |
| 30. Canned braised oxtail dinner | 1962 | SRF | | |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name or Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 31. 'Aseptic cartoning of sterile milk packs - 'tertra-pak' | 1963 | Express Dairies | 1961 | (Switzerland) |
| 32. Canned cornish pasty filling | 1963 | Lemar Foods | | |
| 33. Canned snack meals | 1963 | Crosse & Blackwell | | |
| 34. 'Flash 18' - (used for solids) | | | | (USA) |
| 35. Canned pork pie | 1964 | SRF | | |
| 36. Canned curried prawns with rice | 1965 | SRF | | |
| 37. Canned 'surprise' peas | 1965 | Unilever | | |
| 38. Liquid sugar metering ' bulk storage | 1965 | | | |
| 39. Cooking under vacuum in jam manufacture | 1965 | | | |
| 40. Use of clear gel starches | | | 1968 | (USA) |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name of Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 41. Reverse osmosis and ultrafiltration | 1968 | Milk Marketing Board | 1964 | Danish Sugar Corp. |
| 42. Canned ready meals | 1968 | Cadbury Schweppes | | |
| 43. Cooking under vacuum in apple processing | | | 1970 | (Italy) |
| 44. Aseptic custard, milk puddings etc. | 1971 | Heinz | 1960 | James Dole Corp. (USA) |
| 45. Intermediate moisture foods | 1971 | Quaker Oats | 1969 | Purina (USA) |
| 46. Geriatric canned foods "Senior citizen" | 1971 | Heinz | | |
| 47. Canned pizza pie | 1972 | SRF | | |
| 48. Protein separation by ion exchange | 1973 | Ecotech | 1970 | Dalgety (New Zealand) |
| 49. Use of alginates as suspendants and delayed coagulants | | | 1974 | (USA) |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name or Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 50. Automatic time and temperature control and recording during processing | 1975 | Stratford Upon Avon canners/ Taylor Instruments | | |
| 51. Electronic sorting of wet goods | | | 1976 | (USA) |
| 52. Fluidised bed sterilising | 1976 | | | |
| 53. Filtration of air systems by refrigeration | 1977 | | | |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK

| Name or Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| 3. Miscellaneous food packaging and processing innovations | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 1. Shrink wrapping - 'cryovac' | 1955 | | 1948 | (USA) |
| 2. Aerosols for food | | | 1957 | CCC |
| 3. Baby food in glass jars | 1958 | Trufood | | |
| 4. Glass coffee jars | 1960 | | | |
| 5. Plastic soft drinks bottles | 1960 | | | |
| 6. One-trip beer bottle | 1960 | Whitbread | | |
| 7. Light weight one-trip beer bottle | 1962 | | | |
| 8. Shrink wrapped tray system 'kolatarap' | 1964 | MB | | |
| 9. 'Freeze dried instant coffee' "Gold Blend" | 1965 | Nestle | | |
| 10. 'Cluster pak' - for canned beer | 1966 | Mardon Son & Hall/Mead & Robinson | | |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name of Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 11. Screw-off beer bottle tops | 1968 | | | |
| 12. Non-returnable bottle (beer & soft drinks) | 1968 | | | |
| 13. Glass bottles for mixers | 1968 | Schweppes | | |
| 14. Self-chilling can | | | 1971 | (Australia) |
| 15. 'Plastishield' bottle | | | 1972 | Owens-Illinos (USA) |
| 16. Merolite container | 1972 | ICI | | |
| 17. Retortable plastic pouch | 1973 | MB | | (Japan) |
| 18. 'Hi-cone' packs - (multi-packing beer) | 1973 | | | |
| 19. Plastic can | 1973 | | | |
| 20. Paper can | N/A | Bosch | | |
| 21. Skeleton pack | N/A | Airfix | | |

INDUSTRIAL INNOVATIONS SINCE 1945 IN UK (continued)

| Name or Description of Innovation | Firms First Using or Making | | | |
|---|---|---|---|---|
| | UK | | WORLD | |
| | Yr. of Intro. | Name of Firm | Yr. of Intro. | Name of Firm |
| 22. Widemouth Rip-cap bottle | 1976 | Rockware | | |
| 23. Widemouth bottle (seidel sealed) | 1977 | United Glass | | |
| 24. 'Winged' pallets | 1977 | Rockware | | |
| 25. Plastishield | 1978 | United Glass | | |