THE ROLE OF INDUSTRIAL DESIGN IN TECHNOLOGICAL INNOVATION

by

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A thesis submitted for the degree of

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SUMMARY

This is an exploratory study in a field which previously was virtually unexplored. The aim is to identify, for the benefit of innovators, the influence of industrial design on the commercial success of new science-based products used for professional and industrial purposes. The study is a contribution to the theory of success and failure in industrial innovation.

The study begins by defining the terminology. To place the investigation in context, there is then a review of past attempts by official policy-making bodies to improve the competitiveness of British products of manufacture through good design. To elucidate the meaning of good design, attempts to establish a coherent philosophy of style in British products of manufacture during the same period are also reviewed.

Following these reviews, empirical evidence is presented to identify what actually takes place in successful firms when industrial design is allocated a role in the process of technological innovation. The evidence comprises seven case studies of new science-based products used for professional or industrial purposes which have received Design Council Awards. To facilitate an objective appraisal, evidence was obtained by conducting separate semi-structured interviews, the detail of which is described, with senior personnel in innovating firms, with industrial design consultants, and with professional users.

The study suggests that the likelihood of commercial success in technological innovation is greater when the form, configuration, and the overall appearance of a new product, together with the detail which delineates them, are consciously and expertly controlled. Moreover, uncertainty in innovation is likely to be reduced if the appearance of a new product is consciously designed to facilitate recognition and comprehension. Industrial design is an especially significant factor when a firm innovates against a background of international competition and comparable levels of technological competence in rival firms. The likelihood of success in innovation is enhanced if design is allocated a role closely identified with the total needs of the user and discrete from the engineering function in company organisation.

Recent government measures, initiated since this study began, are corroborative of the findings.

Key words: Industrial Design; Technological Innovation.

CONTENTS

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S.M.

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CHAPTER 1

OFFICIAL ACTIVITY RELATED TO BRITISH PRODUCT DESIGN

1.1 Introduction

The title of this study infers that industrial design has a role to play in technological innovation. Because both these terms are open to misinterpretation, working definitions are stated below so that at the outset the basic hypothesis may be restated in more fundamental terms. An established definition of industrial design is that due to Maldanado[1]:

> "Industrial design is a creative activity whose aim (sic) is to determine the formal qualities of objects produced by industry. These formal qualities include the external features but are principally those structural and functional relationships which convert a system into a coherent unity both from the point of view of the producer and the user. Industrial design extends to embrace all aspects of the human environment conditioned by industrial production."

There is a difference between industrial design and engineering design; the two terms are adjacent in meaning but have discrete definitions:

> "Engineering design is the use of scientific principles, technical information, and imagination in the definition of a mechanical structure, machine, or system to perform prespecified functions with the maximum economy and efficiency."[2]

An established definition of innovation is that due to Schumpeter: [3]

> "An invention is an idea, a sketch, or model for a new or improved device, product, process, or system. Such inventions do not necessarily lead to technical innovations. In fact, the majority do not. An innovation in the economic sense is accomplished only with the first commercial transaction involving the new device, product, process, or system, although the term is also used to describe the whole process. The chain of events from invention to social application is often long and hazardous."

Freeman [4] makes a distinction between technical innovation and technological innovation:

> "Technical innovation, or simply 'innovation', is used to describe the introduction of new and improved products and processes in the economy, 'technological innovation' to describe advances in knowledge."

However, especially in the field of the exact sciences, advances in knowledge derive to some extent from the introduction and spread of new and improved scientific instruments and equipment[5]; products and knowledge are part cause and part effect of the other. Therefore, the introduction and spread of new and improved science-based products is an aspect of technological innovation. It is in this sense that the term 'technological innovation' is used in this study.

On a number of counts, technological innovation is an important element in economic development. Progress in technology is a feature of modern societies; there is an increasing awareness at government level of its importance to the well-being and wealth of nations. It is through technological and associated managerial factors that intellectual power creates wealth and influences the material environment [6]. Innovation not only brings material prosperity but also enables things to be done which have never been done before. It influences the quality of life; is critical for the conservation of resources and the improvement of the environment. Innovation is a means, therefore, not only of accelerating economic growth in nations but also of changing the direction of economic advance. Without technological innovation, economic progress would cease; new knowledge, and the products derived from it, is the basis of modern civilisation [7].

However, success in innovation is elusive. Some nations are better than others at fostering successful innovation. Some firms more than others within the same economy have a better record of success in innovation; commercial failure in attempts at innovation is not uncommon. Evidently there is not a simple recipe for success. On the contrary, the process by which an idea evolves, the men with the energy and commitment, and the source of high-risk capital get together to produce consequential innovation, is very complex and only partially understood.[8] Moreover, modern scholarship has had only limited success in imposing schematic order on empirical observations.[9] It is against this background that the role of industrial design is appraised in this study; the intention is to contribute to a better understanding of technological innovation at the level of detail concerned with the creation of the hardware.

Because of its relevance to economic prosperity, attempts have been made to construct models of technological innovation. However, the practical activity now termed technological innovation pre-dates by a considerable interval attempts to define it, model it, or devise theories about it. These attempts to construct a theoretical framework for technological innovation have followed, very belatedly, in the wake of related practices so long established as to be in a number of important respects traditional in their modes of operation. The existing practices are rooted in intuition, belief, conviction, commitment and enthusiasm - essentially irrational, if human factors - and an attempt must be made to take account of these in innovation theory.

Schumpeter's definition of innovation states that the chain of events from invention to social application is often long and arduous. With a new engineering product, part of that process is devising the hardware to embody the invention in a form which can be made and sold at a profit. Based on the way in which the hardware is usually perceived - simply an assembly of mechanical, electrical and electronic components which make up the whole, the arrangement of which is determined by the imperatives of technical function - it might be supposed that this is the reasonably straightforward if onerous task of engineers and their assistants. Several alternative arrangements of the component parts and sub-assemblies may be feasible and the selection of a particular arrangement emerges from draughting a series of elevations on a drawing board. New products can and do emerge in this way; simply an assembly of components, the arrangement of which has been devised by an engineering draughtsman whose pre-occupation is with the details of mechanical practicability. In firms which handle innovation in this way, designing is the job that engineering draughtsmen do; essentially an amalgam of practical experience, convention, empiricism and arbitrary decision-making, with relatively little recourse to formal theory.

Several reasons are given for the emergence of industrial design as an activity distinguishable from engineering design. It is said that the latter is too limited in its scope; there would be no need for industrial design if engineering design were wider in compass. Industrial design seeks to rectify the omissions of engineering; a conscious attempt to bring form and visual order to engineering hardware where the technology does not of itself provide these features. There are a few instances where technology has an intrinsic elegance: the steam-turbine rotor has complex symmetry which derives from the mechanics of fluids; the exterior of the modern aircraft fuselage has a continuous organic form which derives from its aerodynamic purpose; the modern suspension bridge is the essence of structural simplicity. In most instances, however, neither the form nor the configuration of an engineering product have this degree of technological determinism and considerable discretion rests with the designer.

Industrial design seeks to relate the hardware to the dimensions, instinctive responses, and emotional needs of the user where these are relevant requirements. Through the conscious control of form, configuration, overall appearance, and detailing, industrial design is capable of conveying to the user the abstract characteristics of a product, e.g. robustness, precision. It can be an aid to comprehending the technical characteristics of a product; making the technical performance visually explicit. It is a means of making explicit the operation and control of a product. It can arrange for controls to be comfortable, pleasant, and easy to operate. It is capable of imbuing a product with a distinctive ambience, style, and feeling of good quality which equates with the personal taste of the user. By these various means, industrial design is capable of bringing a rounded contribution to innovation, reaching out sensitively to the user. After all, there is a communication gap between the innovating firm and the users which has to be bridged if the new product is to be commercially successful. A user's knowledge of a new product is scant compared with that of the firm; whereas the firm's development personnel are totally familiar with the technical performance and capability of the product, the users cannot know all the facts and rely on impressions, many of which are visual and irrational. This issue can be formulated as a hypothesis:

> A new product may either succeed or fail because of various human factors. Industrial design is a means of consciously catering for these factors in the new product, thereby increasing the likelihood of success.

Perhaps it needs to be stressed that engineering hardware can be devised without the aid of industrial design just as buildings can be devised without the aid of architecture. Indeed, industrial design services are not widely employed in the manufacture of British products.[10] This may be one reason why British performance in innovation is so poor. Because relatively few firms utilise whatever potential it offers, this study appraises the significance of industrial design in the context of the quest for success in technological innovation.

1.2 Nineteenth Century Product Design

Should new products of manufacture which have utility also be tasteful in design? Is this simply a cultural issue or does the standard of design in manufactures also affect commercial success in innovation at the level of the firm and economic prosperity at national level? These questions are indicative of a particular form of controversy about the place of design in the British product manufacturing industry which has persisted since the early part of the nineteenth century. Though the issue appears to be a simple one, and which some even regard as trivial, it has proved to be largely intractable.

If it should be thought that the controversy exists only in the minds of dilettanti and design devotees, the chronology of official and semi-official activity which follows indicates the attention the issue has received from successive governments and other bodies. Since the early part of the nineteenth century concern has been expressed in various quarters about the low standard of design in British products manufactured industrially, both in absolute terms and relative to the standards of other industrial countries such as France and Germany. The implication is that the place given to industrial design and concern for human values in manufacture has a bearing on industrial (and therefore national) prosperity; that industrial design is a factor in the development of a successful manufacturing capability; that to deny industrial design a place in manufacture is to retard industrial progress. The quest, it seems, has been to discover a means of achieving good design in new products of industrial manufacture so that their quality and value may be enhanced.

It will be seen that historically the impetus for change came not so much from the manufacturers themselves as from the political and social reformers on the one hand and artists and designers on the other. Moreover, the relatively slow unfolding of events should be seen against a background of laissez-faire. Unlike its Continental competitors, Britain in the nineteenth century subscribed to a policy of laissez-faire, which does much to explain the apparent indifference of manufacturers to attempts at change by outsiders. In the view of a manufacturer, what he produced and how he produced it rested with him alone. Perhaps also, the manufacturers regarded other problems - the growth of militant trades unionism, for instance - as more pressing. James Nasmyth, an able inventor, a successful entrepreneur, and a pioneer of production engineering, found to his chagrin that mistrust on the part of the trades unions frustrated his efforts to introduce methods of manufacture which were capable of improving and expanding his business. There was a serious strike soon after the establishment of his Bridgewater Foundry.[11] According to Nasmyth's evidence before the Royal Commission on Trades Unions in 1868, 'self-acting' machine-tools enabled him to halve his labour force. If the increased profits had been invested in plant, he could have employed up to one thousand more workers and expanded the business but he declined to do so because of the trouble he had with the trades unions.[12] Pleas from outsiders for artistic refinement in manufactures must have seemed irrelevant if not perverse to someone like Nasmyth, engulfed by industrial strife which threatened the survival of his enterprise. Eighty years later, the gap between manufacturers and the promoters of good design was still so wide for Milner Gray, a Past-President of the Society of Industrial

Artists and Designers, to state in a paper presented to the Royal Society of Arts in 1949 that the usual attitude of manufacturers to industrial design was one of resentment against the 'pretentions of such outside experts'. The manufacturers would not accept that anyone could know more about their products and markets than themselves or the people they employed.[13]

It will also be seen that from the earliest time the means of achieving good design in products of manufacture was identified as being through a process of education. Again, this notion has to be seen against the background of the times and which has died hard. In nineteenth century England, formal state-aided education at all levels was still in embryonic form and informal modes of enlightenment were still widely preferred. It is possible to identify these two approaches to the issue, very similar in character to the movements which sought to promote science in England during the nineteenth century.[14] On the one hand, there were those who sought to professionalise design, a direct approach to the problem. On the other, there were those who sought to diffuse an awareness of good design throughout the population, convinced that an ensuing groundswell of popular demand would induce the desired response from the manufacturers. This latter movement may be symptomatic of a general distrust in England - encountered in other fields such as science - of prescription decreed by professionals; better to encourage demand from below, leaving the hour to find the man.

It was recognised in government circles at the beginning of the nineteenth century that an expanding industrial economy depends upon industry's ability to satisfy the needs of consumers at home and abroad. In 1832, Sir Robert Peel, whose personal fortune was founded on the invention of spinning-jenny, attributed Britain's fall in exports to a deficiency in design. In a statement to the House of Commons, he said that although British machines were superior to all foreign equivalents, the pictorial designs which were so important in recommending the products of industry to the taste of the consumer were not equally successful. To instil a sense of design in manufacturers and to elevate public taste, he urged the Government to establish a National Gallery.

According to Read,[15] Peel's statement is very significant. Not only was it the first time that design was introduced into an official discussion on economic affairs but also the foundations were then laid for a fundamentally false and futile policy to deal with the matter. The latter relates to a fallacy about the nature of design. When the manufacturers in the nineteenth century decided to have design with an artistic content, they bought it like any other commodity and applied it to their manufactures, and even to production machinery. They mixed the styles and muddled the periods. Moreover, they assumed that design in this sense is distinct from the process of machine production, something to be applied to the manufactured object. Read [16] maintains that this fallacy arose through a confusion in semantics. When an object is decorated, an extra known as ornament is added to its form. Ornament can be added to almost any object, e.g. pictures to pottery, carved capitals to architectural columns. All such ornament is <u>applied</u> to the object; in this sense, 'applied' has its original and correct meaning. However, the epithet was taken from ornament and given to 'art' and the resulting transformation, 'applied art', gave rise to confused thought. Museums and schools of design have been prone to this confusion ever since, as exemplified by descriptions such as 'museum of applied art', 'college of applied art'.

According to Blake,[17] The term 'industrial design' comes directly from a nineteenth century term, 'industrial art', originally used to describe machine-made ornament. Industrial design carried this concept a stage further, referring not simply to the ornament applied to products but to the design of the product as a whole. The term was also used to distinguish the process from craft design. In this way, industrial design emerged as the extension of an artistic activity rooted in ornamentation and was associated with the existing product types previously made by hand, e.g. household goods such as tableware. This association has persisted until the present day. Initially, the term industrial design did not encompass concern for human factors such as ergonomics and ease of maintenance; its role in new product development was limited to applying the finishing touches.

In 1836, as a consequence of increasing competition from France and Prussia, a Parliamentary Select Committee was set up to investigate 'the best means of extending a knowledge of the arts and principles of design among the people (especially the manufacturing population) of the country'. The Committee published its Report later that year.[18] It deplored the failure of this country to encourage good design in manufactured products. In response, the Board of Trade established in London a Normal School of Design[19] and a Museum of Ornamental Art (later to be called the Victoria and Albert Museum). According to Blake,[20] this interest in design was directed predominantly towards particular product categories; textiles, furniture, metalware, pottery and glass. The form and decoration of such products had evolved slowly over the years through a process of modification and refinement by the craftsmen who made them. When the mechanised production methods of the Industrial Revolution superseded handwork, manufacturers attempted not only to imitate the craft tradition but also to improve upon it. However, the products of mechanisation could be compared directly with the norm of the craft tradition still in existence and for the discriminating purchaser, the former were regarded as inferior.

Prince Albert, Queen Victoria's consort and an amateur designer, took a personal interest in promoting art in industry. From 1843, as President of the Society for the Encouragement of Arts, Manufactures and Commerce, he stressed the need for '... the application of Fine Art to our manufactures in order to wed high art with mechanical skill'.[21] It will be noted that Prince Albert is revealing the semantic confusion to which Read refers. However, the Prince seems to be suggesting that there is a need in manufacture to link what today would be described as design and technical innovation. He initiated a series of small exhibitions of products. Medals were awarded for outstanding achievement. These exhibitions presaged the Great Exhibition of 1851. Commenting on the Great Exhibition, the social reformer Owen Jones deprecated the shortsightedness of manufacturers unable to see it was in their interests to commission designs from practising artists.[22] To overcome the problem, he advocated extending education in art to both manufacturers and the general public, proposing the establishment of an art museum in every town and a drawing school in every village.

However, Read, Blake, and other writers about design in this period reveal partiality in their historical surveys by making no reference to the development of the early railway rolling-stock, a product category in which, quite independently of the movement described above, the scope of the non-technical design was not limited to the ornamentation of otherwise finished forms. Within a relatively short period of development, the crude mechanical assemblies which were the first locomotives (Figure 1) and the improvised goods wagons which were the first passenger rolling-stock were superseded by designs which reflected concern not only for technical performance but also aesthetic refinement, human factors, and corporate image. Steam locomotion was of course one of the important technical innovations of the period and its success is not in doubt. Apart from the rapid diffusion of railway networks and associated rolling-stock throughout the United Kingdom under intensely competitive conditions, the British locomotive manufacturing industry developed markets for its products not only in colonial territories such as India and Southern Africa but also in Latin America, notably Argentina.

In 1849, twelve years after its foundation, the Normal School of Design was investigated by a Select Committee.[23] It seems that the staff of the school could not agree whether students should be given a broad training in art, including life drawing, or whether the course should be commercial and technical. This highlights a problem still to be resolved: the satisfactory combination of training in art and technology appropriate to the needs of industrial manufacture. Redgrave, a teacher at the Normal School of Design, advocated that students of design should have technical education, including an element of school-based workshop training.[24] He also recommended the employment of designers at an executive level in firms.

Following the Select Committee's investigation, a new administrator, Henry Cole, was appointed to the Department of Practical Art. He sought to strengthen the School as a supplier of designers for immediate use in industry and of teachers for the state schools. He also sought to establish a network of practical art schools in the provinces. He believed that there would be improved design in manufactures if there was a demand for it, and this would stem from the ability of consumers to discriminate between good and bad design.[25] By 1864, at the time of another Select Committee, there were in England ninety art schools with 16,000 students and art teachers were teaching 70,000 schoolchildren.[26]

Cole's commercial approach to design training encountered opposition from the Victorian reformer John Ruskin. He did not subscribe to the view that art should be confined to an instrumental role in manufacture; rather, he believed that art should have a more fundamental role in society as an aspect of its culture.[27]

Ruskin inspired William Morris, later to become well-known as the founder of the Arts & Crafts Movement, to embark on his 'holy crusade of the age'. Morris believed that Ruskin pointed to a new road the world should travel; away from competitive commerce to small groups of men and women working together; away from large factories to individual workshops; away from the mechanically banal to skilful craftsmanship.[28] A significant effect of Morris relevant to this study is that he began the tradition in England of designers in small workshops, establishing a cult of truth to materials and attention to detail which is a facet of British industrial design today.

Morris also influenced the development of design education in England. In 1894, William Lethaby, an architect and admirer of Morris, became adviser on art to the Technical Education Board of London County Council. In 1896, the Central School of Art in London was established 'to encourage the industrial application of decorative art' with Lethaby as its first Principal. He developed a curriculum based on craft techniques and the correct use of materials. Later, in 1900, Lethaby became the first Professor of Design at the Royal College of Art. His views on design are summed up as:

> "... Designing is not the abstract power exercised by a genius. It is simply the arranging of how work shall be done.... Design is just appropriate shaping and finishing for the thing required... A work of art is first of all a well-made thing.... Art is not a special sauce applied to ordinary cooking; it is the cooking itself if it is good..... The products of industrial design have their own excellence; good in a secondary order, shapely, smooth, strong, well-fitting, useful; in fact, like a machine itself......"[29]

1.3 Product Design between World War I and World War II

The Design & Industries Association, founded in 1915, began as a splinter group of the Arts & Crafts Movement, stating that it would not be content until ordinary folk could buy at moderate prices commodities suited to their needs and satisfying their sense of beauty.[30] Contrary to Morris's original socialist intentions, the Arts & Crafts Movement became an elitist cult. The Association hoped that the general public would help its campaign of fitness for purpose in design by refusing to buy domestic articles which they could see to be sub-standard.

After the 1914-18 war, both government and industry showed some interest in industrial design. For instance, the Ministry of

Reconstruction issued a pamphlet entitled Art and Industry.
In 1920, the Federation of British Industries formed an Industrial Art Committee with the object of considering its role in British industry. The outcome was a Designers' Register and Employment Bureau. Also in 1920, the Board of Trade and the Board of Education with Treasury support initiated the formation of a British Institute of Industrial Art, aiming to create a market for industrial designers. With the onset of the industrial slump soon afterwards, however, Treasury support was withdrawn.

In 1930, the Society of Industrial Artists was founded. It aimed to establish the profession of design by forming a controlling authority to promote and protect the interests of those engaged in designing for industry, publishing and advertising; to assist in the advancement of British trade, both at home and abroad.[31] The link between the professional interests of designers for the manufacturing industry, publishing and advertising warrants an explanation.
The beginnings of consultant industrial design practice in Britain stemmed more from the growth in advertising than from the aesthetic inadequacies of consumer goods. At the time when the Society was formed, posters and press advertisements were being used increasingly while packaging and display material provided a new system of communication between producers and consumers. Much of the work produced was of poor quality; the directors of many advertising agencies, like the majority of the consumer goods manufacturers, believed that the interests of commercialism could not be equated with aesthetic idealism.[32]

In 1932, a Board of Trade Committee on Art and Industry published its Report, concluding that in order to raise national design standards, consumers must be made design conscious and they must be shown what constitutes good design.[33] The outcome was a Council of Art and Industry, established with government support in 1934. Its objects were to educate consumers in design appreciation, to consider design training for industry and commerce, and to encourage good design, especially in relation to manufacturers.[34] The Chairman of the Council, Frank Pick, had acquired a good reputation in design circles as chief administrator, first of the London Underground Railway and later the London Passenger Transport Board. For instance, he commissioned posters from well-known artists which led to the Underground stations being also galleries of art for the travelling public with the poster as a medium for enlightenment. He is also credited with developing the distinctive identity of London Transport through his commissioning of new buildings such as the Underground station at Arnos Grove, new route maps, and a new letter-face.[35] The Council of Art and Industry appears to have become defunct at the outbreak of World War II.

In 1943, a committee of the Department of Overseas Trade produced a report which stated that since there is such a thing as good design, and since there is not a fundamental conflict between giving the public what it wants and good design, then a Central Design Council, not directly responsible to a government department, should be established.[36] In 1944, the Meynell-Hoskin Report[37] was submitted to the Presidents of the Boards of Trade and Education. It considered ways and means of making art training more useful in the post-war period and recommended that the proposed Central Design Council referred to above be a grant-aided body financed by the Board of Trade. As a consequence, on 19th December 1944, Hugh Dalton, the then President of the Board of Trade, announced in the House of Commons that he had appointed a Council of Industrial Design to promote by all practical means the improvement of design in the products of British industry.[38] Later, when addressing the Council, Dalton said 'we must make a sustained effort to improve design and bring industry to recognise the importance of this task. You have to arouse the interest of ordinary men and women...Our export trade, and our volume of business at home, will both be greater if our goods are planned and made with skill and imagination to meet the user's real need, to give pleasure in the using.'[39] The Chairman of the Council was Sir Thomas Barlow and the membership included Gordon Russell and Josiah Wedgwood, both principals of design-conscious firms manufacturing furniture and ceramic wares respectively.

In 1945, Dalton was succeeded at the Board of Trade by Sir Stafford Cripps. At his instigation, the Council of Industrial Design mounted a 'Britain Can Make It' exhibition 'to intensify the interest of manufacturers and distributors in industrial design....to arouse greater interest in design in the minds of the general public as consumers; and to stage a prestige advertisement, before the world, for British industry, industrial design, and standards of display'.[40] The exhibition included not only examples of consumer goods but also scientific instruments. Commenting at the time on the latter, Beresford-Evans shows an understanding of the place of industrial design relative to the development of scientific instruments.

When an instrument is intended solely for use in a laboratory, there is not overt claim about style; the user believes his choice is influenced only by performance but knows instinctively that a well-groomed appearance, with carefully considered detail and colour, is a fair indication of good working and wearing properties.[41]

The Britain Can Make It exhibition aroused considerable public interest; it was attended by one-and-a-half million people.

1.4 Product Design after World War II

In 1946, the Training Committee of the Council of Industrial Design (COID) produced a report on the state of design education in Britain.[42] It deprecated the traditional division in British education between the arts and science, the arts schools and the technical schools, and schools of commerce and the universities. It argued for a broad and realistic training for industrial designers. It recommended radical reorganisation of the Royal College of Art, the premier institution for the training of artists and designers. In 1948, the education officer at COID and secretary of this Training Committee, Robin Darwin, was appointed to be principal of the Royal College of Art. Radical reorganisation followed. The college was given complete academic freedom; the right to develop its own teaching methods, set its own examinations, and issue its own awards. Teaching staff participated in the selection of new colleagues and practising designers were appointed as professors. Darwin was influenced by the Bauhaus, a German school of design at which students received training by working on professional commissions.[43] (In 1967, the Royal College of Art was granted university status following a recommendation in the Robbins Report on Higher Education.[44])

Darwin's appointment at the Royal College of Art coincided with the appointment of Gordon Russell as the new Director of the Council of Industrial Design. At the time when Russell became Director, the COID was the subject of criticism in the trade press. It maintained that the Council was jeopardising exports by criticising the design of products which were earning income.[45] As a consequence, Russell drafted a new plan for the development of COID. He described the reorganisation as a twin drive for better design; an Industrial Division to encourage industry to employ trained manpower and to produce well-designed goods; an Information Division to stimulate public demand for well-designed goods.[46]

During World War II, the Royal Society of Arts had proposed a 1951 exhibition to commemorate the centenary of the 1851 Great Exhibition. This culminated in the 1951 Festival of Britain. The organisers were directed to display the British contribution to civilisation, past, present, and future; in the arts, in science and technology, and industrial design. At this time the juxtaposing of science and technology with industrial design seems to have been accidental.

In 1956, the COID opened its London Design Centre, supported by a subscription of £27,000 from industry. The Duke of Edinburgh performed the opening ceremony.[47] His interest in design was aroused when in 1948 he attended an exhibition, Design at Work, jointly sponsored by the Royal Society of Arts and the COID. From then on he became an enthusiastic promoter of design. In 1959, the COID was awarded the Gran Premio Internazionale la Rinascente Compasso d'Oro in recognition of it being the oldest and most efficient organisation for the development and popularisation of good design.[48]

In 1963, following the submission of the Fielden Committee's report on Engineering Design[49] to the Department of Scientific and Industrial Research, which stated that 'British machines are being compared with foreign machines whose designers have understood better the refinements of design and the requirements of the user', the COID appointed a Capital Goods Officer. This was intended to reflect the Council's interest in product categories other than consumer goods. In 1967, the Design Centre Awards were renamed the COID Awards and broadened in scope to include engineering design and a capital goods category.[50] In 1968, an Institution of Mechanical Engineers working party submitted a report to the Ministry of Technology advocating a single design council to promote design across the whole of British industry.[51] In May 1972, the Council of Industrial Design was renamed the Design Council, reflecting a policy to place greater emphasis on engineering design.[52] Internal reorganisation of the Council followed. The post of Head of Industrial Design was discontinued and his duties taken over by the Head of the Industrial Division, who is an engineer.[53]

It can be seen, therefore, that only within the last twenty years have policy-makers at a national level in Britain attempted to establish a link between industrial design and the development of new technical products. In recent times, there have been further attempts to do so. In their various ways, the reports of the Moulton[54], Carter[55], Corfield[56], and Finniston[57] Committees stress the need for British manufacturers of technical goods to improve their design standards and reflect the continuing concern in official circles about the ability of the British product manufacturing industry to remain competitive. There is a consciousness of new opportunities for industrial leadership coupled with a fear that simply by default British manufacturers will fail to fully exploit them.

It could be inferred that whereas the place of industrial design in the manufacture of consumer goods had some bearing on economic performance in the previous era, the emergence of science-based high-technology manufacturing industry has relegated the issue to be one of mainly historical interest. The greater emphasis on engineering design at the Design Council makes this inference credible. However, there are grounds for believing that the issue is as important as ever; that unless the place of industrial design in the manufacture of high-technology products is clearly identified and widely understood by policy-makers, the muddle and groping associated with the design of consumer goods that has persisted for over 100 years in Britain will be perpetuated in the high-technology sector.[58] If the post World War II period can be characterised by the emergence of new science-based high-technology manufacturing industries, it can also be characterised by the intense international competition with which these manufacturing industries have to contend. One consequence of this competition is that the users and purchasers of these new technical products have the opportunity to choose between competing makes. It is in its potential to influence the choice of a purchaser in competitive market conditions that points to a role for industrial design in technological innovation.

The emergence of an engineering lobby in British industrial design organisations can be attributed to a cause unrelated to design in manufactures. It has been described as part of a movement aimed at improving the status and extending the influence of the engineering profession in Britain.[59] An exploration of that issue is beyond the scope of this study. However, linking the aspirations of the engineering profession to the quest to achieve tasteful design and fitness for human purpose in products of industrial manufacture could result in a digression from the original aim. The continuing need, it seems, is to develop a paradigm for industrial design which will accommodate the changing face of the British product manufacturing industry rather than subsume industrial design in the manoeuvrings of a profession experiencing a crisis of confidence.

1.5 Evaluation

(cf 1.2) It can be seen from the statement of Peel in 1832 that in the early stages of industrial development in the United Kingdom, the standard of artistic design in manufactured products was identified by a policy-maker as having a bearing on their commercial success, even if that is not the terminology used at the time. The early recognition of this relationship indicates that businessmen at the time were quick to sense the existence of invisible factors for success and failure in manufacturing enterprise even if they were unable to prescribe appropriate courses of action to ensure positive results.

The remedy actually prescribed by Peel to elevate the standard of design (and therefore increase the volume of exports) - a National Gallery - now seems eccentric. It indicates that Peel only partially understood the nature of design and the process of designing. This serves to highlight a situation that has persisted until the present time. Businessmen are often astute in anticipating connections and relationships in manufacture but if their specialist knowledge or capacity for expert opinion is lacking, the action their power enables them to initiate may prove ineffective or even counter-productive. A working knowledge of design and the process of designing has to a very large extent remained the province of the designers themselves. Businessmen use design instrumentally with varying degrees of success, placing their own often imperfect interpretation on its nature and deploying it accordingly.

(cf.1.2) The problem of semantics in relation to 'applied art' and 'industrial design', referred to by Read and Blake respectively, is part of a wider problem of design terminology. The nature of both design and the process of designing are difficult to define concisely. 'Design' has become an omnibus term with a wide variety of both meaning and nuance. Ironically, in spite of its imprecision, the English word has been adopted for use in other languages (e.g. German, Czech, Bulgarian). This imprecision in the terminology has a number of adverse consequences. When people from different backgrounds in design (e.g. engineering, industrial design), engage in a dialogue on the subject, they often talk at cross-purposes. The implied and subsumed content of design terms is large and often out of reach of the uninitiated, resulting in a low level of communication between the adviser and the advised. The practice of design is rooted in drawing rather than words and designers have a tendency to use terms loosely and even vaguely, without thought for introducing rigour into their language. These and other semantic deficiencies place the design activity at a disadvantage in a business environment. Other activities which compete for the same resources are capable of deploying lucid argument to explain more effectively purpose, objective, and relevance to profitability.

(cf 1.2) Blake's insight about the origins of industrial design in England is instructive. Perceived only in the context of today's manufacturing capacity for mechanised production, it is easy to dismiss industrial design as mere icing on the cake of industrially-produced goods, taking the actual process for granted. However, in the historical perspective offered by Blake, industrial design was an implicit means of effecting that unprecedented and critical transition from craft to machine production at the level of customer acceptance during the formative stages of mechanisation. That during this transition there were, in terms of design, blunders is a comment on the form rather than the substance of the intent. Industrial design was a means of providing a benign face to mechanisation, not only through the products which customers bought for themselves but also the machinery and equipment which were the means of making the products.

(cf 1.2) The establishment of the Normal School of Design in London following the Ewart Report in 1836 had a number of unfortunate consequences, the effects of which are still evident today. In the context of the current definition of design, the title of the School is a misnomer. Set up to provide a pool of skilled labour for what would now be described as the consumer product manufacturing industries - textiles, metalware, pottery and glass - initially the school instructed pupils in surface decoration only. Essentially, it was a drawing school for pupils destined to become decorators of products. On a number of counts, the experiment was disastrous for industrial design in England. The mode of instruction was ill-conceived; pupils were taught to draw by copying drawings of flora and fauna, developing skills of a very limited kind. There was no instruction in either creative drawing or manufacturing techniques related to the decoration of products. As a consequence, the pupils were ill-equipped for employment even as decorators of products, much less as designers.

Manufacturers were critical of the School. Almost from the outset, the School was in conflict with the government of the day; it failed to implement the state policy of providing a pool of labour skilled in design techniques to match the competition of Continental manufacturers. Nevertheless, the School survived. And as survivors - or empire builders - the staff gradually steered the school curriculum towards painting, sculpture, and the traditional crafts, e.g. silversmithing. As indicated by Bell and the Northcote Report of 1864, many similar schools of art and crafts were set up in the provinces. They represented a contradiction. Set up to serve the factory system of the day, instead they were backward-looking and inculcated the traditional techniques and values of the pre-industrial era associated with the protest movement of William Morris.

Over the years, this institutional framework of schools of art and crafts absorbed the resources earmarked for what should have been training in industrial design. It not only failed to provide relevant training but alas, through its self-indulgence, brought the activity of industrial design into disrepute in the minds of politicians, entrepreneurs, factory managers, and scientifically-trained personnel. The ethos of fine art predominated. Remote from the norms and values of manufacturing enterprise, the schools were regarded as largely an irrelevance and did not act as pace-setters in good design.

(cf 1.4) The Normal School of Design is the direct antecedent of the Royal College of Art; the latter is the only institution in England with a Chair in Industrial Design. Directly funded by the Department of Education and Science, in the post-war period there have been two major enquiries into the operation of the college. The most recent was initiated by the Thatcher administration, critical of its failure to meet the needs of the manufacturing industry, a recurring theme which indicates that 150 years after its foundation, the basic problem of credibility with the manufacturing industry remains. The latest enquiry culminated in the resignation of the Rector in 1983 after only two years in office, having failed to reform the college and modify the outlook of the entrenched traditional faction led by fine artists. This history of enquiry into the operation of the Royal College of Art can be linked with the widespread practice of art college staffs undertaking private commissions for payment. Darwin, a post-war Rector of the Royal College of Art, took this a stage further and encouraged the Bauhaus practice of professors working on private commissions on the college premises, using college facilities, and involving students in the work. The practice is commendable as a means of introducing a sense of realism into the educational activity but demands a rigorous system of accountability if there is not to be corruption, a conflict of interests, and misuse of public property, all of which offends the Puritan ethos of public administration in England.

The experience of the early railway companies is instructive. Contemporaneously with the heart-searching at the Normal School of Design, they achieved with their own resources and without the aid of either precedent or a formal education system a high standard of industrial design in railway rolling-stock in a relatively short time. This suggests that the significant influence in developing crude prototypes into refined products was not so much the availability of trained manpower, more the conviction of the management in the rightness of the endeavour; if senior management perceive good design as dynamic and progressive, enhancing the competitiveness of technically similar products, the means of doing so is not difficult to find. Evidently the visionary railway pioneers such as Robert Stephenson and Isambard Brunel created the conditions which enabled good design to emerge in their products. They not only managed their firms as commercial enterprises but also were committed in a very direct way to the improvement of the products. The division of labour in their firms did not become the raison d'etre of the enterprise; the essence of traditionally-made artifacts was maintained, a continuous blend of utility and aesthetic quality which infers a hand guided by a practical and sensitive mind. This is a characteristic of man-made items from the earliest civilisations; design is intrinsic to the artifact and reflects the level of skill and sensitivity of the maker. That a modern artifact may be a mechanical contrivance and the making aided by operatives and machines located in a factory should not alter the characteristic; the need for a guiding mind remains, even though the handling is delegated to other men and machines. And whereas with the traditionally-made artifact the designing is largely an intuitive process, for the factory-made product the same process has to be conscious and deliberately arranged so that precise instructions can be communicated to others, which is easier said than done. The quest in good design is to achieve balance; none or too little results in crudeness, too much results in contrivance.

(cf 1.2) Lethaby, the first Principal of the Central School of Art in London, articulated this view of industrial design as a working hypothesis at the turn of the century but it did not become established. Perhaps Lethaby's ability to describe a complex process in simple terms made design seem so elementary as to be trivial, unworthy of consideration as an industrial activity. (cf 1.3). Instead, as indicated by the formation of the Federation of British Industries Industrial Art Committee and similar bodies in the 1920s, the idea took root that this form of design was an entity discrete from industry, a commodity which manufacturers could purchase only if they wished to do so. The term 'commercial art' came into the vocabulary. The formation of the Society of Industrial Artists is a further indication that 'industrial art' was identified by some as a marketable commodity which could be exploited to form the basis of a trade or profession. The 1932 Gorell Committee Report on Art and Education and the subsequent formation of the Council of Art and Industry to make consumers design-conscious and to show them what constitutes good design shows that industrial design is also capable of being bogged down in a ponderous bureaucracy. Gorell's deliberations were followed by those of first Weir and then Meynell-Hoskin, inflating good design into something special when really the process had been quite simply and adequately described by Lethaby as intrinsic to manufacturing half a century earlier.

(cf 1.3) Though making industrial design a subject for inclusion in exhibitions such as 'Britain Can Make It' and the 'Festival of Britain' brought it to the notice of manufacturers and the general public, the projection of it as something trendy, fashionably glossy, and ephemeral was unlikely to persuade conservative manufacturers of engineering goods to re-appraise their approach to the development of new products. To them, industrial design must have seemed an end in itself, linked to the world of fashion rather than manufacture. Seen in this perspective, it is not surprising that manufacturers were hostile when the Council of Industrial Design, which they would regard as an arm of state bureaucracy, became so bold as to publicly criticise their products.

(cf 1.4) Though the Council was to have its imitators internationally and even received formal recognition for its pioneering role, it had its detractors in Britain. There is probably not one but several reasons for this. The Council came into being during World War II, at a time when there was already the Utility system of centralised control for certain categories of consumer goods. Some manufacturers would regard the Council as an extension of this state control by the first socialist administration in post-war Britain, a source of resentment generally in private enterprise. However, even open-minded manufacturers must have been disappointed if not dismayed by the Council's activities. Far from elevating discussion on industrial design, its preoccupation with commonplace household goods succeeded only in trivialising it. Moreover, the Council's practice of releasing journalistic copy to women's magazines suggested a less-than-serious approach to the subject. In attempting to lead a reasoned discussion on the elements of good design in its own publication, Design, the products chosen as examples (a sugar dredger, a tea-strainer, and a potato-masher) invited ridicule. Though it is the practice in philosophy to use commonplace examples to illuminate profound points of principle, for manufacturers and a general public unaccustomed to this mode of discourse, the examples can easily be mistaken for the substance of the argument. The impression of a Council staffed by dilettanti was reinforced when commonplace household goods received Design Centre Awards. People generally are impressed by new knowledge turned to practical purpose; on the other hand, they are bored by those who dwell on what is obvious. Given that the terminology of design is imprecise, for some people a product is inseparable from its design, and design is inseparable from invention. Not unreasonably, therefore, they expected that in effect Design Centre Awards would be given for technical innovation - elegant new products which reflected Britain's capacity for invention. The Council was slow to grasp the point; for almost twenty years, its activities were confined to improving the design of existing consumer goods. The turning point was the appointment of a Capital Goods Officer in 1963, prompted by the report of the Fielden Committee on engineering design. This was the beginning of the Council's association with the engineering profession, which proved to be a cuckoo in its nest. The reconstituted Design Council, which replaced the Council of Industrial Design, also caters for the needs of the engineering profession and in so doing has until very recently diluted the efforts to consolidate a role for industrial design in manufacture.

Reports such as those cited in this chapter draw attention to only broad issues of policy and recommend general courses of action. Moreover, there is a tendency to aggregate, to indulge in rhetoric and assertion. This proselytising seems to be directed at manufacturers generally and thus seems to apply to no one in particular; in overstating the case, its relevance to a particular firm is obscured. The study which follows is an attempt to remedy that deficiency. It aims to examine the issue empirically and analytically insofar as it is susceptible to this kind of treatment. The next Chapter is a review of taste and style in British products of manufacture and indicates its relationship with the development of new technical products.

Figure 1. The early steam locomotive 'Puffing Billy' built by William Hedley of Wylam in 1813. Crude assembly and lack of form are evident.

Source: Reed B. 150 Years of British Locomotives. David & Charles. Newton Abbot. 1975.

CHAPTER 2

STYLE AND TASTE IN BRITISH PRODUCTS OF MANUFACTURE

2.1 Introduction

Evidently the task of achieving good design and fitness for human purpose in products of manufacture has proved to be difficult. It is not a norm of manufacture, and probably so for a number of reasons. There is a disparity between the nature of art, in which industrial design has its roots, and that of manufacture, as well as between the attitudes and values of the respective adherents. The ethos of art is not readily acceptable in the rational and measurable order of things which has influenced Western thinking since the time of Descartes. In contrast, art focuses on the embodiment of aesthetic values.[1] These are primarily visual expressions of individual opinion about beauty, the human condition and human aspirations. As expressions of belief, they are not necessarily representative and may be the subject of popular controversy. Moreover, the state of opinion about art - and the manifestation of it in works of art - is fluid. What is highly acceptable to one generation may be quite unacceptable to another. Artistic opinion is capable of turning back on itself. For instance, in one period it may subscribe to rules of form, composition, and proportion and in another it may favour an anarchic approach. Such diversity can exist contemporaneously. In this sense, art cannot be characterised as incremental or developmental. Rather it reflects contemporary attitudes which at any point in time may have any of a number of preferences; high morality, rationality, decadence, sensuality, permissiveness, vulgarity.

The absence of a paradigm in artistic design, and the absence of consensus even among artistic designers themselves, conflicts with the tendency to interlocking method and order which characterises the development of both the factory system and science. Industrial manufacture is rooted in the pragmatism of coping with the day-to-day problems which arise when trying to organise human and material resources to produce goods profitably. If there has been an underlying trend in the manufacturing industry, it is in the development of systems aimed at reducing levels of uncertainty in entrepreneurial activity. In science, the trend has also been to elaborate systems so as to provide more comprehensive explanations of natural phenomena on the one hand and to develop a capability for manipulating them on the other. In these circumstances, it is understandable that whereas industrialists have shown an increasing tendency to enlist the aid of science, they have been less ready to acknowledge the need for an artistic contribution to their activity.

A more fundamental explanation, connected with the tendency in Western cultures to concentrate on developing verbal skills, is also available. It is known that the brain is functionally divided into two halves. The left-hand half plays a major part in the use of language and for most people controls the right-hand side of the body. Traditionally, the left-hand side of the brain is regarded as the 'major' half. The function of the right-hand 'minor' half of the brain was, until recently, less clear. It was known that this half controlled the left-hand side of the body but its role in language was in dispute. However, by testing the two halves of the brain separately, Sperry and Gazzaniga found that even though the 'minor' half of the brain has a very limited capacity to handle words, in some other respects it can out-perform the 'major' half. For instance it can handle shapes, spatial relationships, and visual patterns better.[2] Smith[3] has shown that, faced with an urban scene, the 'major' half of the brain can only read the street signs and reduce an otherwise chaotic scene into a semblance of order by attempting to classify what it 'sees'. However, the 'minor' half not only assimilates the variety of shapes, colours, tones, and textures which form this urban scene but also comprehends the way things fit together to make a unified whole. It has been suggested that this power of aesthetic response in the right-hand half of the brain could be increased if more attention was paid to educating it instead of concentrating only on the verbal skills associated with the left-hand half of the brain. Conversely, people educated according to the norms of Western cultures are likely to be imbued with a very limited capacity for aesthetic response.

The above notion should be weighed against the cautionary words of Read[4]: the necessity for ornament is psychological rather than aesthetic. There exists in Man an incapacity to tolerate empty space. This feeling is strongest in certain savage races and during the decadent periods of civilisation. It is probably the same instinct that causes certain people to deface walls with graffiti, others to doodle. This instinct is not essentially aesthetic. All ornamentation should be treated as suspect. The only aesthetic justification for ornament is that it should emphasise form. For example, cosmetics applied with discretion delineate features more precisely.

This study is about the place of industrial design in the development of new products used for professional and industrial purposes. These products are made by firms forming part of the engineering manufacturing industry. This point is emphasised because industrial design is also associated with products of the furniture, pottery, and textile industries. And in general, designers as well as manufacturers in the engineering industry maintain that there is a distinction to be drawn between industrial design related to their industry and that related to these other industries. Black[5] has written at length on this issue. However, it will be shown in the following review that attitudes about style and taste in relation to products form a continuum across all the manufacturing industries. For instance, a 'rational aesthetic' was not conceived especially for the engineering industry or high-technology manufacture; it pre-dates by a considerable interval the engineering industry's conscious adoption of industrial design. For these reasons, style and taste relative to the products of the engineering industry are discussed within the context of industrial design generally.

2.2 Innovators in Style

Style has been described as the signature of a civilisation.[6] A man-made object can be dated by its style, be it Egyptian, Gothic, Renaissance or Art Nouveau, and it reflects the society in which it was conceived. In this sense, every man-made object has style. A good style reveals attainment coupled to restraint. Style is debased when factors other than the achievement of excellence become the dominant motives. Taste is the faculty of aesthetic discrimination. The concept seems to have originated in seventeenth century France, where it was a frequent topic of polite conversation in the salons. In England, the term was adopted by the Virtuosi, gentlemen accustomed to discussing art, literature, antiquities, and science. By the early eighteenth century the term was used in essays on literature as a metaphor for judgment. In this way, the elements of refinement and restraint became part of the concept of taste.[7]

There is a distinction to be made between the opinions and attitudes of those who create and influence style and taste, and the popular response to them. As in technology, there are innovators, relatively few in number, and those who adopt the stylistic innovations. That is not to deny in both forms of innovation there is a degree of interaction between the innovators and the adopters; success in both forms can be assessed by the extent of the adoption. But dynamic movements in style - trends - are set by innovators in the field. A style may become popular but it is not an expression of 'popular taste'. In the following review, the members of a Movement, the trend-setters, are in effect the stylistic innovators. Personalities are identified, not because of a misplaced sense of romance or the heroic but because individuality is the nature of the activity.

Whereas there is general acceptance of personalities related to stylistic trends in some industries, there is very limited acceptance in others. For instance, Yves St.Laurent, Hardie Ames, and Norman Hartnell are well known as designers of garments but the majority probably could not name a designer in an adjacent field, men's shoes. The majority know names of the past in furniture design - Hepplewhite and Sheraton, for instance - but are much less familiar with those of the present. Basil Spence achieved popular fame but few other contemporary English architects have done so. In the field of engineering products, Pininfarina and Issigonis became closely identified with certain designs of motor-car but as yet there is no comparable personality associated with the design of body-scanners or electron-microscopes. The absence of well-known designers in a particular industry may not be because there is no place for them; this may simply reflect that policy-makers or entrepreneurs have not considered the matter. British firms manufacturing engineering products were, with exceptions, late in giving attention to style. As a consequence, attitudes towards style in the engineering industry are still both uneven and immature. It seems as though in some firms policy-makers are still unable to distinguish between stylistic innovation and popular response to it. The industrial designer has achieved only limited acceptance.

2.3 Style in the Nineteenth Century

In Victorian times, it was said of British product design that there was no consistency of style. Generally, manufacturers adopted a miscellany of styles from the past and to this extent were imitators. The imitating was not limited to style; it attempted to also make products appear to be what they are not. For example, the body of the clock in Figure 2 is not the architectural structure it pretends to be. The architect Pugin was of the opinion that all beautiful forms in architecture stem from utility and the test of architectural beauty is the fitness of the design to the purpose for which it is intended.[8] His term, fitness for purpose, became a canon of good design.

The nineteenth century designer William Morris is well-known for his patterns for textiles and wallpapers. However, after studying at Oxford where he came under the influence of John Ruskin, Morris also made his mark as a design theorist and an entrepreneur. In partnership with six of his friends, he set up in 1861 a cooperative to produce hand-made goods. This venture inspired others to do the same and the activity became known as the Arts and Crafts Movement. During the eighty-year existence of Morris & Company - it went into voluntary liquidation in 1940 - the firm made not only textiles and wallpapers but also stained glass, furniture, metalware, pottery, leathergoods, and jewellery.[9] It seems that Morris and his colleagues in the Arts and Crafts Movement were protesting against the prevailing style of decoration; the ponderous and complex Second Empire style from France.[10] This protest revived the mediaeval spirit in design: good materials and sound workmanship; simple construction and rich surface decoration. It was also a reaction against the purely commercial, industrial and material tendencies of the day. Morris's workshops created a sophisticated cult of everyday simplicity and which became a fashion among cultured people.

The Arts and Crafts Movement also made an impact in Continental Europe. By 1895, England was acknowledged in Europe as the source of a new visual style. Art Nouveau in France, Jugendstil in Germany, Secessionstil in Austro-Hungary, Stile Liberty in Italy, and all the variations in Holland, Scandinavia, Spain and Russia can be traced back to the influence of Ruskin and Morris. In 1901, it was noted that in Germany both the government and the manufacturers were aware of the potential of good design and seemed determined to challenge the supremacy of British designers and craftsmen.[11] This had been prompted by the work of Muthesius, an architect attached to the German embassy in London, who became interested in the Arts and Crafts Movement. He interviewed designers, borrowed designs, and reported back to Germany. In 1907, as Superintendent of the Prussian Board for Schools of Arts and Crafts, he persuaded German manufacturers, architects, artists, and interested laymen to form the Deutscher Werkbund, which sought to achieve high quality in manufactured goods.[12] However, the Arts and Crafts Movement had its critics. In England, there were appeals to the Movement to produce good design in household goods at a reasonable cost.[13]

The controversy in nineteenth century England about the design of household goods and other personal possessions was largely an argument about preferences in style related to existing product types, e.g. tableware, where there were the precedents of hand-made goods on which to base aesthetic judgment. Technical innovation in household goods was in processes rather than products; mechanising the production of existing product forms. In contrast, the development of the railways, a major technological innovation in the nineteenth century, gave rise to entirely new product forms on a large and public scale. The innovation was not beset by controversy about style even though the railway companies soon projected strong stylistic imagery through their products. The use of iron for structural elements became fairly common in English industrial building only after 1800. During the first half of the nineteenth century exposed columns and decorative ironwork appeared, particularly in non-traditional structures such as railway stations.[14] By the mid-1840s, the railway network was so extensive as to create a need for large termini in major cities. This need, allied to improved techniques in iron manufacture, gave rise to a series of great iron-and-glass roofs, beginning with that for Newcastle Central Station in 1845 by the architect Dobson.[15] These great roofs combined architecture and engineering on a large scale. Architecture is, of course, one of the most ancient and highly developed arts of civilised man. The way in which it was adapted to the requirements of the new railways, bestowing a sense of stability, dignity, and purpose upon this innovation in travel, is one of the great achievements of Victorian design.

The railway companies also pioneered product presentation which complemented the architectural achievement. This development is now described in some detail because it was initiated, not by the professional aesthetes of the day but by entrepreneurial railway engineers conscious of market forces. As a phenomenon, the development was to command lasting admiration. By 1828, only three years after the opening of the Stockton & Darlington Railway, Robert Stephenson was concerned about the appearance of his locomotives. Perhaps the need of the railway companies to pay attention to landscaping as a condition of obtaining way-leaves through the estates of the gentry also prompted them to be conscious of the appearance of the rolling-stock. In a letter dated 1st January 1828 to Michael Longridge, one of his partners in the firm of Robert Stephenson & Company, Stephenson wrote that he had been talking to his father (George Stephenson) about 'endeavouring to reduce the size and ugliness of our travelling engines'.[16] This he proposed to do by placing the cylinders either on the sides of the boiler or below it. Hackworth had probably inspired this by the improvements he had demonstrated on his 'Royal George' locomotive for the Stockton & Darlington Railway, which had proved to be a considerable advance over the two original Stephenson locomotives built for the line.

Stephenson commenced his endeavours with the 'Lancashire Witch' of 1829, placing the cylinders in an inclined position on the sides of the boiler at the rear end. (Figure 3) The 'Rocket' of 1829 was considerably more refined in proportion and detailing and displayed his efforts to improve the appearance. (Figure 4) The standard of workmanship was much higher than previously and the colour scheme of bright yellow and black, with a white chimney and polished brass mountings, was Stephenson's own choice. A well-known coachbuilder, Nathaniel Worsdell, was employed on the design of the tender. By winning the Rainhill Trials, the 'Rocket' helped to determine the direction of future steam locomotive design development in the United Kingdom. Stephenson's concept was a feature of British steam locomotives for over a century.

After only a few Rocket-type locomotives had been constructed, Stephenson introduced his 'Planet' design. (Figure 5) As proposed in his letter to Longridge, he placed the cylinders inside and at the front end of the configuration. He also introduced a wood-and-iron sandwich frame, an arrangement which was to be used for more than fifty years on hundreds of locomotives. Robert Stephenson & Co. developed the inside-cylinder single-driver design, and its 'Patentee' of 1834 was the precursor of the characteristic 2-2-2 express passenger locomotive with sandwich frames. From an aesthetic viewpoint, the 'Patentee' was a significant advance on the 'Rocket' in the space of five years, and displayed in embryonic form the features of classic Victorian locomotive design. Engine and tender seem to belong to each other. (Figure 6) The general sense of balance in the proportions is good, apart from the clumsy chimney which gives a heavy appearance to the leading end. The driver and fireman, though exposed to the elements, have a foot-plate and are protected at the sides by railings.[17]

Stephenson's attempts to produce a good-looking locomotive were enthusiastically received by I.K.Brunel of the Great Western Railway. For its opening in 1838, Brunel ordered twenty loco-motives, two of them from Robert Stephenson & Co. Named 'North Star' and the 'Morning Star', they followed Stephenson's typical layout described above but were larger than his earlier locomotives. (Figure 7) Comparison of the illustrations of 'North Star' and the 'Patentee' shows the family resemblance. At the time of ordering the locomotives, Brunel specified that they should be not only big and fast but also as handsome as could be made because 'a plain young lady, however amiable, is apt to be neglected'. When Brunel took delivery of the 'North Star', he wrote to a friend, 'We have a splendid engine of Stephenson's. It would have been a beautiful ornament in the most elegant drawing-room'.[18]

Other locomotive builders produced variants of Stephenson's 'Patentee'. The use of distinctive detail design as on the 'Jenny Lind' (1852) became a form of house-style adopted by the builders to distinguish their products. (Figure 8) The emergence of variety in locomotives of essentially similar technical design stemmed partly from the increase in the number of firms building locomotives. At least sixteen firms began building steam locomotives between 1844 and 1855. Another eighteen firms established before 1844 were still in business and at least a dozen railway companies were building locomotives. However, within a few years, the demand for locomotives had fallen well below productive capacity and there was a period of intense competition for the available business.[19] Moreover, competition from Continental manufacturers was emerging. In 1847, George Stephenson was expressing concern that 'some of the talented Continental men might take part of the business from England'. He had been to the Continent, and when he saw the locomotive building there, considered it would require all the talent in England to keep it in check.[20]

The refinement in the appearance of locomotives was accompanied by refinement in the design of passenger-carrying rolling-stock, albeit for different motives. The promoters of the earliest railways such as the Liverpool & Manchester Railway had in mind the conveyance of goods rather than people and they were taken unawares by the extent of the public demand for rail-travel. The volume of passenger traffic soon exceeded that of goods. The railway engineers delegated the task of designing the passenger rolling-stock to skilled coach-builders who derived the designs from the contemporary road equivalents, e.g. open brakes, closed road-coaches. Walker[21] provides a contemporary account of two designs from 1820:

> "The most costly and elegant contain three apartments, and resemble the body of a coach (in the middle) and two chaises, one at each end - the whole joined together. Another resembles an oblong square of church pews, panelled at each end, and the rail which supports the back so contrived that it may be turned so that passengers may face either way, and the machine does not require to be turned."

Subsequently, competition between the railway operating companies for the available passenger traffic seems to have been the main reason for the attention given to the external appearance and the interior design of railway carriages. As well as following road-coach practice in the construction of passenger rolling-stock, the railways also followed in the use of external liveries. The upper panels of coaches were usually black, the lower, yellow, green or red. Names were carried as on road-coaches. The intention seems to have been to bestow as much familiarity as possible on the externals of the coaches in order to reassure passengers undertaking their first rail journey. In due course, it became the practice for each railway company to have a distinctive uniform livery on its rolling stock together with a monogram of the company's initials. Traditional coach-building finishing was still followed, with great care taken over 'lining out', often in gold leaf edged each side with a fine vermilion stripe. Varnish was skilfully applied to achieve a mirrorlike surface.

In 1872, the Midland Railway imported Pullman railway carriages from the United States and introduced them to the British public. They became a symbol of luxury which has remained synonymous with the name of Pullman to the present day. They were of superior construction, had better riding qualities, and were finished with gilt work, velvet cloth, walnut panelling, and flower-patterned ceilings. Pullman carriages set the trend of British railway-carriage design in the last decade of the nineteenth century. Woods such as mahogany and oak were used for walls and partitions. For upholstery, leather, plush velvet, and moquettes were used. Ceilings were usually finished with relief mouldings. Windows, other than the main side windows, were decorated with etched patterns. The interior fittings, e.g. luggage-rack brackets, light-pendants, were of polished brass. The influence of Art Nouveau was detectable in some of these fittings but on the whole this style did not penetrate into British railways, as on the Paris Metro.[22]

Another important technological innovation occurred towards the end of the nineteenth century; the advent of powered private road transport. Like the railways, it was unaccompanied by the controversy about style and taste which had beset the manufacturers of household goods. Initially, the private motor-car was generally regarded simply as a new mechanical contraption, devised by mechanics and therefore not a subject for aesthetic debate. In outward appearances the early motor-cars were derivative, characterised by the inclusion of elements from other products, e.g. carriage lamps. Moreover, the configuration of the 'horseless carriage' owed even more to the horse-drawn carriage than the railway-carriage. Within only a few years, however, a distinctive configuration for the motor-car emerged which owed considerably less to the horse-drawn carriage even though car-body building was an off-shoot of the carriage-building trade. Subsequently, style related to especially the exterior form of private motor-vehicles was to engage the enthusiastic attention of almost the whole of the population, including the lowest levels in society. An urchin could accurately date by stylistic detail the model and make of a motor-car which, translated into commensurate knowledge of pottery or silverware, would rate as connoisseurship.

The motor-car manufacturing industry developed its own trade-orientated approach to embellishment of the product which owed nothing to the participants in the Arts & Crafts Movement or their successors. The firms had studios where new exterior forms for vehicles were developed by wage-earning employees described as stylists and styling engineers. Approved exterior forms - in fact, skins compatible with mechanical assemblies already developed - were then sculpted full-size in clay by model-makers, followed by painting and trimming to simulate the appearance of the finished product. This operation was under the control of a firm's engineering department. The approval of new models rested not with professional artist-designers but leading members of the Board of Directors of the manufacturing firms, e.g. William Lyons at S.S.Cars, Leonard Lord at the Austin Motor Company. British motor-vehicle manufacturers have only in recent times acknowledged college-trained industrial designers as potential recruits for their studios. Previously, they maintained that art college training failed to inculcate the discipline of the market-place or the organisational ethos of industry. The manufacturers arranged their own forms of factory-based trade-training for recruits to the studios and model-shops. Until recently, there was little or no contact between trade-trained 'stylists' and college-trained designers.

2.4 Style between World War I and World War II

Chermayev, a Paris-trained Russian artist, is credited with bringing the Modern Movement in design to Britain ten years after it began in Continental Europe. In 1928, he mounted an exhibition of modern furniture in a London store. Chermayev had decorated a bathroom in red and black and produced some room-settings with chromium-plated metal-tubing furniture and unit storage systems.[23] Rogers, in a plea to the Design and Industries Association to overcome its insularity, suggested that if Chermayev's work was supported by other designers and retailers, it could represent a turning point in the style of British household goods and good modern design would sweep the country.[24]

Some British manufacturers were moving with the times. For example, it was partly economics and partly a new attitude to architecture which prompted the Worcestershire firm of Gordon Russell to change its course from craft-made finely-detailed furniture to plainer mass-produced units. After training at the Architectural Association, one of the partners, Richard Russell, favoured the concept of bare functional design linked to mechanised production. From then onwards, the firm concentrated on low-priced furniture for serial production and also developed some radio-cabinet designs for Murphy Radio Limited. These cabinets, machine-made, economic yet presentable, were on the market for a decade, produced at the rate of 40,000 units per annum.[25] They served to present the major technological innovation of broadcasting by radio to the domestic consumer.

Russell[26] gives a contemporary account of the way in which industrial design influenced the development of radio receivers. Following the application of Marconi's invention to military communications during World War I, commercial radio was developed in the immediate post-war period. The Marconiphone Company broadcast its first programme in 1920. From the beginning, broadcasting had widespread popular appeal. Up to 1939, the annual production of domestic radio receivers in the United Kingdom was 1.5 million units, most of them manufactured by a dozen firms. Initially, the receivers were simply a haphazard assembly of components with a separate speaker horn, as gramophones had begun. The first important design change was the enclosure of the chassis in a casing with a control panel on the front but still with a detached horn-speaker. The second change, which set the trend in all subsequent designs of radio receivers, was the enclosure of the speaker and the chassis in one casing. Having achieved this simplification in form, all manufacturers for the next few years left the design of the casing to their own staff or to the staff designers of cabinet-making firms employed by them. Even though during this period nothing of aesthetic interest was produced, it became generally accepted that the radio receiver was a domestic product and no longer only a laboratory gadget.

Early in the 1930s, a new firm, Murphy Radio Limited, decided to apply modern design to its radio receiver cabinets with the aid of a consultant industrial designer. The first radios with these cabinets were launched in 1931-32 (Fig. 9). This design innovation was to have considerable influence on the design policy of the whole industry. In 1933-34, Ultra Electric Limited commissioned two architects (Chermayev and Wells Coates) to design cabinets for its radio receivers. These cabinets were produced in Bakelite (Figure 10). A significant result of this design innovation is that now industrial designers are employed by manufacturers of radio equipment as a matter of course. Just before World War II, the general standard of radio cabinet design in Britain was regarded as the highest in the world.

In an entirely different industry, Anderson, a member of the family firm which owned the Orient shipping line, decided to provide his customers with surroundings that looked more in keeping with the technological innovations in modern marine engineering. He took charge of the general design of two new ships; the Orion delivered in 1935 and the Orcades delivered in 1937. Anderson, assisted by a New Zealand architect O'Rorke, broke with the then prevailing style in ship decor and instead drew on the Modern Movement. In doing so, he set a new style in overall design and in fixtures and fittings for ship interiors. It was achieved only with difficulty; the traditional suppliers of fittings for ships could not provide items in the style of the Modern Movement.[27]

At about this time, Pevsner [28] carried out a study at Birmingham University under the supervision of Professor Sargent-Florence. In a survey of 149 manufacturers, 15 shops, 14 art schools, and 17 designers, artists and architects, he concluded that 90% of British products had no aesthetic merit and the aim of any campaign for better design could only be to reduce this percentage from 90% to 80% or 75%.

It can be seen, therefore, that the British Modern Movement in industrial design was the enterprise of individuals, involving a few champions actually in industry, like Anderson of the Orient Line, and a few designers and manufacturers. The designers were mainly architects and did not regard themselves as an integral part of the manufacturing industry; as yet, there was no formal training of industrial designers. During the 1930s, now eminent but then relatively obscure designers from the Bauhaus, a school in Germany which regarded crafts and industry as opposites and the function of handicraft to be industrial research, sought refuge in England from the Nazis; Gropius, Breuer, and Moholy-Nagy. Finding no response in Britain to their approach, they settled in the United States. Subsequently, however, emigres from the European continent who settled in Britain before and during World War II were to become leading figures in industrial design in Britain. Inevitably, they were influential in introducing a Continental dimension to industrial design in Britain.

2.5 Style During and after World War II

In 1942, the President of the Board of Trade (Hugh Dalton) convened a Utility Furniture Committee. From November 1942, the only furniture to be manufactured in Britain was Utility. Hundreds of small firms throughout the country, with all kinds of methods of production, were to make a single range of furniture under the control of a central committee, of which Russell, the furniture manufacturer from Worcestershire, was a member. In effect, it was state control of one category of product design. Dalton gave the Committee some directions: Utility furniture had to be soundly made of the best possible materials and pleasant in design. Russell's view of 'pleasant' was Modern and this was accepted by the Committee. After initial adverse public reaction, Utility significantly influenced the stylistic trend in British furniture design. Within fifteen years, the style was fashion and influenced the design of other household goods.

As mentioned in Chapter 1, Russell was appointed Director of the Council of Industrial Design in 1948 and almost immediately encountered difficulties. The manufacturers of household goods disliked selection by outsiders; they had full order books in the post-war boom and argued that if a product sold, it must be well-designed. The retailers resented their ability to select well-designed products being brought into question. Designers asserted that the Council's standards were too low; the manufacturers thought them too high.[29] Undeterred by this hostility, the Council promoted the idea of identifying by name designers of particular household products, e.g. Robert Welch stainless steel tableware. This cult of special objects for the home, chosen for their good design, first emerged at the time of William Morris in the nineteenth century and was a feature of the Arts and Crafts Movement. This elitism was fostered by sophisticated people through into the twentieth century.

As part of the preparations for the Festival of Britain, the Council of Industrial Design persuaded 28 British manufacturers to work for eighteen months in the Festival Pattern Group,[30] decorating products with patterns derived from crystal-structure diagrams, e.g. dress-prints based on haemoglobin, crystal-structure curtain fabrics, crystal-structure light-fittings, a crystal-structure foyer for the Science Exhibition. It was an attempt to link art and science through a style. It was part of what became known as the Festival style which soon degenerated into a cliche.

In 1957, a panel of judges at the Council selected twelve household products for the first Design Centre Awards; various categories of tableware, ovenware, cutlery, wallpaper, a curtain fabric, a carpet, a settee, a television receiver, a convector heater, and a lamp-shade. Given the Council's preference for the Modern Movement, it was inevitable that these award-winning products would be stylistically similar.[31]

This activity at the Council happened at a time when the cult of youth was on the ascendant in Britain; the pop group, the boutique; the concentration on the personal, the off-beat, and the jolly. It was said that this new image which Britain presented to the world from about 1961 onwards had its origins in the art schools, where there seemed to be no requirement to conform. The abandonment of the conventions of style and taste arose out of a newly-acquired confidence to please oneself, trusting only personal sensibility.[32] What began as a small and earnest movement soon became extrovert. This fashion made design more popular. The styles of Art Nouveau and William Morris came back into favour with a following much larger than they had in the original forms.

It was in this social climate that Conran, an industrial designer by training, opened his first design-orientated Habitat store in 1964. The influence of the Arts & Crafts Movement was evident but in effect Habitat was selling a coordinated design package as fashion.

In this time of 'swinging' London, the Council of Industrial Design was still trying to convert manufacturers to the wisdom of adopting a modern design policy. However, the style it favoured appeared rigid, sterile, and out of date when compared with the preferences of youth. In retrospect, Russell's successor as Director confirmed the Council's dilemma. Earlier it had been so much easier. The reformers of design were confident of their criteria; functional efficiency, fitness for purpose, truth to materials, and economy of means. Design Centre selectors had easily picked out good design from the bogus; there was a consensus of informed professional opinion in favour of direct, neutral solutions. Unintentionally, the Council had established its own sober neutral style which now looked rather dowdy and irrelevant. It seemed necessary, therefore, to loosen this attachment to permanent universal values and accept that a design may be appropriate at a given time for a given purpose to a given group of people in a given set of circumstances. Outside these limits, the design may be quite inappropriate.[33]

Blake[34] also regards the emergence of the Pop movement as a turning point in style; that it banished the idea of any single 'correct' approach to the aesthetics of design. Moreover, it put pressure on the then current 'functional' style. Some products, e.g. television receivers, were made to <u>look</u> functional but the style did not symbolise the function. The concept of function had been translated into bareness, simplicity, squareness or roundness, solidity, seriousness, and the impersonal. The Pop movement revealed not that an austere style is wrong but that different styles can co-exist.

It is against this background of change in consumer preference that changes took place at the Council of Industrial Design. It began to take an interest in industrial design related to machine tools, computers, and even heavy engineering. It seemed that the talent of British engineers, which a century earlier had produced design of high technical and aesthetic quality, had gone astray; since the days of Stephenson and Brunel, engineers appeared to have lost their sensitivity. However, there had been isolated pockets of improvement in some industries. For instance, in 1956 British Railways established a design panel which planned and coordinated all subsequent work in this field. Industrial designers were engaged to work with British Rail engineering and other staffs. The Design Research Unit, an industrial design consultancy headed by Professor Misha Black of the Royal College of Art, was commissioned to develop exterior designs for seven locomotives. Mather & Platt Limited, manufacturers of heavy electrical equipment, set up an industrial design unit in the firm and developed an approach based on three factors: simplicity, standardisation, and modern configuration. In 1958, only about six firms in the capital goods sector of British manufacturing industry employed an industrial designer. By 1968, over 200 firms in this sector were engaging industrial design consultants.[35] At about this time, Ashford, an industrial design consultant of good repute and a former tutor at the Royal College of Art, produced a studied dissention to this trend of professionalising industrial design in the engineering industry. With a carefully constructed theory of the aesthetics of engineering design, he argues against this matter being the province of only art college trained industrial designers; engineers are well-placed to deal with the aesthetics of engineering products if only they will take the matter seriously.[36]

The 1960s saw the advent in Britain of large general design consultancies, undertaking commissions in product design, graphic design, corporate identity, and exhibitions. Alongside this, with the kind of contradiction which has recurred from time to time in design, a cult of individuality emerged. No doubt influenced by Schumacher's philosophy and kindred movements, individual enterprise in design surfaced. Designer-manufacturers and designer-shopkeepers set up in business. For others, it was a period of moral fervour, asserting the right to design according to the dictates of conscience by improving the lot of the handicapped at home and the underprivileged abroad.

The 1970s witnessed a development which has profound consequences for both industrial design and engineering; the advent of computer-aided design. It has already made a visible impact on style in motor vehicles. Moreover, as a result of this technological innovation, working practices in engineering manufacture are undergoing significant change; for instance, engineering draughtsmanship is already becoming a redundant trade.

During the 1970s also, international competition in manufactured goods intensified. In addition to the traditional rivals in trading - the French, the Germans, the Americans and the Japanese - British manufacturers also experienced competition from the emerging industrial economies in the Far East. It became apparent that once technology has crystallised into hardware, even nations with only a short history of industrial manufacture can soon become formidable competitors. The realisation has come rather late to both government and manufacturers that rather than attempt to compete on price in existing product categories in such trading conditions, a wiser course for mature economies like Britain is to more fully utilise its trained manpower and produce entirely new high-technology products of exquisite design.

2.6 Evaluation

(cf.2.1) In Chapter 1, industrial design is identified as being at the interface of user and product. This chapter identifies industrial design as being at an interface of a different kind; that of art and technology in manufacture. Due to a variety of influences, polarisation is a characteristic of modern society; between capitalism and communism; between democracy and totalitarianism; between developed and underdeveloped economies; between work and leisure; between art and science; between art and technology. Snow wrote at length on the polarisation of the two cultures. Specialisation, though an effective means of accelerating the accumulation and development of organised knowledge, is one of the influences which has induced polarisation. It has resulted in points of discontinuity between domains of specialisation, the practical effect of which is a low level of understanding and communication between them in a world which works better as a continuum. Interdisciplinary studies are an attempt to both bridge the gap between specialist domains and to heighten the level of communication between them but in the main this development has been confined to academic work. There is also a need for it in practical work. Nowhere is this more evident than in engineering product manufacture. Industrial design has the potential to be a practical interdisciplinary activity, a bridge between art and technology, but it is still far from realising that potential.

The main weakness of industrial design is the absence of an authoritative repository of organised knowledge from which to husband a paradigm. The Society of Industrial Artists and Designers, the chartered professional organisation for industrial designers in the United Kingdom, is primarily concerned with promoting and protecting the interests of its members; it is not a learned society. The Design Council, like its predecessor the Council of Industrial Design, is a state-sponsored promotional body allied to the Department of Trade; unlike a number of similar organisations in Continental Europe, it does not have a research function. Polytechnic institutions are the custodians of industrial design education in the United Kingdom but the mode of instruction follows the traditional pattern of art colleges; essentially practical training in design techniques with minimal recourse to theory or the literature. There is a literature of industrial design but it is diffuse. Because the practical manifestations of industrial design are superficially similar to those of mechanical engineering, the tendency is to assume that the two activities have the same root; that the way to increased intellectual rigour in industrial design is through the inculcation of engineering theory. The findings of this study challenge that assumption. The role of industrial design in technological innovation transcends its practical connections with engineering. A more meaningful affinity is within the domain of technology policy studies, where the interface of art and technology in manufacture can be studied with a greater degree of objectivity.

(cf 2.3) Even though ornamentation is usually regarded as a norm of nineteenth century product design, it is evident from the testament of contemporaries that at the time it was a source of contention between industrialists and authoritative opinion on design. Evidently some industrialists regarded extravagent ornamentation of machine-made products, made possible by precision casting techniques, to have commercial value; for their part, the design pundits contended that the aesthetic content of a product should stem from its utility. The argument, which has overtones of taste, persists in a modified form to this day, and has implications for the role of industrial design in technological innovation.

Though the study of aesthetics does not feature in the formal training of engineers, they are often in a position to influence the aesthetic content of a new product simply because of the personal opinions they hold and the decisions they make during the development phase. Most engineers, though not all, acknowledge that the appearance of a product has a bearing on its acceptance in the market-place but their response to the issue varies. Some engineers are of the opinion that appearance is a non-issue; a fait accompli of mechanical assembly. Others subscribe to a crude variant of that held by the nineteenth century design pundits who contended that the appearance of a product should stem from its utility; they invoke a maxim, 'If the engineering is right, it looks right'. This holds that a design based solely on sound engineering considerations will yield automatically a product with good visual qualities. Conversely, poor engineering yields poor visual quality. Deliberate visual manipulation is regarded as disingenuous. To substantiate this viewpoint, it is customary to refer to examples where the engineering reveals intrinsic elegance; a turbine rotor, an aircraft fuselage, a suspension bridge. However, a contradiction emerges when the external form of the engineered hardware is not derived from mathematical curves, as it is in the particular examples just cited. Though the conscious aesthetic approach to form is eschewed on the grounds that it in some way demeans the engineering, many engineers who design configurations empirically have developed subconscious habits in their draughtsmanship which associate 'looking right' with geometry and symmetry. A configuration based on these factors is sometimes imposed on a design even when they have no relevance to the function of the product. Some engineers deal with external appearance consciously, albeit by cosmetic treatment of the mechanical arrangement which emerged during the technical development of the new product; for instance, by encapsulating the mechanical assembly in a brightly-coloured sheet-metal casing. The terminology used by engineers to describe this method of dealing with external appearance suggests a certain flippancy: 'tarting-up' the product;

giving the product a 'face-lift'; 'styling' the product. In effect, it is a tacit admission that the visual quality of the technical design is poor and which they attempt to remedy by a form of ornamentation. Simply to assume, therefore, that an engineer can deal adequately with the aesthetic content of a new product is to risk introducing avoidable uncertainty into the innovation process. At best, his interest in this aspect of the design is marginal to his main technical responsibility, his perspective of its objectives narrow, and his capability limited.

(cf 2.3) The Arts & Craft Movement did not succeed in its objective of stemming the tide of industrialisation, either in Britain or other countries where its influence was felt. Besides, there was naivety and romanticism in the idealism of Morris and his friends, all of whom had a background of social privilege. Their idea of having a mission to preserve a purist tradition in the hope that one day the people would reject industrialisation and return to a pastoral life was a fantasy. For the people whose lot they purported to champion, industrialisation and mechanisation were the lesser evils; though ugly, they offered hope of a better life to come. Though Morris perceived humanity being threatened by the tyranny of machine-made mediocrity, that was preferable to the tyranny of mass poverty; a hungry man is unlikely to be preoccupied with the aesthetic quality of his empty feeding-bowl. Moreover, through economic necessity Morris was deflected from his goal of egalitarianism in good design and instead became the focus of an elitist cult. As indicated by commentators at the time, the goods his company produced were too expensive for the ordinary man in the street. Traditionally, art has been sustained by patronage of one form or another and Morris did not succeed in breaking that mould.

However, the Arts & Crafts Movement left a legacy. It succeeded in creating a fresh simple style, an appreciation of high quality in household goods, and a respect for craftsmen's handwork. Though British manufacturers generally were slow to respond, German manufacturers did so under the enlightened leadership of the Prussian government. They created a buoyant home market for machine-made household products of good design which is now part of the German tradition; this has influenced other sectors of product manufacture such as technical equipment and which has proved to be an asset in the competitive conditions of today. Also, the practice in England of freelance industrial designers operating from their own small studios and workshops had its beginnings in the Arts & Crafts Movement.

(cf 2.3) There seems little doubt that the early forms of product differentiation and presentation in British locomotives of essentially similar technical design were prompted by competition within the industry. In Chapter 1, mention is made of the crudeness and lack of form in the early locomotives; attractive appearance is not a 'natural' attribute of locomotive technology. Notably Stephenson the younger sought to refine the appearance of his locomotives, the aesthetic content stemming from their utility, but this seems to have been exceptional during the experimental period of the railways. However, it is instructive to compare the development of locomotive design in which engineers of stature were directly involved and the derivative designs of passenger rolling-stock supplied by sub-contractors. It seems the railway pioneers were caught unawares, expecting mainly goods rather than passenger traffic. The configurations to accommodate passengers were hurried improvisations of existing products but which nevertheless set a firm trend in the design of this category of rolling stock. The result was discontinuity. Though designs were refined to create visual continuity between locomotive and tender, there was an abrupt discontinuity of form between the power unit and the rest of the train. A lengthy period elapsed before the concept of the unit train emerged. The example of locomotive design illustrates the error of being hasty with generalisations about national characteristics in product design. Though British manufacturers of household goods lagged behind their Continental rivals, the manufacturers of locomotives did not. Steam locomotives of British design established an early lead with a distinctive refined appearance and which set them apart from Continental designs until the demise of this form of traction in the 1960s.

(cf 2.3) The introduction of the motor car is an example of innovation which has few if any equals in the extent of its social impact on the world at large; the details are so well-known that further elaboration here would be superfluous. However, the widespread appeal of style related to both the exterior form and the interior fitments of the modern motor-car is relevant to this study. It indicates that form is capable of stimulating interest in an engineering product to such a degree that for many, the stimulus transcends the raison d'etre of the product. The public interest in new models of motor-cars relates primarily to form and configuration rather than technological improvements. Today, the motor car is perceived by many as a piece of sculpture. Possession of a particular model has connotations of the personal taste and the social status of the owner.

In these circumstances, it is reasonable to suppose that those with a professional interest in industrial design - the Society of Industrial Artists and Designers, the Design Council, the industrial design consultants, and the teachers in art and design colleges - would have been quick to identify the potential of this groundswell of popular interest in form and to have participated; contributing to the design of new products and helping people to heighten their level of appreciation. In the event, they did not do so and have only recently dropped their earlier reluctance to acknowledge the motor car as a subject amenable to industrial design. The first industry-sponsored course in industrial design related to motor vehicles started at the Royal College of Art only in 1975. Prior to this, it was the custom of teachers in colleges of art and design to dissuade students from embarking on a career in the motor industry. The first Design Council Award to a motor car was made in 1970. British motor car manufacturers have engaged consultants for car-body design since the 1950s but have obtained this outside assistance from mainly Italian studios, e.g. Pininfarina, Ghia. It seems that until recently the British industrial design fraternity regarded the ethos of car design as too commercial for their taste; a vulgar response to the Philistine demands of a mass market. At first, there was an attempt to sustain industrial design as a genteel profession, purveyors of tasteful refinement for discerning customers in the tradition of the Arts and Crafts Movement. However, it seems that this ostensibly moral stance concealed other considerations. Close involvement with the motor manufacturers, which already had their own in-house facilities for designing new models, would inevitably invite odious comparisons between the work of tradesmen such as model-makers and the contribution of consultants. However, for the same reason that distinguished actors abandoned their earlier moral objection to appearing in commercial advertisements on television, so British industrial design consultants of repute no longer spurn commissions from motor manufacturers. A class structure is also evident in other fields of artistic design. For instance, a distinction is made between a trade-apprenticed cabinet-maker and a college-trained furniture designer even though their activities overlap. A similar distinction is made between trade-apprenticed paintresses in the pottery industry and college-trained ceramic artists.

(cf 2.4) The Design and Industries Association, though one of the oldest organisations of its kind and still in being today, has had little if any direct influence on style. Though it began as a cohesive splinter group of the Arts & Crafts Movement, it lacked a leader with the dynamism of Morris, its membership became diffuse, and the organisation came to adopt an insular, clubbish vision of a design ideal which owed much to the taste values of the English upper classes. Its main achievement, if it can be so described, was to act as custodian of some of the idealism of the Arts & Crafts Movement which subsequently influenced the approach of the Council of Industrial Design in its role as the state-sponsored promoter of good design.

Evidently the support Rogers sought to sustain the Modern Movement in Britain was not forthcoming; modern design did not sweep the country. Even today, furniture in the style of the Modern Movement dating from the 1920s and now available in reproduction form is still regarded as too modern by many personal shoppers. Though the style of the Modern Movement is now the norm in new business premises, it has not ousted the vernacular style in private households. In their preference for interiors, the British are incurable romantics and hanker after the cosiness of the country cottage.

In practice, the so-called rational aesthetic, difficult to distinguish from the style of the Modern Movement, shows itself to greatest effect in functional products. It is a visual style which complements technical function simply because it looks both functional and economic, in contrast to ornamental styles which suggest opulence and romantic extravagence. Almost inevitably, it is the preferred style for professional equipment and is likely to remain so. The apparent simplicity of the style is deceptive. It is not 'natural' to technology; it has to be consciously developed and controlled through aesthetic manoeuvre of the visual elements in the configuration. Handled with subtlety, the style is capable of projecting an impression of refinement, restraint, and high quality. Handled inexpertly, the style is capable of projecting an impression of crudeness and cheapness.

(cf Figures 9 and 10) It is instructive to note the difference in the approach of Russell and Chermayev-Coates to radio cabinet design, influenced to some extent by the materials used. With the former, made exclusively of wood, the radio receiver is given a low profile as an instrument and instead is presented as an item of contemporary furniture suitable for any room. With the latter, made in plastic, the radio receiver is given a high profile as an instrument, presented as an elegant object in its own right. This is an example of the phenomenon referred to earlier in this chapter, namely, that the aesthetic element in design cannot be characterised as incremental or developmental (cf 2.1); rather, it reflects contemporary attitudes which at any point in time may have a number of preferences. Another example is the television receiver. Today, it is simultaneously presented as an item of contemporary furniture, as an item of period furniture, and as a high-technology instrument.

(cf 2.5) Evidently the same phenomenon appeared in a more generalised form in the 1960s, when the cult of youth in effect challenged the values of the Council of Industrial Design and kindred institutions. Until then, the design pundits inferred that in truth there is at any point in time a single mainstream trend in style, the general direction of which is determined by leading professionals of the day, even though there are eddies of past styles and a vernacular at the periphery. Blake's contention that the Pop movement revolutionised style is a misapprehension. The evident plurality of trends simply ousted the dogmatism of the design pundits. They were obliged to perceive stylistic preferences differently; what previously they regarded as Philistinism became part of the orthodoxy.

(cf 2.5) Though the emphasis on the designer of the product may have been meaningful for followers of the Arts & Crafts Movement, the same elitist, rather clubbish practice of the Council of Industrial Design relative to selected mass-produced household goods was confused, misleading, and at times counterproductive. The individuals named by the Council as the designers of the products were actually industrial design consultants who had made a mainly aesthetic contribution. However, the Council was not entirely to blame for this practice. It was aided and abetted by the industrial design consultants, for whom it was commercially advantageous to have their names associated with products. For them, it was an indirect means of advertising their services without cost at a time when a professional code of conduct disallowed direct advertising. Later, relative to capital goods and professional equipment, this issue proved to be a divisive irrelevance and may even have retarded the acceptance of industrial design as an element in technological innovation. By naming only the industrial design consultant, the Council appeared to be placing undue emphasis on the aesthetic aspect of design and disregarding or even belittling the contribution of engineers. Moreover, the inference that users of products in this category would be impressed by the name of an industrial designer bordered on the perverse. Bowing to pressure from the engineering fraternity and manufacturing firms where it is the custom for employees to remain anonymous, the Design Council has all but abandoned this practice. Moreover, the industrial design consultants now have less cause to press their interest following the Monopolies Commission Report on the Professions which in effect lifted the ban on direct advertising.

(cf 2.5) Whether this newly-acquired interest of the Council of Industrial Design in capital goods was a direct result of the challenge of the Pop movement, whether it was simply part of a policy of expansion by the new Director, or whether it was a response to an approach by a delegation from the professional engineering institutions, perhaps will never be known. The decision probably stemmed from a combination of these factors. Whether or not it was realised at the time, capital goods offered the Council an opportunity to adopt a new raison d'etre at a time when its role as a promoter of good design in existing types of household goods was becoming increasingly irrelevant. Instead of being simply an agency for style and good taste in existing products, there was an opportunity to identify and promote the complex role of industrial design in the development of entirely new science-based products. Probably because it was uncharted territory, the Council fudged the issue. Instead of giving a clear lead as an activist in the field of technological innovation, it took the more pedestrian course of wedding its interest in industrial design to the orthodoxy of engineering. Nevertheless, the outlook is favourable. More recently and with a further change of Director, there are signs that the Council has belatedly grasped the opportunity to promote the role of industrial design in innovation, as is shown later.

The chapters which follow present empirical evidence to not only give substance to the role of industrial design in technological innovation but also to identify the conditions which must prevail if it is to be a harbinger of commercial success.

Figure 2. Mantel-shelf clock shown at the 1851 Great Exhibition.

Source: Francis McNally.

Figure 3. The locomotive 'Lancashire Witch'. Circa 1829. Stephenson's first attempt to improve the appearance of his locomotives.

Figure 4. The locomotive 'Rocket'. Circa 1829.

Source: Haresnape B.[15]

Aston University

Illustration removed for copyright restrictions

Figure 5. The 'Planet' locomotive. Circa 1830. The overall design has a visual simplicity which became a characteristic of Stephenson's locomotives.

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Illustration removed for copyright restrictions

Figure 6. The 'Patentee' locomotive. Circa 1834. Manufactured by Robert Stephenson & Company. Visually, the engine and tender seem to belong to one another.

Source: Haresnape B.[15]

Aston University

Illustration removed for copyright restrictions

Figure 7. The 'North Star' broad-gauge locomotive. Circa 1838. Ordered by I K Brunel from Robert Stephenson & Company for the opening of the Great Western Railway.

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Illustration removed for copyright restrictions

Figure 8. The 'Jenny Lind' locomotive. Circa 1852. Designed by David Joy and built by E B Wilson of Leeds for the Midland Railway. The influence of Stephenson's 'Patentee' (Figure 6) is apparent.

Source: Haresnape B.[15]

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Illustration removed for copyright restrictions

Figure 9. Radio cabinet. Circa 1931. Designed by R D Russell for Murphy Radio Limited.

Aston University

Illustration removed for copyright restrictions

Figure 10. Radio cabinet in Bakelite. Circa 1933. Designed by Chermayev and Wells Coates for Ultra Electric Limited.

Source: Newman W.H. [26]

CHAPTER 3

EMPIRICAL EVIDENCE : THE METHODOLOGY

3.1 Introduction

This is an exploratory study in a field which previously was virtually unexplored. The empirical evidence presented aims to identify what actually takes place in successful firms when industrial design is allocated a role in the process of technological innovation. Since both design and its apprehension are very individualistic, compiling a number of case studies is considered to be the most appropriate mode of investigation.

Before selecting the particular products for the case studies, the type of product was selected. For a product to be within the domain of technological innovation, a prerequisite is that it is science-based. (cf 1.1). By selecting equipment used for industrial and professional purposes, the vagaries of the consumer market are eliminated. Therefore, it was decided that science-based equipment used for industrial or professional purposes would be appropriate.

Having selected the type of product to be investigated, it remained to select the particular products. The Design Council proved to be a source of information about products of the type sought, manufactured by firms in which personnel could meaningfully discuss the role of industrial design in technological innovation. The Council operates an annual Design Awards scheme. There are various product categories in the scheme, including engineering products and medical equipment. The engineering products category includes all types of industrial machinery; mechanical, electrical and electronic equipment;scientific instruments; processing equipment; mechanical handling and construction plant; machine tools and agricultural equipment. The medical equipment category includes that used for scientific analysis, diagnosis and treatment; health care equipment; aids for the disabled; patient-handling equipment; artificial limbs; dental equipment; ophthalmic equipment; equipment designed specifically for education and training in the professional aspects of medicine.

To be eligible for a Design Council Award, a product must have been designed and manufactured by a British firm and should have been in production and service long enough to enable reliable user reports to be obtained. The judging panels use the following criteria to assess the products: design innovation; manufacturing advantages, including effective use of materials and resources; industrial design; service performance and reliability; commercial impact. Engineering products are expected to show general benefit to the British economy and the environment. Medical equipment is expected to show general benefit to medical science.

The Design Council agreed to allow access to its records of award-winning products. The records comprise photographs of the products, details provided by the firms on the Award Scheme entry forms, and Press notices released at the time when the Awards were made. The products shown in Table 1 were selected from the records. The Council also provided details of the appropriate personnel to be contacted at the firms.

TABLE 1 : SELECTION OF PRODUCTS WHICH HAVE RECEIVED A DESIGN COUNCIL AWARD

Product	Manufacturer	Year of Design Council Award
Maylite ophthalmoscope	Gowllands	1977
Micro 2000 electronic micrometer	Moore & Wright	1978
Magnascan 550 colour scanner	Crosfield Electronics	1978
M85/M86 scanning micro-interferometer and microdensitometer	Vickers Instruments	1975
Stereo Three microscope	Ealing Beck	1976
F30 gas chromatograph	Perkin Elmer	1974
SL75-20 linear accelerator	MEL-Philips	1978
Perkins applanation tonometer	Clement Clarke International	1975
Airstream anti-dust safety helmet	Racal Amplivox	1978

It was decided that semi-structured interviews with senior personnel in the innovating firms, industrial design consultants, and professional users would be the most appropriate means of obtaining the evidence required. It was intended by this means to exercise control over the direction and content of each interview without excluding unforeseen contributions from the interviewee. Moreover, it enabled each interview to be completed within a time scale which acknowledged that the interviewee would otherwise be engaged in commercial activity.

The evidence sought was not only factual data but also opinions, attitudes, preferences, and prejudices. The innovation process proceeds from decisions and these are often based on such diverse factors. With this in mind, a list of issues for discussion with each category of interviewee was compiled, the details of which are shown as agenda in 3.3, 3.5, and 3.7. The appropriate agenda was sent in advance to each interviewee, alerting him or her to the issues to be raised. The agenda also served to control the interview in a way which facilitated correlation of the findings. However, some flexibility is desirable if an interview is also to yield the unexpected and the interviewee encouraged to be expansive. The aim was to create a climate for the dialogue such that an interviewee would also provide evidence beyond the confines of the agenda.

3.2 Evidence from Innovating Firms

The issues raised with the interviewees in the innovating firms are in two broad categories: the firm and the product, details of which are shown in 3.3. The human environment in which innovation takes place is considered to be significant and this is confirmed by Freeman. Innovation entails a process of coupling creative dialogue during research and development, and during the introduction of the new product. In an established firm, this process of coupling links and coordinates different sections, departments, and individuals.[1] Moreover, providing a contextual background to each case study illustrates by example the manner in which innovation proceeds. The findings are presented in Chapter 4.

3.3 Issues for Discussion with Interviewees at Innovating Firms

3.3.1 The Firm

1. Size of firm, e.g. number of employees, market share. Whether an independent firm or a Group subsidiary.

This is an attempt to establish whether the size of a firm and its corporate affiliation has any bearing on the employment of industrial design services. Freeman indicates that the relative contribution of large and small firms to innovation varies considerably between industries; in the field of scientific instruments, for instance, new small firms make outstanding contributions. It is to be expected that a large firm, or a firm which is a member of a Group, is more aware than a small independent firm of the range of services available to industry; it is more likely to have evaluated the contribution, if any, that industrial design can make to innovation; it is more likely to have a formal organisational structure within which there is a clearly-defined role for industrial design.

2. The business strategy of the firm and its bearing on the design/product policy.

This is an attempt to identify the strategy a firm adopts towards innovation; to establish if it also has a related design policy.

3. The rating of product presentation in the firm's approach to technological innovation.

The term 'product presentation' signifies the presentation of technology in the form of a product which also satisfies the wider needs of the user. It allows for the possibility that a firm may present the technology in this way without actually describing the activity as industrial design. The term 'industrial design' is associated with a particular occupational grouping; a firm may apply the principles of industrial design without actually employing an industrial designer.

4. The extent to which industrial design is regarded as a significant element in successful innovation.

This is an attempt to test the hypothesis that industrial design plays a significant role in the innovation process. It may not be an absolute issue, varying between firms according to awareness of and attitude to product presentation generally and industrial design in particular. It is to be expected that a firm with a record of successful innovation has accorded industrial design an appropriate role, if any.

5. The particular contribution of the industrial designer in the innovation process.

If a firm employ an industrial designer, it is to be expected that his contribution is specific. It cannot be assumed, however, that an industrial designer's contribution is the same in all firms; depending upon what a firm's management considers this contribution to be, it is likely to vary between firms. For instance, engineers are capable of perceiving design in different ways and this may have a bearing on the tasks allotted to an industrial designer in any particular firm.

6. The level in the firm's management structure at which the industrial designer operates.

The results of the SAPPHO project[2] indicate that the responsible individuals in successful attempts at innovation are usually more senior and have greater authority than their counterparts who fail; senior personnel have the influence to overcome difficulties and opposition which would prove unsurmountable to those of lesser status. It may be that there is a parallel in respect of design. Since firms are capable of assigning the design function to technicians, it may be more effective if championed at a senior level; for instance, the authority to exercise control over the implementation of design proposals may be a decisive factor.

7. The background to the firm's employment of industrial design services, e.g. in response to competition, to take the initiative in the market.

Because industrial design services are not widely used in the United Kingdom, it is pertinent to establish the manner of their adoption and diffusion among those firms which do so.

8. The management's perception of an industrial designer's function, e.g. a stylist, a spokesman for the user.

9. The management's assessment of the merits of employing a design consultant rather than an in-house designer.

The practice of firms employing design consultants is a controversial issue. The employment of consultants generally can be a source of friction in firms. However, the results of the SAPPHO project[3] indicate that successful innovators make more effective use of outside technology and scientific advice. It may be that they also make more effective use of outside design expertise.

10. The significance, if any, of the personality of an industrial designer in relation to his function.

3.3.2 The Product

1. The extent of the involvement, if any, of the industrial designer during the formative stages of the project.

In any project, it is usual for specialist contributors to maintain that consultation should take place during the formative stages. It is said that by this means the specialist contribution can be both creative and efficient. If initial involvement takes place after the project has 'crystallised', the full potential of the specialist's contribution may not be realised. For instance, his contribution may be restricted by constraints imposed earlier by other participants in the project or his contribution may be limited to the rectification of adverse effects.

2. The extent of the interaction between the industrial designer and research and development personnel.

This is an attempt to establish whether or not an industrial designer's proposals prompted further research and invention; whether he was a support for R & D within the firm.

3. The extent of the interaction between the industrial designer and mechanical engineers and/or engineering draughtsmen.

This is an attempt to establish the extent of an industrial designer's involvement in determining the configuration of a product and in detailing. Traditionally, the in-house design function in a firm is part of its engineering capability. The function is usually centred on a firm's drawing office, which is staffed by development engineers, engineering designers, and draughtsmen. In many firms, the office is under the control of the chief engineer. Depending upon the role assigned to an industrial designer, he may have the authority to oversee the production of dimensioned working drawings to ensure that his proposals are accurately interpreted by a firm's draughtsmen. Conversely, the development engineers may have the authority to modify the industrial designer's proposals. This overlap in function between industrial design and engineering may be a source of fruitful cooperation or a source of friction.

4. The extent of the interaction between the industrial designer and product planners and production engineers.

This is intended to establish whether or not an industrial designer influenced the choice of materials and production processes. Compatibility between design proposals and production feasibility makes for efficient manufacture. A designer may have to work within the constraints of a firm's existing production facilities; alternatively, the opportunity is sometimes taken during new product development to introduce into the firm new materials and processes. Whatever the decisions relative to materials and processes, a product should be capable of being manufactured efficiently.

5. The extent of the interaction between the industrial designer and marketing, sales and advertising personnel.

This is intended to establish whether or not an industrial designer influenced the form of presentation of information to potential users through sales brochures and handbooks. The industrial design profession maintains that there should be continuity between the design of the product and that of the packaging, the sales brochures, and the advertising material.

6. An indication of the cost of industrial design services as a proportion of the total cost of development of the product and/or in absolute terms.

7. The effect of winning a Design Council Award.

3.4 Evidence from Industrial Design Consultants.

Each industrial design consultant was interviewed separately at his own premises. The issues raised correspond broadly with those raised with the interviewees at the innovating firms. In each case, the object was to obtain evidence on the same subject, i.e. the project which resulted in a particular new product, from a different standpoint. This evidence would either corroborate or refute the evidence of the interviewee(s) at the innovating firm. In addition, a number of issues of a more general nature related to innovation were raised with the consultants in order that their evidence on particular cases could be placed alongside their broader views. Details are shown 3.5. The findings are presented in Chapter 4.

3.5 Issues for Discussion with Industrial Design Consultants.

3.5.1 The Firm

1. Your understanding of the firm's design policy.

2. Your impression of the firm's attitude towards industrial design.

3. The level in the firm's organisational structure at which you operated.
Rider in 3.3.1.6 applies.

4. The background to your association with the firm.
Rider in 3.3.1.7 applies.

5. Your relationships within the firm. In particular, your relationship with the firm's engineers.

Engineers have a central role in technological innovation and they often have an enabling role relative to industrial design. Some engineers in firms are opposed to the engagement of industrial design consultants because they feel it is an intrusion on their work. The relationship between the industrial design consultant and the firm's engineers is therefore a significant issue.

3.5.2 The Product

1. The extent of your involvement, if any, during the formative stages of the project. For example, did you participate in formulating the concept of the product?
Rider in 3.3.2.1 applies.

2. The extent of the interaction between you and the firm's research and development personnel. For example, did your proposals result in further research, development, or invention? Were you a support to R & D within the firm?
Rider in 3.3.2.2 applies.

3. The extent of the interaction between you and the firm's engineers and draughtsmen. For example, were you involved in determining the configuration of the product; in the design detailing?
Rider in 3.3.2.3 applies.

4. The extent of the interaction between you and the product planning and the production engineering personnel. For example, did you influence the choice of materials and production processes?
Rider in 3.3.2.4 applies.

5. The extent of the interaction between you and the firm's sales, marketing, and advertising personnel.
Rider in 3.3.2.5 applies.

6. Your particular contribution.

3.5.3 General

1. Your views about the role of industrial design in technological innovation.

2. The significance of industrial design relative to product categories.

This is an attempt to establish whether industrial design is more significant for some product categories than for others; and if so, whether the particular product categories can be identified.

3. Design techniques and design innovation.

This is an attempt to establish the extent to which a consultant is able to make a contribution embodying invention rather than solely the application of design techniques.

4. Foreign competition.

3.6 Evidence from Professional Users.

The commercial success of a product ultimately depends upon customers purchasing it. The factors which influence a customer to purchase a particular product, and one firm's product rather than another, should therefore be of special interest to innovators. Formerly, it was common practice for a firm to design, develop and manufacture a product then set about finding customers for it. In recent times, with a view to lessening the risks in this approach, many firms now try to establish the customers' needs first, then set about developing a product to satisfy them. While commercially the latter approach seems the more sensible, it is not a recipe which guarantees success. This so-called market-led approach assumes that purchasing is a rational activity, that customers know their needs generally and can accurately specify a product which will satisfy them. Moreover, it is not enough for an innovator to know that, for instance, customers need a particular scientific instrument with a certain technical specification and that they are prepared to pay a certain sum for this product. A firm also needs to know the factors which influence a customer to purchase one make of the instrument rather than another with a similar specification when both are available. When they have a choice, customers may not simply compare prices.

Whilst a key to commercial success is for a firm to know the purchasing patterns for its products, it is difficult to identify with certainty these patterns for science-based equipment used for industrial or professional purposes. For instance, many scientific instruments are the property of organisations and therefore not purchased by the individuals who actually use them. However, independent ophthalmic opticians are a professional group who both use and purchase scientific instruments. Bearing in mind that the sample of Award-winning products selected includes two ophthalmic instruments, it was decided to investigate the purchasing preferences of a sample of independent ophthalmic opticians. It was realised from the outset that any findings from the enquiry would not necessarily apply to scientific instruments in general. Nevertheless, the findings may provide some useful indicators for innovating firms.

An approach was made to the Department of Ophthalmic Optics at the University of Aston in Birmingham with a view to enlisting the cooperation of the academic staff in the enquiry and using their good offices to obtain introductions to practising independent ophthalmic opticians. Key members of the staff[4] agreed to participate in pilot interviews and to effect introductions to practising members of the profession on the Ophthalmic List of the Birmingham Area Health Authority.

Each optician was interviewed separately by appointment in his own consulting room. The issues raised are in two broad categories; general considerations related to the choice of ophthalmic instruments and the factors which influenced choice in particular cases. The details are shown in 3.7 and Table 2 respectively.

Pilot interviews with staff in the Department of Ophthalmic Optics at the University of Aston in Birmingham suggested that the following are the main factors that influence choice when purchasing particular instruments: lowest cost; terms of trade; value for money; best technical performance; industrial design features. 'Terms of trade' covers discount, extended credit and leasing. Value for money is defined as facility/cost. 'Industrial design features' covers configuration, overall appearance, 'feel' and handling characteristics, and finish. Subsequently, the following additional factors were identified by opticians during interviews: reputation of the manufacturer; familiarity from training; portability. It was realised that while an optician may have purchased a particular make of instrument for one very definite reason, e.g. lowest cost, he may have purchased others for more than one reason, e.g. value for money, industrial design features, and familiarity from training. Where there was more than one reason for purchase, interviewees were asked where possible to distinguish between primary and secondary factors.

A preliminary interview with an independent ophthalmic optician indicated that a practice is equipped with many scientific instruments. (See Table 4). Arising from this experience, it was realised that it would be impractical to expect every optician in the sample to provide an analysis of purchasing preferences for every scientific instrument in his inventory. It was decided, therefore, to restrict the enquiry to five instruments in common use; a focimeter, a slit-lamp biomicroscope, a keratometer, a hand-held ophthalmoscope, and a tonometer.

The evidence obtained from the independent ophthalmic opticians is presented in 4.2

3.7 Issues for Discussion with Independent Ophthalmic Opticians.

1. When you purchase ophthalmic instruments, is it your experience that you can choose between competing makes?

2. Is 1 too general a statement; does it apply to some instruments and not to others? Can you state the types of instrument where there is no choice?

3. For the types of instrument where there is choice, is elegance a factor which influences your choice; in terms of (a) appearance (b) handling qualities (c) general compatibility relative to both you and your patient?

4. Is your expectancy in respect of elegance heightened by the standard of design of competing American, Japanese, and West German products?

5. Can you comment on British manufacturers of ophthalmic instruments, either generally or in respect of particular firms?

6. Has elegance in ophthalmic instrumentation a utility value; is it a means of projecting a modern efficient image?

7. Do you have any views about imagery relative to your work, working environment, or instrumentation?

8. Can you comment on the following proposition?
There are three stages in the evaluation of ophthalmic instruments:

a. good general appearance stimulates initial interest;

b. high tactile quality and 'feel' strongly reinforce initial stimulation;

c. response to technical facility and performance is strongly influenced by feel.

9. Do you regard your instruments as an extension of your person and personal skill? If so, is this reflected in your purchasing policy; do you choose the best, the highest quality?

10. It is said that there is a high degree of job satisfaction in ophthalmics which is closely linked with the use of instruments equipment, and gadgets.[5] Is this so? If so, have you a favourite item? Can you describe the features that make it pleasurable?

11. Have you any further comments about the design of ophthalmic instruments?

TABLE 2. FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : SPECIMEN

						Factors influencing choice: order of preference.								Name of optician
														Date of interview
Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features				Remarks
Focimeter														
Slit-lamp microscope														
Keratometer														
Hand-held ophthalmoscope														
Applanation tonometer														

CHAPTER 4

EMPIRICAL EVIDENCE : THE CASE STUDIES

4.1 General Introduction

There are seven case studies. The starting point of each one is a product which has received a Design Council Award. The products are respectively an ophthalmoscope, an electronic micrometer, an electronic colour scanner, a scanning micro-interferometer and micro-densitometer, a stereoscopic microscope, a gas chromatograph, and a linear accelerator. Each case study is developed and evaluated in turn.

4.2 Ophthalmic Instruments

4.2.1 Introduction

The starting point for this case study is the 'Maylite' hand-held ophthalmoscope manufactured by Gowllands Limited, a small independent firm of Croydon, Surrey. (Figure 11). The product received a Design Council Award in 1977. The evidence presented in this study comprises that obtained from the literature[1,2,3], from academics in the field of ophthalmic optics, from Gowllands Limited, from other British manufacturers of ophthalmic instruments, from the industrial design consultant involved in the Maylite project, and from users of ophthalmic instruments.

4.2.2 Ophthalmic Instruments: British Manufacturing Capability

Ophthalmic instrument manufacture in the United Kingdom went into a decline in the period after World War II. Manufacture is now confined mainly to four firms: Clement Clarke International Limited, Gowllands Limited, Hamblin (Instruments) Limited, and Keeler Optical Products Limited. The relative sizes of the four firms are indicated in Table 3.

TABLE 3 : BRITISH MANUFACTURERS OF OPHTHALMIC INSTRUMENTS

Firm	Number of Employees	Annual Turnover £	Output of hand-held Ophthalmoscopes units/annum
Clement Clarke Internat.	100	2.5×10^6	*
Gowllands	100	Unavailable	50,000
Hamblin Instruments	20	750,000	350
Keeler Optical Products	250	4×10^6	20,000

* Clement Clarke International does not manufacture hand-held ophthalmoscopes.

Gowllands is a family firm. Clement Clarke International is a manufacturing subsidiary of a Group, the principal interest of which is a chain of ophthalmic optician practices. Clement Clarke International is therefore part of a vertically integrated enterprise with assured outlets for its products. Hamblin Instruments is now similarly placed to Clement Clarke International. In 1981/82 it was hived off by its parent firm to become a manufacturing subsidiary of Dolland & Aitchison, another Group which operates a chain of ophthalmic optician practices. Keeler Optical Products is the manufacturing arm of the Keeler Group of Companies. The group, which includes a number of overseas subsidiaries, has a total of 600 employees. Evans[4] suggests a (perhaps biased) market ranking for British ophthalmoscope manufacturers: Hamblin is up-market of Keeler and Gowllands is very down-market. The innovation policies of Hamblin Instruments and Keeler Optical Products are described later for comparison with that of Gowllands, but first the market strategy of Gowllands is set in a wider context.

4.2.3 Market Strategy relative to Ophthalmoscopes.

Gowlland's evidence on the market strategy of his firm can be summarised as follows.[5] The United Kingdom market for ophthalmoscopes is very small for two main reasons: the life of an ophthalmoscope is infinite; the rate of growth of the United Kingdom population, and the related growth in eye-care facilities, is relatively low. Therefore, the firm depends upon exporting for its business. The growth market for ophthalmoscopes is in the developing countries, where there is a high incidence of ocular disorder and where the requirement is for low-cost instrumentation. There is competition in this market from principally Chinese and Pakistani manufacturers. Gowlland maintains he has countered this competition by adopting high-technology labour-saving production techniques to produce a low-cost product. With the firm's Maylite ophthalmoscope, special expertise is required to produce the tooling and to control quality during production. As yet, the Chinese and Pakistani competitors have not developed this technological capability.

Sabell[6] has a different perception of the British market for ophthalmoscopes as well as Gowllands' participation in it.

Between the two world wars, opticians in the United Kingdom were essentially suppliers of spectacles rather than analysts of ocular defects and diseases. The latter was the role of ophthalmologists, medical practitioners who specialise in ophthalmology, few in number compared with opticians. Therefore, the pre-war British market for ophthalmic instruments generally was relatively small. In the development of ophthalmics, however, the point was reached pre-war when legislation on the one hand and professional rules on the other decreed minimum levels of instrumentation for general medical practitioners and ophthalmic opticians. In practice, this did not necessarily entail usage of the instruments. Consequently, low-cost instrumentation became a widespread market requirement in the United Kingdom. Gowllands catered for this market.

The work of ophthalmic opticians is now much closer to that of ophthalmologists in the pre-war period. If an optician was previously a technician, now he is a technologist; judgment and interpretation are now a much stronger feature of his activity. Moreover, post-war development has entailed greater professional responsibility, with more accountability demanded of opticians. They are now required to not only possess instruments but also take certain measurements and undertake certain examinations of patients. There is also a higher risk of litigation. Consequently, the widespread use of a variety of instruments by opticians has become a norm; scientific measurements are regarded as good documentary evidence. Table 4 is an example of the inventory of equipment held by an independent ophthalmic optician.

TABLE 4 : INVENTORY OF EQUIPMENT OF AN INDEPENDENT OPHTHALMIC OPTICIAN

Instrument	Function	Manufacturer	Country of Origin	Approx. price £	Year of purchase
Keratometer	Measures corneal curvature	Carl Zeiss Jena	GDR	1,500	1977
Biomicroscope	Examining interior segment of eye	Carl Zeiss Jena	GDR	2,000	1977
Phoropter	Supports sight testing lenses in front of eye	A.O.C.	USA	2,500	1977
Direct ophthalmoscope	Examining fundus oculi	Heine	GFR	120	1980
Indirect ophthalmoscope (H.H.)	Examining fundus oculi	A.O.C.	USA	400	1977
Streak retinascope	Objective assessment of error of sight	A.O.C.	USA	80+	1979
Hydraulic instrument stand. I	Supporting & adjusting height of instruments 1-5	A.O.C.	USA	2,500	1978
Project-O-Chart	Projects test chart on to screen	A.O.C.	USA	1,200	1977
Non-contact tonometer	Measuring intra-ocular pressure	A.O.C.*	USA	3,500+	1978

* American Optical Corporation

\+ Hire purchase price. Subject to hire charge.

TABLE 4 (cont.)

Instrument	Function	Manufacturer	Country of Origin	Approx. price £	Year of purchase
Hydraulic Chair	For patient	Belmont	Japan	800	1977
Hydraulic Stool	For practitioner	Labofa	Denmark	120	1980
Hydraulic Chair	For patient	Belmont	Japan	500	1977
Microfilm reader	Examining contact lenses	Carl Zeiss Jena	GDR	250	1978
Focimeter	Measuring strength of lenses	Nilcon	Japan	800	1977
Maddox wing	Measuring near phorias	London Williamson	UK	15	1977
Pocket ophthalmoscope	Examining fundus oculi	Keeler	UK	25	1979
Digital sphygonomanometer	Measuring blood pressure	Astropulse Marshall Electronics	USA	100	1980
Screening seotometer	Measuring visual field		UK	400	1977
Audio visual unit & films	Patient education	Macmillan	USA	250	1977
Hydraulic instrument table - II	Supporting heavy instruments	Carl Zeiss Jena	GDR	200	1977
Hydrovane	Examining & measuring soft contact lenses		USA	450	1979

TABLE 4 (cont.)

Instrument	Function	Manufacturer	Country of Origin	Approx. price £	Year of purchase
Aseptor	Sterilizing soft contact lenses	Bausch & Lomb	USA	100	
Teaching unit	Teaching handling of contact lenses	Wohlk	GFR	100	1977
Trial case	Lenses for sight testing	Carl Zeiss Jena	GDR	550	
Burton lamps	Examining fit of contact lenses	Thorn	UK	25	1977
Domiciliary kit		Keeler	UK	5	1977
Lens analyser	Computer for measuring strength of lenses	Humphrey Instruments	USA	5,500+	1980
Frame	Adjusting spectacles	Essel	France	100	1977
Clavulus	Tightening joint on spec.frames		UK	120	1979
Polishing mop		Rodway	UK	50	1979
Photochromic lens demonstrator		Indo	Spain	120	1979
Pupilometer	Measuring pupillary distance	Essel	France	120	1980
Kool shades	Stops overheating		USA	800	1980

+ Hire purchase. Subject to hire charge.
Source: Docker & Wilson, Stourbridge.

This increase in the use of instruments by ophthalmic opticians has been accompanied by an increase in the demand for instruments of higher quality than those previously available. Gowllands, however, is associated with basic instruments rather than sophisticated variants of them. Because the British market for basic low-cost instruments has declined, it is to be expected that Gowllands has sought growth in the less sophisticated markets of the Third World.[7]

British manufacturers of ophthalmic instruments, in attempting to identify the needs of the market, have by tradition regarded the medical profession as their alma mater. For instance, it is customary for the manufacturers to rely on eminent ophthalmologists to evaluate prototypes. It is not common practice for the manufacturers to consult with ophthalmic opticians about their needs in instrumentation.[8,9,10,11] In the volume market, the manufacturers assume that by catering for the ophthalmic instrument requirements of general medical practitioners they are also catering for the needs of ophthalmic opticians. It seems that this is a false assumption; the respective needs are quite different from one another. Medical students are required for their formal studies to possess certain ophthalmic instruments. The majority of them buy the cheapest instruments available in the certain knowledge that when their studies are completed, they are unlikely to use the instruments again. (If a general medical practitioner does not use ophthalmic instruments regularly, he does not acquire the skill necessary to use them expertly. Mainly for this reason, it is now common practice for general medical practitioners to refer patients with ocular defects to an ophthalmic optician, whose facilities for testing are much more extensive than their own.[12])

In catering for medical practitioners, therefore, British manufacturers generally are orientated towards producing instruments with a low selling-price in the belief that this is the general market requirement. By contrast, today's ophthalmic opticians, the most numerous of the expert users of ophthalmic instruments, seek high quality instruments for a variety of reasons which are elaborated later. A minority of medical practitioners who use ophthalmic instruments regularly also seek instruments of better quality than those they purchased as medical students.[13]

4.2.4 Innovation in Ophthalmic Instruments : From the Standpoint of an Academic in Ophthalmology.

Ophthalmology owes its development to instrumentation.[14] Ophthalmic practitioners depend heavily upon instruments; without them, they cannot function. (This is in contrast to general medicine, where practitioners use more visible signs and also symptoms in the diagnosis of patients). Moreover, ophthalmology owes its progress to the inventiveness of practitioners; initially, they invented, made, and used their own instruments. Some ophthalmologists have made their professional reputation by inventing instruments.

Until recent times, the quest in ophthalmology has been for simple reproducible methods of measuring and testing the functions and conditions of the eye. Many of the measuring and testing instruments used today are essentially the same as when they were invented in the nineteenth century. Subsequent improvements in these instruments have in the main been limited to changes in materials and methods of production.

Prior to World War II, ophthalmic opticians only examined eyes. In the post-war period, however, they have learned to also manipulate eyes. As a consequence, the personal confidence of the practitioner is now linked to manipulative skill with inevitable implications for his confidence in the instrumentation. To that extent, the operation of these instruments is more directly linked to personal performance than in the case of a factory operative, who has not a direct personal interest in the equipment he uses. Ophthalmic practitioners have a vested interest in the design of the instruments they use and are inevitably design-orientated in their attitude to them. Partly as a consequence, ophthalmic practitioners generally have a fascination for gadgetry. Moreover, instrument design is regarded as so important to ophthalmic practice that it features as a subject in the curricula of university courses in ophthalmology.

The advent of electronics and micro-electronic computers has prompted innovation in ophthalmic instrumentation different in kind from that just described; the initiators are manufacturers rather than practitioners. The commercial exploitation of computation has led to a proliferation of instrumentation which is not strictly necessary to the practice of ophthalmology, e.g. a computer read-out for the cost of lens-grinding relative to the size and shape of a spectacle frame. In this category of innovation, some excess capability in the instrumentation is also evident. Like personal electronic calculators, some of the instruments are used for basic functions only by the majority of users. In parallel with this trend, there are some modern versions of hand-held ophthalmoscopes, various types of which were invented by practitioners, which also have excess capability.

It is against this background of innovation in the field of ophthalmology that the related policies of British firms which manufacture ophthalmic instruments are now considered.

4.2.5 Technological Innovation : The Standpoint of British Manufacturers of Ophthalmic Instruments.

4.2.5.1 Keeler Optical Products Limited

Keeler Optical Products manufactures a range of medical instruments and associated equipment. Besides hand-held and head-mounted ophthalmoscopes, the firm manufactures otoscopes, head-mounted magnifiers, ophthalmic charts, fibre optics, and associated light sources. The hand-held ophthalmoscope range comprises six models: Standard, Practitioner, Specialist, Pocket Diagnostic Set, Medic, and Medic-Lux. The designs of the Standard and Practitioner models have remained the same for about 25 years. Output of the Practitioner is about 8,000 units per annum, and the Pocket Diagnostic Set about 8,000 units per annum. Orders for the recent Medic model are said to be encouraging. The Medic-Lux was launched in 1982. In ophthalmoscopes, the firm asserts it is a market leader and regards Welch Allyn (U.S.A.) and Heine (West Germany) as its main competitors.[15]

During the last few years, there have been significant changes in the firm's policy on innovation. Previously, new product development centred on Charles Keeler, the firm's founder and Company Chairman, aided by one development engineer and a draughtsman. In 1972, when Charles Keeler retired, the development engineer, a long-serving employee, was put in charge of new product development. His status within the firm's decision-making structure was low and his approach to product development was characterised by its lack of planning. When he retired in 1976, the firm's records showed a list of 50 ideas for new products, none of which had been brought to maturity. The present Chief Design Engineer was appointed in 1976. There are now 14 design staff (e.g. engineering designers, detail draughtsmen, and model-makers) working in teams, each covering a range of products. There are no industrial designers on the staff.

The firm used to have a strongly imitative approach to innovation, responding defensively to the initiatives of competing firms such as Welch Allyn. American firms especially are likely to take new initiatives simply because American ophthalmic practitioners are more orientated towards new products than their British counterparts. For instance, halogen illumination was taken up quickly by practitioners in the United States but British practitioners were slow to respond. Previously, the imitative approach at Keelers induced a panic mentality which showed in the firm's hastily-designed new products. However, it is said that the firm now takes a more orderly approach to innovation. The Chief Design Engineer analyses critically competitors' claims before the Company responds. Whereas previously imitative responses accounted for about one-third of the new products at Keeler, this has been reduced to 5%.

The firm now has a New Product Group comprising the Technical Director, the Marketing Manager, and the Production Director. This Group also serves as a focus of communication; for instance, ideas are fed to it from medical practitioners and overseas subsidiaries. The Chief Design Engineer, who is responsible to the Technical Director, takes part in the activities of the New Product Group.

In 1977, the directors of the firm were said to be incensed when they learned that the Maylite ophthalmoscope manufactured by Gowllands had received a Design Council Award. The innovative feature of Maylite, the single-piece integral-moulded dioptre lens-wheel and the raison d'etre for the Award, had been a feature of the Keeler Pocket ophthalmoscope since 1972, anticipating the Gowllands development.[16] In 1978, as a direct consequence of the Design Award to Maylite, Keeler Optical Products submitted its Pocket ophthalmoscope to the Design Council. The submission was unsuccessful, the Council ruling that it does not make an Award to the same type of product in consecutive years. However, the Keeler Pocket Diagnostic Set, a package of the same ophthalmoscope and an otoscope, received a Design Council Award in 1979. It was this first encounter with the Design Council - albeit in consternation initially - which led to the firms adopting a conscious approach to industrial design as part of its policy on innovation.

Product presentation is one of the responsibilities of the Chief Design Engineer. Oddly, the design of the cases for the instruments used to be the responsibility of the Production Manager, a legacy from an ad hoc approach to company organisation when the firm was much smaller than it is now. Product presentation at the firm now embraces not only the design of the instrument cases but also those features of an instrument which interact directly with the user.

The firm neither employs an in-house industrial designer nor engages an industrial design consultant to deal with product presentation. Rather, two of the firm's in-house engineering designers who are regarded by the Chief Design Engineer as having artistic ability deal with this aspect of new product development. Since 1978, the firm has been registered with the Design Council's Design Advisory Service. For an annual registration fee of £200, two advisers visit the firm on request to discuss new product design proposals.

The advisers' first encounter with the firm was in connection with the development of the 'Medic' hand-held ophthalmoscope.(Figure 12). At the time, the engineering of that project was well advanced and though the advisers' influence on the final technical design of the instrument was slight, it was considerable on the presentation of the product.[17] The advisers did not produce drawings or sketches but participated in a creative dialogue with the Chief Design Engineer and his assistants. The observations and the questions of the advisers were directed at the general rather than the technical features of the design, e.g. handling characteristics, and their suggestions reflected an ability to link aesthetic objectives to economic methods of production. Subsequent visits by the advisers were said to have been as constructive and the firm's in-house engineering designers are enthusiastic participants at these meetings. It is said that the personalities of the advisers is a crucial factor in this relationship.

The Chief Design Engineer perceives an industrial designer as a stylist who is also able to relate the ergonomics of a product to economic methods of production. He does not regard an industrial designer as a spokesman for the users; at Keelers, feedback from users is obtained from a panel of thirty medical practitioners who test the firm's new products and complete a questionnaire. The Chief Design Engineer gave two reasons for not engaging an industrial design consultant on new product development: the Board of Directors would not agree to pay the fees which industrial design consultants with a national reputation charge; even if the directors could be persuaded to do so, there would be pressure on the Chief Design Engineer to accept the proposals of the industrial design consultants. When at Cambridge Instruments Limited, the Chief Design Engineer had observed that industrial design consultants have a tendency to press their proposals on the client. Moreover, at Keelers it is the policy not to associate the names of individuals with the designs of the firm's products, a practice that consultants press on clients.

4.2.5.2 Hamblin (Instruments) Limited

The firm of Hamblin was previously a subsidiary of Pratt Engineering Limited. In 1981, Pratt's optical interests were sold to the Dollond & Aitchison Group, best known for its chain of ophthalmic opticians. Under Pratt, the firm of Hamblin also operated a chain of ophthalmic opticians. Hamblin Instruments in its early days was a loss-making subsidiary providing a service to the Spectacle Manufacturing Division of Hamblin. With the acquisition by Dollond & Aitchison, there was a requirement for Hamblin Instruments to become a profit-making centre. A streamlining of operations followed; the drawing office, the paint shop, and the plating plant were closed. Seven employees were made redundant.[18]

Policy on new products is formulated by three directors, one of whom trained as a medical practitioner. Besides ophthalmoscopes (Figure 12), the firm manufactures a variety of other ophthalmic instruments, e.g. Lees Screen, Maddox Wing. The firm also manufactures related non-technical products, e.g. instrument-cases, cabinets and consoles for ophthalmic consulting rooms. The development and production facilities at Hamblin Instruments are relatively small. There is a machine-shop, an area for building prototypes, and a lens-grinding section. Tool-making is carried out on the premises. There is a 'clean' room in which one employee repairs ophthalmoscopes and another employee assembles new ophthalmoscopes.

Prior to its acquisition by Dollond & Aitchison, the firm conducted its business in a very traditional manner. It supplied equipment to ophthalmologists, as distinct from opticians, and mainly to

British customers. This sector of the British market is very small and in the view of this firm, very conservative; there is a general resistance to technical change and a lack of enthusiasm for new instrumentation. This is said to contrast markedly with the equivalent American market. There, ophthalmologists, whose training includes a study of physics, are receptive to technical change.

Following the acquisition by Dollond & Aitchison, there has been a change in the innovation strategy. The target market is now broadened to include that of ophthalmic opticians over a range of products. Initially, the intention is to supply the Dollond & Aitchison chain of practices and to enter the volume market with an extended range of products. This will entail significant change in working practices at the firm. For example, ophthalmic equipment destined for use in hospitals is governed by stringent specifications issued by the Department of Health and Social Security whereas with independent ophthalmic opticians there is a wide measure of discretion in the specifications.

Recent new product developments include a re-charging facility for battery-operated hand-held ophthalmoscopes and a remotely-controlled ophthalmic chart. The ophthalmoscope has been re-designed in order to be compatible with the re-charging system. A common ophthalmoscope-head can be attached to a handle which houses alternatively a re-chargeable battery, a normal dry battery, or a mains attachment. A slim-line form has been adopted for the handle. The colour has been changed from black to beige. Knurling has been retained on the handle because it is believed to be popular. The scales on the instrument are engraved.

The configuration of ophthalmoscopes is perceived to be determined largely by functional considerations, e.g. size of lens wheel, position of practitioner's eye-socket. These dimensional constraints are seen as limiting the extent of changes that can be made in the form of ophthalmoscopes. The 'feel' of a hand-held ophthalmoscope is regarded as an important consideration. The development team is said to be conscious of the need to up-date the style of the firm's products when production has been made more economic. Some progress has been made in improving the economics of production at the firm. For instance, the lens-race on the ophthalmoscope used to be machined from the solid; now it is a steel pressing with plastic inserts.

The new remotely-controlled ophthalmic chart was inspired by the Health & Safety at Work Act requirement that electrical cables for equipment in hospital consulting-rooms must be housed in conduit. A remote-control facility to operate the change-mechanism of an ophthalmic chart eliminates the cable and hence the conduit. Initial advice suggested such a facility was technically impossible. Nevertheless, experiments with an infra-red system were successful. A bonus is that the infra-red system is superior to an ultra-sonic system for hospital applications. However, there is a design problem with the hand-held control-box. Currently, the design of both the box and the control-buttons is crude when compared with the high standard of design of control boxes available in the consumer electronics market.

The new product development team, which comprises the Assistant Works Manager, a development engineer, and an electrician, believe they fully understand the needs of users. The Assistant Works Manager monitors user needs and user criticism through attendance at ophthalmic conferences. The team feels capable of integrating the technical and general design in new product development without the assistance of an industrial designer, a design consultant, or the Design Council. Instead, the team utilises the consultancy services of technical suppliers which provide free advice on materials and finishes. The firm engages graphic designers for the production of brochures.

The management regards the presentation of a product as very important and seeks to project an image of high quality. Surface finish is perceived as the main means of achieving quality in presentation. In the past, the firm's sub-contractors could not achieve the high quality of plating and painting Hamblin Instruments sought so the firm installed plant for these operations. However, the plant was under-utilised and therefore uneconomic to operate. Meanwhile, the technology of the sub-contractors improved. The reversion to sub-contracted plating and painting has not been to lower the standard of the finishing. Moreover, low investment on capital plant is said to encourage a more flexible approach to finishing in new product development so the policy of using sub-contractors is likely to continue.

The need to project an up-to-date image without abandoning connotations of tradition has given rise to some design problems. For instance, there is a dilemma about the design of the electrically-wired wooden cabinets and consoles used in ophthalmic consulting rooms. As furniture, style is inevitably a consideration but because some of these units are purchased by conservative Harley Street specialists, it is felt that Modern is inappropriate.[19]

4.2.5.3 Gowllands Limited

Gowlland provided evidence on the innovation which resulted in his firm's new product, the Maylite ophthalmoscope.[20] No originality in concept or function is claimed for this instrument. The wheel of dioptre lenses is the innovative feature (Figure 11). Twenty positive and twenty negative lenses of different focal lengths are produced as a single-piece plastic moulding. In the previous design of ophthalmoscope, superseded by Maylite, forty glass lenses had to be separately ground, mounted, and then aligned during assembly. These operations are both labour-intensive and prone to faults.

Neither plastic lenses nor integral-moulded optical systems are new; the plastic lens was invented in the 1930s and integral-moulded optical systems were developed in the 1960s. However, Gowlland's innovation - initiated in 1972, in association with the Imperial College of Science & Technology (ICST) and the industrial design consultancy Martyn Rowllands Associates - lay in applying these technologies to the manufacture of a dioptre lens wheel. Gowlland, a physicist by training, compiled the technical specification for the lens system. Staff at ICST used computer techniques to translate this specification into a technical design of the lens wheel, and Martyn Rowllands Associates created the product design which embodies it. After lengthy development of production techniques at Gowlland's factory, the result was an instrument in which manufacturing costs had been significantly reduced - the basic selling price of the instrument is about one-third of the model it replaced - without impairing either optical or medical performance. It was this combination which impressed the Design Council judges and led them to make a Design Award to this product in 1977.[21]

Gowlland regards an industrial designer as the equivalent of an architect. And in the same way that an architect is normally provided with a brief for a building project, Gowlland provided the industrial design consultants with a brief for the Maylite project. Even though Gowlland had engaged the services of the same consultancy for a number of years on previous projects, providing an adequate brief for Maylite proved to be difficult; defining precisely the requirements at an appropriate level of detail, identifying the non-requirements, and effectively communicating these constraints to the consultants. After producing an exhaustive brief, its content was discussed at length with them to incorporate suggestions and to obtain agreement on its definitive form.

The brief required the consultants to engineer the product; the number of parts and fastenings had to be minimal; there had to be a means of keeping the lenses free of dust; the shape of the plastic mouldings had to be consistent with economical production; appropriate plastic materials had to be selected. Gowlland decided that periodic stylistic changes in this type of product is not a relevant issue; he specified that Maylite should be timeless in appearance. Maylite had to be designed not only as a single unit but also as the basis of a range of diagnostic sets.

Gowlland did not consult users of the instrument before compiling the design brief. In his view, medical practitioners by and large are incapable of adequately specifying the technical requirements of the instruments they need. The operational need for the instrument was not in doubt and the essential aim of the Maylite project was to reduce the cost of manufacture. The mode of operation of Maylite was deliberately kept the same as the model it replaced with the intention of making it readily acceptable to the users.

The bulk of the firm's output is exported to the developing countries and at first, Indian and Pakistani users resisted the introduction of Maylite because it has a modern appearance and with which they associate poor quality. It seems that users in these countries associate high quality in this product category with instruments which have a solid traditional appearance.

Since the product was launched, minor modifications to the internal detailing have been made to the design. An ophthalmoscope has a long life; Gowllands receive for repair instruments manufactured during the 1920s. Very few Maylite models have been returned; there is very little that can become defective.

The evidence of the industrial design consultant directly involved in the Maylite project is now presented.

4.2.6 The Maylite Innovation : From the Standpoint of the Industrial Design Consultant

The industrial design consultant directly involved in the Maylite project regards Gowllands' approach to innovation as unexceptional.[22] In terms of new products, the firm is a follower. For instance, it is currently seeking to develop a pocket ophthalmoscope, an instrument other firms (e.g. Keeler, Welch Allyn) already manufacture. The firm does not seek to break new ground technically; rather, it is prompted by the activities of its competitors.

The consultant's approach to the Maylite project was not simply to produce a plastic copy of the previous model; rather, to re-design appropriately in plastics, exploiting special material properties wherever possible. This included a suggestion by the consultant's partner that the instrument should incorporate an integral plastics moulded lens system as a replacement for the set of individually-mounted ground-glass lenses featured in the previous model. Though Gowlland himself probably knew about integral moulded lenses, it seems he needed reassurance to embark on this innovation. At the time, the idea was 'in the wind' but the consultant maintains that it was not known in 1972 that a competitor of Gowllands was developing an integral-moulded lens system for a hand-held ophthalmoscope. Insofar as they proposed an integral moulded lens system to Gowlland, the industrial design consultants initiated the R & D activity at Imperial College of Science and Technology, even though they did not subsequently interact directly with the staff there.

The consultant asserts that he could have produced a better overall design for the instrument but was obliged to compromise his proposals so as to make them compatible with Gowllands' production facilities, which are basic. Opportunities for better design could not be fully exploited. For example, an insert in the head of Maylite is fastened by three metal screws. The special properties of plastics could have been exploited so as to fasten the insert by heat-swaging or by the snap-fastening technique. However, these alternatives would have entailed investing in special machinery and Gowlland demurred. There were other similar instances of compromise in the detailing. The consultant was also obliged at Gowllands' insistence to incorporate into the design an existing component, a bulky electrical contact which adversely affected the profile of the instrument. Had there not been this constraint, a more compact electrical contact could have been devised and the neck of the instrument would be less obtrusive. Moulding considerations affected the overall appearance of the instrument. The consultant proposed a thin section for the moulded lens-wheel in order to achieve a slender head on the instrument. However, the sub-contractor who made the prototypes insisted on a thick section to achieve the optical properties required.

The consultant, reflecting with the benefit of subsequent experience and greater confidence, said he should have pressed his proposals more firmly. In the event, the design of Maylite reflects Gowllands' approach to manufacture; the utilisation of existing production facilities which embody only a limited amount of mechanisation. In its own terms, however, the firm <u>has</u> broken new ground. The production of integral plastic moulded optics has entailed installing special processing machinery at considerable capital cost and risk.

The next section describes how a sample of users of ophthalmic instruments perceive innovation in this field.

4.2.7 Innovation : The Standpoint of Users

Success in innovation depends upon buoyant sales of the new product. It is held that the opinions and beliefs of customers for the product, however erroneous, have some bearing on the preferences they exercise when making purchases. This section examines how a sample of ten independent ophthalmic opticians perceive British manufacturers of ophthalmic instruments and their capacity for innovation.

4.2.7.1 The Visibility and Standing of British Manufacturers.

In the ophthalmic instrument market, British manufacturers are not very visible; there are not many of them.[23,24,25,26] The firm of Gowllands is not highly regarded by the opticians. One of the older generation knew the firm and its products before World War II. Then, Gowllands had a good reputation but in the post-war period it went into a decline. One optician assumed the firm had already gone out of business. Overall, Gowllands has a reputation among opticians as a manufacturer of cheap instruments for medical students.[27]

Keeler has a reasonable if not outstanding reputation among the opticians. Almost all the sample uses a Keeler hand-held ophthalmoscope and this stems mainly from the influence of formal training.[28,29] The firm is more progressive and workmanlike than British manufacturers generally;[30] for example, it has adopted halogen illumination in its ophthalmoscopes, applied ergonomics to the design of ophthalmoscope handles, produces products of modern appearance, and spares are readily available.[31,32,33]

Because the opticians have little or no British instrumentation, some of them offered only general rather than specific opinions of British ophthalmic instrument manufacturers and their products. For instance, they felt that globally, British manufacturers have a poor reputation; their products are regarded as old-fashioned and limited technically.[34,35,36] The products are dated in respect of ergonomics.[37,38] Even those of fairly recent manufacture are of poor design when viewed alongside prevailing international standards; British instruments have a generally cheap and shoddy appearance.[39] Cooper regarded the Award-winning Maylite hand-held ophthalmoscope as typical of the British approach to manufacture in this field; this new model has the same format as the very old model it replaces.[40]

Some of the opticians remarked on the British-made instrumentation being limited to the small hand-held products. Formerly, 'big' instruments were manufactured by British firms, e.g. Green's refractor, but they did not keep abreast of developments internationally. Ophthalmic instrument manufacture was beginning to develop in the United Kingdom just before World War II. There was a lull in development during the war followed by significant developments afterwards but the British firms were left behind.[41] For instance, they were years behind foreign competitors in launching a slit-lamp microscope.[42]

The opticians suggested various causes for the decline in British ophthalmic instrument manufacture. The cost of development in this field is high and the firms failed to invest, even though there was a big potential market in the European Economic Community. Instead, there has been considerable penetration of the British market by especially Continental firms and British firms have found this competition too formidable.[43] The foreign competitors make more effort and support it with greater resources.

In respect of 'big' instruments, British manufacturers have supplied this requirement only to a very limited extent. Traditionally, these instruments have been manufactured by German firms, e.g. Zeiss, Rodenstock.[44] It was German manufacturers who first introduced light into microscopes.[45] The limited involvement of British firms in this 'big' sector of the market is connected with British limited involvement in the manufacture of high-quality cameras, binoculars, and microscopes, which in turn is connected with the demise of optical glass manufacture in Britain.[46] The decline in British ophthalmic instrument manufacture happened at about the same time that British camera manufacture was in a similar situation. Like the cameras, such as the Coronet, British ophthalmic instruments do not have a good 'feel' and the appearance is poor; no match for those aspects of quality in German and Japanese instruments.[47] Japanese firms entered the 'big' instrument market late. Even more recently, Clement Clarke entered this market, which is exceptional for a British firm.[48]

The dearth of good British instruments is regretted by a number of the opticians, in some cases for quite mundane reasons. Were more British instruments available, the choice would be wider and the servicing easier.[49] It is in an optician's own interest to buy British; the buoyancy of his practice is dependent upon the buoyancy of the British economy generally.[50] There were also positive observations. In respect of hand-held instruments, those of British manufacture are as good as any of the foreign makes.[51] Regrettably, British manufacturers have transferred their interest from instruments to ancillary equipment, e.g. charts, chairs.[52]

4.2.7.2 The Orientation of British Manufacturers towards Producing Instruments with a Low Selling Price

It has already been mentioned in 4.2.3 that British manufacturers are orientated towards producing instruments with a low selling price. The sample cited other reasons for British manufacturers having this orientation. They seem to lack confidence in, and commitment to, their new products. They do not finalise the design before commencing development but instead make ad hoc modifications to the design during development; not because of particular technical difficulties encountered but rather a lack of confidence in the completeness in the design, a criticism also made by Corfield.[53] Also, in an attempt to keep manufacturing costs low, new designs are compromised by incorporating components from existing products. Another indication of the lack of confidence in the product is the tendency to begin production with very limited runs. For example, Clement Clarke International developed a Diag Unit 3 slit-lamp microscope, a composite instrument with a modular add-on facility. In the event, only 250 units were produced before the line was discontinued.[54] By contrast, Japanese and German firms begin with a comprehensive design specification. All parts are specially designed for the new product. The design generates confidence that the product will be successful and production is organised on a long-term basis. The design indicates to the customer the manufacturer's conviction in the product. British manufacturers seem to lack the confidence to do that, probably because the senior management are either non-technical or incapable of being directly in charge of design.[55]

The next section describes how the sample of users perceive the significance of industrial design relative to ophthalmic instruments.

4.2.8 Industrial Design : Its Significance for Users in this Product Category

4.2.8.1 Introduction

Generally, the sample professed to being design-conscious. It is their custom to discriminate between ugliness and elegance in purchases for their homes and this discernment extends to the purchasing of instruments for their practices. They have a preference for the visually elegant and conversely, ugliness is a deterrent to purchase. Moreover, when purchasing instruments, ophthalmic opticians like to exercise their choice between competing makes which, in terms of technical function, are the same or similar; to weigh the features of one instrument against those of another. They observe that pricing of instruments is keener when there is choice. The more specialised the instrument, the more limited the choice. For some types of instrument, there is no choice. For example, currently there is only one make of non-contact tonometer available.

New ophthalmic instruments are usually first seen at exhibitions. Opinion in the sample is evenly divided on the value of exhibitions and the response to seeing new instruments at them. Half of the sample are in agreement with the proposition that when they go to exhibitions of ophthalmic instruments,

a) good general appearance of the new instrument stimulates initial interest;

b) high tactile quality and 'feel' strongly reinforce initial stimulation;

c) the reaction to the technical performance and facility of the instrument is strongly influenced by its feel.

A rationale of the response was offered: if a manufacturer has taken the trouble to present the product so that it looks good and feels good, it is probably good technically too.[56]

The other half of the sample are wary of exhibitions because manufacturers' representatives have a tendency to pressurise enquirers into an immediate sale. This group first studies the literature to identify the performance and the capability of a new instrument before physically testing the hardware.

The elegance of instruments can be sub-divided into a number of elements: the immediate visual elegance of the instrument which has a direct personal appeal to the practitioner; a tactile elegance which appeals directly to the practitioner; a visual elegance which contributes to the consulting-room as a whole; a more general compatibility between the patient, the practitioner and the instrumentation.

An instrument is bought primarily because it enables an optician to perform a certain task or tasks expeditiously and accurately. However, an optician works in close and extended proximity to the instrumentation in his practice so he is affected by its appearance, especially when he has a predilection for visually attractive objects. The majority of opticians in the sample are by temperament so disposed. Therefore, in choosing between makes of instrument when the technical performance of them is comparable, there is a preference for the visually elegant.

Optometry, the work of the ophthalmic optician, is a skilled occupation and one means of gaining the confidence of a patient is to communicate this skill. To a degree, an optician does so through dexterity. The tactile quality of an instrument is therefore important to an optician because an instrument that feels right helps him to perform his tasks dextrously. Ease of operation and smoothness in function complement dexterity.

Opinions are divided about the visual effect of ophthalmic instruments on patients. Cooper attributes great significance to the visual effect of instrumentation on the consulting room as a whole and maintains that this is confirmed by unsolicited comments about his instruments from the patients.[57] Bailey maintains that patients continue as clientele because they have confidence in the practice; that confidence, insofar as it is affected by visual impressions, stems from the general appearance of the practice rather than the instrumentation.[58] Priest denies that patients notice either the instrumentation or the surroundings, except when there is a change in the ownership of the practice.[59] Adderley regards the visual effect of the instrumentation on patients to be of psychological rather than aesthetic significance; the instrumentation should not be frightening or aggressive in appearance; rather, it should seem benign to patients.[60] Yeomans confirms this view and for this reason limits the number of instruments attached to the gantry located by the side of the patient's chair.[61] Almost by definition, therefore, there is a link between the visual elements in the consulting room and the image, if any, which a practitioner wishes to project to patients.

Of the ten independent ophthalmic opticians interviewed, nine subscribe to consciously projecting an image to patients. They give several reasons for doing so and they do not all seek to project the same image. To be professionally acceptable to other health professions, it is important for the ophthalmic optician to project skill in eye-care.[62] To attract patients, the image of the practice is important; one of permanence, stability, solidly dependable, and a general impression of high quality. Some practitioners seek to project an efficient up-to-date image;[63,64,65,66,67] it is important for the financial success of a practice that to patients it is evidently up-to-date.[68] To survive, ophthalmic opticians must not only be evidently up-to-date but also professional.[69] There are differing opinions about the appropriateness of a clinical image: preferred to the extent of influencing colour choice in instrumentation,[70] accepted simply as current fashion,[71,72] rejected in favour of a homely caring image.[73]

There are several means of projecting the image of a practice to patients. The general state of the interior of the premises is significant. The decor in good order and the furniture in good condition suggests to a patient that not only is the practice patronised by other patients but also there is enough income to adequately maintain it.[74] Premises which are carpeted project stability[75] and status.[76] Premises without a street-window display of spectacle-frames project professionalism related to eye-care rather than a shop trading in spectacles.[77] High visual value in the instrumentation projects competence[78,79] and only those practitioners who are ill-equipped underrate the importance of high quality instrumentation.[80] An optician has to be seen to be well-equipped.[81] For instance, table apparatus that is visually co-ordinated gives an ordered appearance to a consulting-room, which suggests modernity and efficiency to patients who do not understand the technicalities of the instrumentation.[82] Conversely, equipment that looks out-of-date suggests to patients inaccuracy, imprecision, and an incapacity to diagnose. A consulting room which is visibly sparse does not inspire professional confidence in the patients.[83]

The visual value to patients of instrumentation applies to some items but not to others. For instance, the hand-held ophthalmoscope is used in conditions of subdued light and enveloped in the practitioner's hand and thus not visible to the patient.[84] The visual value to patients is more significant in specialised testing than in routine testing; for instance, patients being tested for contact lenses infer competence from the practitioner's specialised equipment, e.g. slit-lamp microscope, keratometer.[85] However, some practitioners believe the visual value of traditional equipment such as a trial case suggests a caring practice to patients and for this reason retain it in favour of the modern technological alternative, the phoropter, which some practitioners regard as not only visually disturbing to patients but also technically less accurate.[86,87]

There is a division of opinion about the significance of imagery related to instrumentation in practices which serve the lower socio-economic groups. Priest maintains that these patients expect a degree of excellence from the professionally qualified which does not go beyond a general expectancy; they do not ask to see the instruments before having a consultation. Moreover, many of these patients are unaware that the equipment is the personal property of the optician, believing it to be provided by the National Health Service. They may notice differences in equipment between practices but attribute this to the vagaries of the National Health Service rather than the initiative of a practitioner. The lower the socio-economic group, the firmer these impressions.[88]

However, Rope maintains that when he acquired a run-down practice serving low socio-economic groups, 90% of the patients commented favourably on the new equipment he introduced.[89]

4.2.8.2 Packages and Modules

A number of the opticians referred to the need for instrumentation conceived as a package or as a modular system.[90,91,92] Their observations serve to illustrate that in addition to an instrument providing a satisfactory means of measurement, there are wider operational considerations connected with practice which can significantly affect the acceptability to the user of the design concept embodied in the instrumentation.

One way in which an independent ophthalmic optician in the United Kingdom expands his activity is by either acquiring or establishing another practice which is separated geographically from the existing premises. Such expansion is feasible because usually one ophthalmic optician can provide the professional services needed at two or more premises. However, a commercial consequence of an expanded practice which is split geographically is the need to optimise on instrument provision. Therefore, expansion can influence an optician's instrument purchasing policy. For instance, one optician purchased for a newly-acquired practice an instrument package which comprises a slit-lamp microscope, a keratometer, and an applanation tonometer. Separately, none of these instruments are technically the best available. As parts of a package, however, they represent convenience and good value for money, especially for a practice which prescribes and fits contact lenses.[93] By contrast, another optician identified the need for instruments which are dimensionally compatible, capable of being fitted together but without having to be purchased as a total package.[94]

A third optician who operates two practices separated geographically and where there is only a limited demand for contact-lenses in either, sought to economise on instrumentation for this service by purchasing a portable facility. He purchased a Clement Clarke Diag 3 unit, a composite instrument with a modular add-on-facility and in which the microscope element is light-weight. The associated weighty electrical transformer is designed as a separate unit and relatively cheap at £100. By having a transformer at each practice, he is able to transport the (more costly) lightweight microscope element between the practices with ease. Additional modules capable of enhancing the basic unit were available at reasonable prices. In the event, a keratometer module, available at a price of £150, is technically poor but adequate for the limited amount of contact-lens work undertaken. Not every optician perceives portability in instrumentation as an asset; to the patient, it may give an impression that the practice is impermanent.[95]

The next section identifies the purchasing preferences of the opticians for a number of instruments in common use.

4.2.9 Purchasing Preferences of Users

This section presents in tabular form the individual purchasing preferences of the sample of ophthalmic opticians in respect of the following instruments: focimeter, slit-lamp microscope, keratometer, hand-held ophthalmoscope, and applanation tonometer. The details are shown in Table 5. The individual preferences are also arranged in two aggregate forms; firstly, without regard to instrument type (Table 6) and secondly, according to instrument type (Table 7).

It is evident from the data presented in this section that most of the instruments purchased by the opticians in the sample are of foreign manufacture. The next section considers how the opticians perceive this situation.

TABLE 5.1 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Adderley, L.

Date of interview: 9 July 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference. Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Familiarity from training	Portability		Remarks
Focimeter	Eyco		Japan							1				Compact. Easy to operate.
Slit-lamp microscope	Haag-Streit		Switzerland				1			2				Attachment of the Goldmann tonometer possible.
Keratometer	Schiotz		GFR				1							Prefers Javal-Schiotz principle of operation.
Hand-held ophthalmoscope	Keeler	Specialist	UK	50	1973					1	2			
Applanation tonometer	Clement Clarke	Perkins	UK		1976		1			2		2		Easy to transport between practices. With unlimited funds, would choose a non-contact tonometer.

TABLE 5.2 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Bailey, M.

Date of interview: 23 October 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference. Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features				Remarks
Focimeter	*		UK	75	1969				1					* Sub-contracted manufacture. Stockist (Stearman) disposed of this instrument at half-price in closing-down sale. A repeat purchase.
Slit-lamp microscope	Topcon	SL 1D	Japan	1200	1978				2	1				Compact. Easy to operate. Looks workmanlike.
Keratometer	Kelvin		Japan		1978					1				Copy of Bausch & Lomb design (USA)
Hand-held ophthalmoscope	Keeler	Specialist	UK	110	1980					1				
Applanation tonometer	Schiotz		GFR		1967	1								Purchased when setting up practice.

TABLE 5.3 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES.

Name of optician: Canin, R.

Date of interview: 27 June 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference.								Remarks
						Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Familiarity from training.	Part of package.		
Focimeter	Topcon		Japan	300	1971				2	1				Simple. Fool-proof. Easy to operate. These features important because instrument is operated by assistants.
Slit-lamp microscope	Carl Zeiss Jena	110	GDR	1600	1979		1		2					Recommended by University tutor.
Keratometer	Bausch & Lomb		USA		1966	1					2			Purchased second hand early in career.
Hand-held ophthalmoscope	Keeler	Practitioner	UK	40							1			
Applanation tonometer	Carl Zeiss Jena		GDR		1979							1		An element in the Zeiss-Jena slit-lamp package.

TABLE 5.4 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Cooper D.L.G.

Date of interview: 7 November 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference. Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Reputation of manufacturer	Part of package		Remarks
Focimeter	Zeiss Ober-kochen		GFR	1200	1980					1	1			Exquisite design. Easy to operate.
Slit-lamp microscope	American Optical		USA	2500	1979		2			2		1		Co-ordinated design. Projects high quality.
Keratometer	Bausch & Lomb		USA	200	1966		1			2				Choice made between this instrument and Zeiss-Oberkochen. Smoother handling; attractive finish.
Hand-held ophthalmoscope	Keeler	Special-ist	UK	110	1980		1			1				Need a variety of instruments in this category. Other instruments from American Optical.
Applanation tonometer	American Optical	Goldmann	USA	120						1		1		Co-ordinated design. Also purchased non-contact type. (£3,500 Digilab, USA).

TABLE 5.5 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Docker, C.

Date of interview: 1 October 1980

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference.								Remarks
						Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features				
Focimeter	Nilcon		Japan	800	1977		2		2	1				
Slit-lamp microscope	Carl Zeiss Jena	110	GDR	2000	1977		2			1				
Keratometer	Carl Zeiss Jena		GDR	1500	1977		1			2				
Hand-held ophthalmoscope	Heine		GFR	120	1980		1		2	2				
Applanation tonometer	American Optical		USA	3500	1978		1							Non-contact type.

TABLE 5.6 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Gray, M.D.

Date of interview: 24 October 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference.								Remarks
						Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Familiarity from training			
Focimeter	Topcon		Japan	400	1981				2	1				Simple. Easy to operate.
Slit-lamp microscope	Carl Zeiss Jena	110	GDR	1500	1978		1			2	2			Repeat purchase.
Keratometer	Boller		Japan	600	1978				2	1				Copy of Bausch & Lomb design (USA). Better value for money.
Hand-held ophthalmoscope	Keeler	Special-ist	UK	110	1980					1	2			
Applanation tonometer	Goldmann		Switzerland	350	1980		1			2				Choice made between this instrument and Clement Clarke 'Perkins'. More accurate. Compatible with the Zeiss Jena microscope.

TABLE 5.7 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Morris, M.

Date of interview: 26 October 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference. Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Familiarity from training	Portability		Remarks
Focimeter	Topcon		Japan		1979				2	1				Easy to operate.
Slit-lamp microscope	Carl Zeiss Jena	69	GDR		1975				2	2	1			Choice made between this instrument and Haag-Streit (Switzerland). Easier to operate.
Keratometer	Topcon		Japan		1975					2	1			Copy of Bausch & Lomb design (USA). An improved copy.
Hand-held ophthalmoscope	Keeler	Special-ist	UK	50	1972		2			2	1			
Applanation tonometer	Clement Clarke	Perkins	UK							2		1		Choice made between this instrument and new screener. Need to transport between practices was deciding factor.

TABLE 5.8 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Priest, M.J.

Date of interview: 21 August 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference.								Remarks
						Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Familiarity from training	Part of package	Portability	
Focimeter	R&B Miyubi Koden		Japan	160	1976	1								Purchased as a standby.
Slit-lamp microscope	Clement Clarke	Diag 3	UK	1200	1976					2			1	Composite instrument. Choice was between this and Carl Zeiss Jena 110.
Keratometer	Clement Clarke	Diag 3	UK	150	1976				2			1		Offered at extra-low price.
Hand-held ophthalmoscope	Keeler	Practi-tioner	UK	40	1976						1			
Applanation tonometer	Clement Clarke	Perkins	UK	150	1977				1		2			Purchased second hand.

TABLE 5.9 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician	Rope, P.G.
Date of interview	16 July 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference. Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Familiarity from training			Remarks
Focimeter	Topcon		Japan	250	1975				1	2				Cheapest available with the internal reading facility.
Slit-lamp microscope	Neitz		Japan	600	1973	1								Purchased when setting up practice.
Keratometer	Magganio		Italy	550	1974	1								Purchased when setting up practice.
Hand-held ophthalmoscope	Keeler		UK	30	1967						1			Welch-Allyn at other practice. Next purchase will be American Optical; better quality.
Applanation tonometer	American Optical		USA				1							Borrows this instrument. With more resources, would choose a non-contact tonometer.

TABLE 5.10 FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS : INDIVIDUAL PREFERENCES

Name of optician: Yeomans, F.W.

Date of interview: 30 July 1981

Type of instrument	Manufacturer	Model	Country of origin	Approximate price (£)	Year of purchase	Factors influencing choice: order of preference. Lowest price	Best tech. perform.	Terms of trade	Value for money	Industrial design features	Reputation of manufacturer			Remarks
Focimeter	Topcon		Japan		1972					1				Simple.
Slit-lamp microscope	Roden-stock		GFR	1000	1972		1			2				Beautifully made and finished; solid; smooth.
Keratometer	Roden-stock		GFR	600	1972		2			1	3			Matches slit-lamp microscope.
Hand-held ophthalmoscope	Hamblin		UK								1			Prefers to buy British when as good as any available.
Applanation tonometer	Clement Clarke	Perkins	UK		1976					1				Chosen because it resembles a hand-held ophthalmoscope and therefore does not frighten patients.

TABLE 6 : FACTORS INFLUENCING CHOICE OF OPHTHALMIC INSTRUMENTS WITHOUT REGARD TO INSTRUMENT TYPE

Industrial design features	XXXXXXXXXXXXXXXXXX+++++++++++++++
Best technical performance	XXXXXXXXXXXXX+++++
Familiarity from training	XXXXXX+++++
Lowest price	XXXXX
Value for money	XXX++++++++++
Part of package	XXXX
Portability	XX+
Reputation of manufacturer	XX+

X : Primary factor. + : Secondary factor.

TABLE 7 : FACTORS INFLUENCING CHOICE OF PARTICULAR OPHTHALMIC INSTRUMENTS

Factor	Hand-held ophthal-moscope	Tonometer	Focimeter	Slit-lamp microscope	Kerato-meter
Industrial design features	XXXX++	XX+++	XXXXXXX+	XX++++++	XXX+++
Best technical performance	XX+	XXXX	+	XXXX++	XXX+
Familiarity from training	XXXX++	+		X+	X+
Lowest price		X	X	X	XX
Value for money	+	X	XX++++	+++	++
Part of package		XX		X	X
Portability		X+		X	
Reputation of manufacturer	X		X		+

X : Primary factor. + : Secondary factor.

4.2.10 Foreign Competition

Ophthalmology is concerned with systems and devices for measuring and testing. Practitioners seek to know the universe of ophthalmic instruments so that they can choose between the various methods of measuring and testing available. Foreignness per se is not really an issue; a practitioner simply needs to know the full market availability. Nevertheless, it is evident from the data in 4.2.9 that many of the instruments purchased by the opticians in the sample are not of British manufacture. This section elaborates on the opticians' preferences.

4.2.10.1 German Firms

There is a political dimension to German optics manufacture. At the end of World War II, German expertise in optics was dispersed; experts in West Germany went to the United States and experts in East Germany went either to the Soviet Union or remained in Jena, the original home of the Carl Zeiss firm. Both of the German states now have a Zeiss company; the state-controlled Carl Zeiss Jena enterprise in the German Democratic Republic and Zeiss-Oberkochen A.G. in the German Federal Republic.

There is a high investment in optics in the German Democratic Republic connected with the Soviet aerospace programme. It is centred on the Carl Zeiss Jena enterprise, which makes optical instruments for the Soviet space vehicles. In addition to manufacturing high-quality optical glass, the enterprise has had some success in technological innovation; it was the first to apply laser technology to an optical instrument.[96] It has also innovated in the field of ophthalmic instruments with the additional advantage of prices appreciably lower than the norm, which has not escaped the notice of British practitioners. For accurate and reproducible results, Carl Zeiss Jena ophthalmic instruments require the skill of the practitioner and this has a particular appeal to some users. Practitioners with less skill augment their performance by using de-skilling instruments which cost more.[97]

Slit-lamp microscopes manufactured by Carl Zeiss Jena are used by a number of opticians in the sample. Eight years separated the launch of the CZJ 69 and CZJ 110 models; the later model is more compact and has an improved light source. Wolffe purchased the CZJ 110 set after comparing it with equivalent Japanese and West German instruments. At £5,000, its facility/cost ratio compared favourably with the Japanese equivalent, which at £4,000 lacked a number of the technical features of the CZJ 110. The West German equivalent at £20,000 had only marginally more facility than the CZJ 110.[98] Gray encountered the CZJ 110 during his formal training; he believes it is the best available combination of technical facility, order of accuracy, and pleasant handling characteristics.[99] Priest was ambivalent about the CZJ 110. He compared it with the Clement Clarke equivalent and decided in favour of the latter because it is a composite instrument. Moreover, the CZJ 110 is heavier and more bulky, and therefore not easily transferred between practices. Subsequently, however, with an increase in the amount of accurate testing for contact-lens prescriptions at his practice, he purchased a CZJ 110 and a matching keratometer.[100]

Wolffe cited Carl Zeiss Jena to illustrate that the quality of design within the same firm can be uneven; some of its instruments are outstanding but others have weaknesses. The optics of the instruments are of a consistently high quality but the operational features, e.g. lamp-housings, are a source of weakness.[101] Cooper was uncomplimentary about Carl Zeiss Jena instruments: opticians buy them primarily because of the low price then convince themselves about their quality.[102]

A number of West German firms manufacture ophthalmic instruments and export to the United Kingdom, notably Zeiss-Oberkochen, Rodenstock, and Heine. West German ophthalmic instruments generally have a good reputation among practitioners and are admired for their 'solid quality'[103] and for refinement.[104] Prices are well above average.

4.2.10.2 Japanese Firms

Japanese manufacturers used to have a poor reputation among users in Britain. The ophthalmic instrument market was one of the first that they succeeded in penetrating with a new image of value for money.[105] British manufacturers of ophthalmic instruments did not respond aggressively to the Japanese challenge.[106]

The quality of Japanese ophthalmic instruments is uneven. They are competitive in price but do not have the 'solid quality' of West German instruments.[107] However, one effect of Japanese competition has been to bring down the price of instruments.[108] A number of Japanese firms copy existing designs when the patents lapse. During the 1960s, many patents on ophthalmic equipment expired and a spate of copying by Japanese firms followed.[109] Some of these copies incorporate improvements and at a lower selling price, give better value for money.[110] For example, the Boller keratometer is a copy of an (American) Bausch & Lomb instrument but has better handling characteristics than the original and is more competitive in price.[111] Other Japanese firms have copied designs without fully understanding the detail, with unfortunate consequences for the user.[112]

4.2.10.3 American Firms

Ophthalmic instruments manufactured in the USA have penetrated the British market. Besides relatively small firms such as Welch Allyn which are specialist manufacturers of ophthalmic instruments, a number of large American firms with an established reputation in the manufacture of microscopes and similar equipment have diversified into ophthalmic instruments, e.g. Bausch & Lomb, American Optical Corporation.[113] With a large and buoyant home market in ophthalmic instruments, these firms are able to export to markets such as the United Kingdom at competitive prices made possible by the economies of volume production. British manufacturers have not generated the volume of sales to be able to produce instruments of comparable quality at the competitive pricing of American firms.[114] Moreover, the approach of American firms to the market reflects the thrusting tactics associated with other aspects of American business: a new instrument is usually followed twelve months later by an improved version;[115] American Optical offers the phoropter in a range of six colours.[116]

British instruments lack finesse in design when compared with instruments of American manufacture.[117] For example, Cooper previously used a phoropter of British manufacture. To adjust the position of this instrument relative to the patient, three sub-adjustments are necessary. This either irritates or tenses the patient. Moreover, the practitioner's concentration is diverted both from the patient and the task in hand. He replaced the British instrument with one manufactured by the American Optical Corporation because the latter is more elegant in operation; complete positioning adjustment is achieved with one locking toggle.[118] Canin had had a similar experience. Initially, he used a phoropter manufactured by the London Optical Company. He described the instrument as being crudely engineered and giving inaccurate readings. Because of his dissatisfaction, he replaced this instrument with one manufactured by the American Optical Corporation at a price of £1,900. He described the American instrument as an excellent piece of precision engineering which gives accurate readings and is pleasant to operate. Subsequently, he placed a repeat order for the American instrument to equip a newly-acquired practice. At £1,300, the selling price was lower than previously.[119]

4.2.11 Evaluation

British manufacturing capability of ophthalmic instruments is very small when related to both the size of the home and export markets for individual items and the range of products within the category. As with some other British manufacturing industries, this industry has evidently experienced decline since World War II, even though there has been growth in this market during the same period in line with the increased demand from the general public for services in eye-care and scientific developments in the practice of ophthalmology. Currently, four small British firms only manufacture a range of ophthalmic instruments which is very limited when compared with the wide range now used by ophthalmic practitioners. Moreover, the products manufactured by the British firms are mainly the small, low-cost instruments which have undergone relatively minor technical improvements since their introduction in the nineteenth century. Only one of these four firms recently began to innovate in the field of 'big' ophthalmic instruments.

Evidently the vacuum created by the poor performance of British firms has been filled by foreign imports. The inventory of equipment in the small independent practice shown in Table 4, though an isolated example, at least gives an indication of the wide range of items now used by ophthalmic opticians. Of the 52 items listed, 20 can be described as scientific instruments. Of the latter, four of the items are of British manufacture costing in total £465; eight of American manufacture costing in total £12,630; four of East German manufacture costing in total £4,300; one of Japanese manufacture costing £800; one of West German, French, and Spanish manufacture, each costing £120. Table 5 provides corroboration of the widespread use of instruments of foreign manufacture by British ophthalmic opticians. In the sample of ten independent opticians, nine were using a focimeter of Japanese manufacture costing an average £370; nine were using a slit-lamp biomicroscope of foreign manufacture, notably East German, costing an average £1,450; eight were using a keratometer of foreign manufacture costing on average £633; four were using a hand-held applanation tonometer of foreign manufacture while three were using one of British manufacture, costing on average £175. In contrast, nine of the opticians were using a hand-held ophthalmoscope of British manufacture costing on average £54. It is estimated that there are 4,500 independent ophthalmic opticians practising in the United Kingdom[3], which indicates the size of the home market.

(cf 4.2.5.3) Turning to the manufacturer of the Award-winning Maylite instrument, Gowlland seems to be out of touch with the United Kingdom market for hand-held ophthalmoscopes; not one of the opticians in the sample had even considered purchasing it. Evidently Gowlland's business strategy is based on the nominal atypical use of the instrument by general medical practitioners. Moreover, it does not seem to have occurred to him that the reason medical practitioners are incapable of specifying their requirements for ophthalmic instruments is simply because the majority rarely, if ever, use them after leaving medical school. Contrary to his evidence that the life of a hand-held ophthalmoscope is infinite, evidence from the sample of opticians indicates that because the instrument is the one most frequently used by them, it has a life of about 7 years. It is an instrument that wears out through constant use. New models, incorporating technological developments such as halogen illumination and improvements in design to give better handling characteristics, are introduced to the market from time to time. Even a high-quality hand-held ophthalmoscope is relatively inexpensive compared with the order of costs for 'big' ophthalmic instruments, so neither low cost nor value-for-money are primary determinants when an optician purchases a new one. The evidence obtained from the sample of users suggests that they are ready to purchase instruments of high quality and regard the basic minimum-cost Maylite manufactured by Gowllands to be inadequate for their requirements.

Gowllands is not the only firm to be influenced by medical practitioners even though their use of ophthalmic instruments is nominal; Keeler Optical Products relies on a panel of them to test new products. However, there are signs that Dolland & Aitchison, the new parent company of Hamblin Instruments, is breaking the link with the medical profession as a first step in improving its innovation strategy.

(cf 4.2.4) Sabell's observation that ophthalmic opticians have a vested interest in both innovation and design related to the instruments they use because of the direct link with personal performance is instructive. It shows that if innovation results in a new product requiring manipulation by the user, the mode of operation of the product relative to the user can affect its commercial success.

This can be stated as a principle:

> Where the aim of technological innovation is to create a new product which is manipulated manually by the user, part of the innovation process should be to carefully arrange the mode of operation of the product in terms of personal convenience and ease of use.

(cf 4.2.5.1) The evidence obtained from Keeler Optical Products shows that until 1976 the firm handled product design as a low-key activity conducted by employees of low status. To that extent, this evidence corroborates the observations made in 1.1, where it is stated that new products can emerge simply as an assembly of components, the arrangement of which has been devised by an engineering draughtsman whose preoccupation is with the technical detail of mechanical practicability. It is to be inferred that the organisational changes in the firm and the appointment of a Chief Design Engineer as well as additional design staff were prompted by the poor performance in new product development. However, the appointment of a Chief Design Engineer responsible to the Technical Director indicates a conservative approach to new product development; the technology and the engineering are regarded as the main influences on the product design. The users' influence comes from feedback in trials of the finished product, after the design phase has been completed, which does not augur well for radical modifications prompted by users. Though Keeler's acknowledgment of product presentation as a factor in development represents some progress, for this to be perceived as a sub-function of engineering inevitably entails compromise in favour of the latter.

The investment in industrial design services by Keeler Optical Products (£200 per annum) is very modest and the form it takes (Design Council Advisers) indicates a cautious attitude towards it. The Chief Design Engineer's concern that to engage consultants would probably result in increased pressures being brought to bear on him illustrates that product design, rather than being simply the consequence of mechanical practicability, can be sensitive to outside opinion.

(cf 4.2.5.2) The evidence obtained from Hamblin Instruments shows that this firm also handles product design as a low-key activity conducted by employees of low status, providing further corroboration of the observations made in 1.1. That the firm nevertheless regards itself as the foremost British manufacturer of ophthalmic instruments suggests unawareness of an alternative approach to product design and unconcern for the international competition.

(cf 4.2.5.3) In comparison with Keeler Optical Products and Hamblin Instruments, Gowllands has a more enlightened approach to product design. The firm is product-orientated and by engaging consultants in an executive role does not allow the technology or the engineering to dominate the approach. However, its commitment to process innovation is limited, preferring to forego means of increasing productivity stemming from good design and instead retaining labour-intensive methods to avoid investing in new plant.

(cf 4.2.6) The firm innovates at the level of minor technical improvements; as a consequence, its design capability to introduce new products with high added value is under-utilised. It seems that Gowlland perceives invention as a sub-set of the industrial design process and in doing so greatly reduces the probability of introducing entirely new science-based products.

(cf 4.2.5.1) From the evidence, the Design Council Awards cannot be regarded as a reliable and objective indicator of innovation. Bearing in mind that there are only three British manufacturers of ophthalmoscopes, for an Award to be given to Gowllands' Maylite in 1977 partially on the basis of the integral plastic moulded dioptre lens-wheel being novel when this same feature had been included in the Keeler Pocket ophthalmoscope since 1972 shows a lack of diligence in checking claims to innovation by manufacturers. Primarily of course, the Awards are intended to encourage good design rather than innovation but in the Council's rules the latter is listed as one of the criteria and therefore should bear scrutiny. In the Design Council making an award to the Keeler Pocket Diagnostic Set in 1979, there is a suggestion of placating an irritated manufacturer rather than dispassionate concern for design merit; after all, on Keeler's own evidence, at the time when the Pocket ophthalmoscope was introduced, the design capability of the firm was very limited. The unreliability of a Design Council Award as an indicator of innovation did not escape the notice of at least one of the opticians in the sample; Cooper dismisses the award to Maylite as an acknowledgment of aesthetic merit only, with no concomitant requirement to introduce new technical features. Moreover, the opinion of Calvert, the industrial design consultant involved in the project, that the aesthetic merit of the Maylite design was compromised by Gowlland's insistence on the use of an existing component in the product, further devalues the award. Evidently there is considerable scope for improved performance at the Council in the promotion of good design and innovation in firms. That the resources of Imperial College were deployed in re-inventing a plastic dioptre lens-wheel is also cause for concern.

(cf 4.2.7.1) The reputation of British ophthalmic instrument manufacturers among users is evidently unfavourable; Gowllands' standing is particularly low. Keeler Optical Products has a substantial following for its hand-held ophthalmoscopes only and this seems to stem mainly from influences in formal training rather than the firm's visibility in the market. Significantly for innovation in this field, though the products under discussion are scientific instruments, the users evidently look for not only technological improvements but also good design. The low standing of British manufacturers among the users is in part due to poor design. This adverse reputation about poor design is relative; the British instruments compare unfavourably with those of foreign design and manufacture. The failure of British firms to be as determined as German and Japanese firms in introducing new instruments of high quality has not escaped the notice of the users. Nevertheless, in spite of the low standing, there is goodwill and support available to British firms if they can satisfy the needs of the users; not for sentimental reasons but because it makes economic sense for service industries interested in growth to support indigenous wealth-creating manufacturers. There is evidently no shortage of positive advice for the manufacturers from the users - at the level of both policy and practical detailing - to aid them in recovery.

(cf 4.2.8.1) The significance of user needs in this product category is that they call for manufacturers to take a sophisticated approach to design; not in the sense of being visually trendy and highly stylistic but in the capacity to accurately reflect in the hardware the ethos of the user's practice; refined confidence and professional skill. Opticians need to communicate their skill to patients to inspire confidence; instrument manufacturers can use industrial design as a means of aiding the optician to communicate with the patient. Through good design, it is possible for manufacturers to enhance the quality of instruments as perceived by the user without the need for high levels of investment in scientific research and technological development. Instead, it entails a capacity to comprehend the needs of users as expressed by them in general terms and recognise that through design these needs can be translated into features in the hardware. Though firms are often criticised for being slow to adopt the discoveries of scientific research, they are even slower to realise that the general comments of users can be used as design data in new product development. Perceived in this way, the comments of users recorded in this study provide manufacturers with explicit proposals for improving products which embody existing scientific knowledge. It is also evident from these comments that there is enormous scope for variation and distinctive features which manufacturers can incorporate in instruments, given that the approach to design is both imaginative and sensitive.

Considering the results in Tables 6 and 7, it is noted that there are some nil and near-nil responses from the users. Not one optician in the sample was influenced by the terms of trade from the supplier. The reputation of the manufacturer influenced few; only those of the older generation in the sample. Lowest cost does not feature prominently as a factor; only a few of the opticians had ever bought an instrument because it was the cheapest available and when they had done so there were extenuating circumstances, e.g. limited funds when first setting up in practice. Most of the opticians who gave value for money as a reason did so as a secondary consideration; it was complementary to a more significant reason such as familiarity from training or design features. Evidently industrial design and technical performance are by a considerable margin the most important primary factors and industrial design the most important of all when primary and secondary factors are taken together.

When the factors are disaggregated according to instrument types (Table 7), a variety of patterns emerge. Nevertheless, for some of the instruments in the sample, there is a clear pattern of purchasing factors. For instance, in the case of the hand-held ophthalmoscope, though the industrial design of the instrument - its 'feel' and handling qualities, position of controls, and so on - is a significant primary factor, even more significant is the optician's familiarity with the particular make and model of the instrument acquired during formal training. Actually, these two factors are interrelated. The explanation of the purchasing pattern seems to be as follows. The hand-held ophthalmoscope is the instrument used most frequently by opticians. Considerable skill is required to use it deftly and accurately. This skill is developed initially during formal training. At this time, the student-optician is encouraged to select from a variety of makes available a particular model of ophthalmoscope which is to his liking, then to develop a rapport with this instrument so as to gain confidence in its use. The consolidation of this skill transcends all other considerations, and the newly-qualified optician invariably purchases the make and model of ophthalmoscope with which he became familiar during formal training. Bearing in mind the frequency with which it is used, even a high-quality hand-held ophthalmoscope is relatively inexpensive so neither cost nor value for money are significant purchasing factors. It seems, therefore, close liaison on design matters between the innovating firm and a University Department of Ophthalmic Optics, the customary place of training for ophthalmic opticians in the United Kingdom, could directly influence the commercial success of a new ophthalmoscope. The firm may even regard equipping University Departments with its ophthalmoscopes as a sound investment.

By contrast, the purchasing pattern for the tonometer is much more diffuse. Table 7 shows that while technical performance is an important primary factor and industrial design an important secondary factor, the opticians purchased for a variety of other reasons too. For instance, it transpired that the opticians in the sample are divided about the best technical method of measuring intra-ocular pressure. Some prefer the applanation method as employed in the Perkins tonometer while others prefer the air-blast non-contact method, even though an instrument of the latter type is much more expensive (£3,500 compared with £150). Clement Clarke, the manufacturer of the Perkins tonometer, states that its portability enables a practitioner to take the instrument to patients rather than vice-versa.[120] Some of the opticians perceived this portability differently: the instrument can be carried easily from one practice to another, enabling it to be an economical common-user item of equipment.

Like the tonometer, the purchasing pattern for the keratometer is diffuse but industrial design and technical performance are still the most common factors. The design preferred by the majority was that by the American firm of Bausch & Lomb, even if three of the opticians were so astute as to purchase Japanese copies of the instrument at a lower price. The only British instrument in the sample is one manufactured by Clement Clarke and offered to the optician as part of a slit-lamp microscope/keratometer package at a very low price. It proved to be of poor technical performance.

In the case of the focimeter, it seems that all moderately-priced versions are technically very similar so that technical performance is not a decisive purchasing factor. Because the instrument is also operated by unqualified assistants, most of the opticians interviewed prefer one which is very easy to operate and virtually fool-proof. There is a wide price range for focimeters and the majority of opticians were seeking value for money, i.e. facility/cost. Exceptionally, one optician uses a focimeter originally bought as a standby at the lowest cost available. At the other extreme, one optician bought a very expensive instrument because he was attracted by its prestigious qualities. There is only one British made focimeter in the sample, bought by an optician because the stockist was disposing of the instrument very cheaply in a closing-down sale.

As is to be expected when a microscope is purchased for professional purposes, the technical quality of the optical system is a primary consideration for the majority of users. However, ease of use was also an important consideration in choosing between makes of instrument. Two of the opticians were influenced in their choice from familiarity with the make acquired during University training. In the event, four opticians in the sample purchased an instrument manufactured by the East German firm of Zeiss-Jena. Of the remainder, the only British instrument in a miscellany of foreign manufactures is the Diag 3 manufactured by Clement Clarke, now a discontinued line. Only one optician bought the cheapest microscope available; at the time, he was setting up in practice and had only limited funds available.

Summing up, the message from independent ophthalmic opticians seems very clear. Regardless of the technical sophistication of an instrument, the users perceive its value through industrial design. For ophthalmic instruments at least, to be commercially successful, certainly no less attention should be paid to industrial design during development than to technical performance. Conversely, to regard industrial design lightly or to deal with it inexpertly seems to be a recipe for commercial failure.

Aston University

Illustration removed for copyright restrictions

Figure 11. The 'Maylite' hand-held ophthalmoscope manufactured by Gowllands Limited with detail of dioptre lens wheel.

Source: The Design Council.

Aston University

Illustration removed for copyright restrictions

The Keeler 'Medic'.
Source: Keeler Optical Products.

Aston University

Illustration removed for copyright restrictions

The Hamblin 'Morton'.
Source: Hamblin Instruments.

Figure 12. Hand-held ophthalmoscopes: other makes.

This presents technical development personnel - especially those in charge - with a difficulty. Their aim in a new product is to achieve excellence in technical performance but having done so, if they are to be responsive to user needs, this achievement must then be subsumed in the industrial design of the instrument. Such an approach represents a radical change in new product development and only secure enlightened technical personnel can readily accept that their contribution, though in many respects central during development, ultimately appears incidental in the finished product. It calls for a much better understanding of the subtleties of user needs, which have been elevated in expectancy by today's conditions of intense international competition. Currently, there is a wide discrepancy between the level of technology manufacturers embody in new products and the level of design they deploy to convert the technology into hardware compatible with users; the linking of scientific development to the sophisticated needs of users is still relatively crude.

The issue is a significant one for policy-makers in firms. Unless responsibility for industrial design is discrete, there is a risk that it will be compromised to accommodate preferred solutions of technical personnel. This calls for investment in design expertise of a higher order of magnitude than heretofore but lower in order of magnitude than customarily allocated for technical development.

4.3 Electronic Micrometers

4.3.1 Introduction

The starting point for this case study is the Micro 2000 self-contained hand-held electronic micrometer manufactured by Moore & Wright Limited of Sheffield. (Fig.13) The Micro 2000 received a Design Council Award in 1978 and the inventor of its mechanism received the 1978 Duke of Edinburgh's Personal Prize for Elegant Design.

The evidence comprises that obtained from the published literature;[121] from the Engineering Manager of Moore & Wright and its Director of Research; from the industrial design consultant involved in the Micro 2000 project; from manufacturers of competing products.

4.3.2 The Firm

The firm of Moore & Wright was founded in 1906. It manufactures conventional micrometers, other precision measuring instruments, and hand tools such as tap wrenches and scribers. Most of the designs have remained substantially the same for many years. Improvements are related mainly to material specifications and more economical methods of manufacture. Many of the products are sold through retail outlets such as hardware stores.

The firm has 850 employees. In 1970, Moore & Wright Limited became a subsidiary of the James Neill Group. The Group as a whole has approximately 5,000 employees and an annual turnover of £33 millions. Besides Moore & Wright, the Group controls six other firms engaged in the manufacture of measuring instruments and hand tools. All the manufacturing subsidiaries operate as autonomous profit centres.

A Group research facility, James Neill Services Limited, is available to the manufacturing subsidiaries. The ramifications of the Group are shown in Table 8.

Moore & Wright holds 60% of the United Kingdom market in the categories of hand-held precision-measurement instruments it manufactures. Elsewhere, the firm has only a small market share. For instance, the European market is dominated by Japanese firms. In the post-war period the firm has experienced two waves of severe competition in its traditional markets and has been vulnerable to the imitative strategies of others. Firstly, Japanese firms have been able to produce superior products at lower selling prices. More recently, Polish and Czechoslovak manufacturers have made inroads into the home market with low-cost products.[122]

4.3.3 The Micro 2000 Project

The James Neill Group does not undertake fundamental scientific research. Even though the Group has a 'research facility', the work undertaken more nearly equates with engineering development and engineering design. Outside bodies are utilised for research projects, e.g. the University of Aston for materials research.

The Micro 2000 project was not initiated by the firm itself but by a firm seeking to do business with it. In 1973, Patscentre International, the advanced technology wing of PA Management Consultants, approached James Neill (Holdings) Limited and suggested

TABLE 8 : THE JAMES NEILL GROUP OF COMPANIES

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Illustration removed for copyright restrictions

Source: James Neill Holdings Limited

that the latter take advantage of the former's ability to develop new products. Previously, Moore & Wright Limited had contemplated producing a hand-held electronic micrometer. It was realised, however, that the skills required to bring about such an innovation were not available within the Group. Therefore, Patscentre was commissioned to carry out a feasibility study. The sequence of events in the innovation process that followed is shown in Table 9. The feasibility study yielded a potential solution which the Moore & Wright management judged to be attractive and a full design study was commissioned under conditions of strict commercial confidentiality.

TABLE 9 Micro 2000 : The Innovation Sequence

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Illustration removed for copyright restrictions

Source : Taylor, D.[125]

A number of 'design parameters' were set at this stage:[124]

(i) the instrument to be as accurate as the most accurate conventional micrometer;

(ii) the instrument not to be dual reading, ensuring safety in measurement and satisfying the legislation in certain European countries;

(iii) the design to be modular, facilitating servicing and repair, and so that sub-assemblies can be manufactured at the most appropriate production centres in the James Neill Group for final assembly at Moore & Wright;

(iv) the instrument to be compact and lightweight for ease of holding in the hand, to have a self-contained power source, and a displayed digital reading facility;

(v) the instrument to be robust in construction, reliable, and accurate in operation over many years of normal use, with functional components tested to 10^6 cycles.

A simple, low-cost means had to be found of translating the mechanical movement of a micrometer into a signal that could be electronically processed to give a digital read-out. Following a study of possible transducers, it was decided that an optical method was the most appropriate. The moire-fringe effect, produced by the relative movement of two small optical gratings, was adopted for its high magnification of the mechanical movement and because its development would probably yield a low-cost device.[125] However, the design solution presented had the drawback that the product would be difficult to manufacture within the resources of the James Neill Group. Patscentre therefore proposed providing a completely productionised turnkey project which could be introduced into the James Neill organisation as a package.

This prompted the James Neill management to make a number of decisions:

(i) to commit itself to the unaccustomed risks and development costs associated with the launch of a high-technology product;

(ii) to organise the productionising phase of the project as a Group effort (Table 10) with Moore & Wright as the product centre and Patscentre as the design authority;

TABLE 10. MICRO 2000 : PROJECT TEAM ORGANISATION

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Illustration removed for copyright restrictions

Source : Taylor D.[126]

(iii) to monitor progress and authorise major expenditure through a Group R & D Policy Committee comprising directors of the Holdings Board of the Group, the managing director of the central sales and marketing company, and the director of Group research;

iv) to organise the manufacture and testing of electro-optical sub-assemblies at R.A.Stephen Limited, a Group subsidiary with experience in the manufacture of scientific instruments involving precision optical moulding, photo-etching, and clean-room assembly;

(v) to coopt the services of an industrial designer from Patscentre and those of the James Neill Group industrial design consultant to ensure that the instrument would be aesthetically pleasing and ergonomically balanced;

(vi) to organise final assembly, testing of the finished product, and after-sales service at Moore & Wright Limited.

The integrated circuit required for the hand-held electronic micrometer could not be obtained in the form of a standard circuit module. Therefore, the following specification for the integrated circuit was drawn up by Patscentre in 1976 and translated into a technical design by the Wolfson Liaison Unit at the University of Edinburgh:

count square wave pulses at a frequency of 62,000 per second;

detect direction;

drive directly a six-digit l.e.d. display (a function not before achieved in similar designs);

zero the display whenever the voltage supply is interrupted;

illuminate the appropriate decimal point according to whether the imperial or the metric model is being used;

suppress zeros prior to the decimal point;

detect and indicate low battery voltage by illumination of all decimal points;

count both up and down and indicate negative values.

The integrated circuit was manufactured by General Instrument Microelectronics Limited.

This phase in the development was more difficult than expected. As a consequence, planned time-scales had been widely underestimated and the availability of tested integrated circuits determined the critical path of the network analysis. However, the finished product meets the requirements of British Standard 870 and the draft International Standards Organisation regulations. Moreover, the new instrument is more versatile than that which it supersedes; it can be used additionally as a comparator and as a calliper. Unlike conventional micrometers, the instrument can hold its reading when removed from the work-piece. This facility enables readings to be taken in awkward locations.

The contractual arrangement with Patscentre entailed a series of phased budgets. Patscentre invoiced Moore & Wright weekly and the contract could be terminated by Moore & Wright at one week's notice. In the event, the development budget for Micro 2000 was greatly exceeded. Patscentre originally estimated the development costs at £75,000 but the actual costs to the point of production approached £300,000. It is not possible to separate out from this the industrial design costs. The original product cost objective for Micro 2000 was £12.00, with a selling price of two or three times that amount. The actual initial selling price was £125.00. Subsequently, when quantity production was fully established, the selling price was reduced to £89.00.[127]

4.3.4 The Finished Product

In Micro 2000, the vernier of a conventional micrometer is replaced by a moire-fringe transducer. The moire-fringe effect is created by two glass blocks, each inscribed with a fine-pitch grating, sliding over one another. The glass blocks are assembled to provide a specified angle between the lines of the gratings. Solid-lubricant rails deposited on the surface of the blocks act as low-friction bearings and provide the correct spacing for maximum contrast in the moire-fringes.

The micrometer spindle is supported in two plain solid-lubricant bearings and attached by a universal joint to one of the slider-blocks of the transducer. A tension-spring operating in the flexural mode provides a constant closure force on the spindle. A sealed viscous damper controls the closure speed of the spindle.

Infra-red light from a light-emitting diode is collimated by a lens and passed through the glass blocks of the transducer. Movement of the micrometer spindle produces relative movement between the glass blocks, causing the moire-fringes to modulate the infra-red light. This light is de-collimated on to a pair of photo-detectors to give two electrical signals. These signals are conducted to an integrated circuit which measures the spindle movement. The reading is shown on a digital l.e.d. display. The instrument is powered by a re-chargeable battery. The accuracy of the instrument is ±0.002mm.

The product could have been given any of a number of images, ranging from a technological gadget to a familiar workshop instrument. The extent to which the technological innovation should be reflected in the appearance of the product was carefully considered. The image chosen was a compromise; obviously modern and superior in capability, yet derived from and recognisable as a micrometer.[128]

4.3.5 The Place of Industrial Design in the Firm

The management of the James Neill Group acknowledges industrial design as a discrete activity and it is closely identified with the activities of the Group Research Centre. Industrial design is seen as the means of exercising control over and improving the presentation of products. To this end the Group Research Centre retains on a regular basis the services of an industrial design consultant; in a general consultative capacity and on specific projects. His services are available to all the manufacturing subsidiaries in the Group.

The consultant, David Mellor, has a national reputation and a considerable personal standing in Sheffield. He is a trend-setter and innovator in modern cutlery design. Products with which he has been associated were among the first to receive a Design Centre Award, the forerunner of the Design Council Award. He is a Royal Designer for Industry. Besides designing, Mellor manufactures household products and retails them through his own high-class ironmongery stores in Sloane Square and Covent Garden. In 1981, he received a Duke of Edinburgh Design Management Award in recognition of this entrepreneurial activity.[129]

The Director of Research[130] identified the following as the consultant's particular contributions:-

(i) during the early stages of projects provides advice on product configuration, materials and finishes;

(ii) provides advice on the ergonomics, styling and colour of hand-held tools and instruments; as a perceptive outsider, brings suggestions for design improvements which could not be supplied by in-house personnel;

(iii) produces in his own workshop, models of design proposals to demonstrate handling qualities, desirable shapes, and the visual effect of various finishes;

(iv) provides advice on appropriate production processes for the forms he proposes based on his contact with other industries;

(v) produces attractive shapes which reflect a knowledge of economic methods of production, especially in the case of plastic mouldings and precision die-castings;

(vi) brings to the Group his experience as the principal of an integrated firm which is engaged in the design, manufacture and retailing of products in a kindred field;

(vii) an aide when presenting development proposals to Boards of Directors.

With reference to the last-mentioned contribution, particular skills are required to adequately communicate development proposals to Boards.

Proposals have to be explained to accountants and financial directors who are unfamiliar with the minutae of technicalities related to particular products. Even technical directors have difficulty in visualising the outcome of partially-resolved projects. On the other hand, they are attracted by, and become interested in, projects which are presented in such a way that the outcome is seen as an attractive (and therefore saleable) product. In these circumstances, models which demonstrate function simply and the likely form of the finished product are a means of gaining Board approval of development proposals.

The consultant has direct access to, and addresses his advice to, the Director of Research. In normal circumstances, the consultant is paid an annual retaining fee. He is paid extra for work on specific projects. Normally for a project, industrial design is less than 2% of the total cost of development and in the range £1,000 - £2,000.[131]

The Group has not developed the use of industrial design to the extent which warrants a full-time employee. Moreover, knowledge obtained from outside contacts is regarded as an important contribution of the consultant, which would be lost if he were to deal only with the Group's products. For a period, the Group employed a newly-qualified industrial designer as a member of the in-house engineering design team. It was an experiment to assess the value of the alternative contribution stemming from formal training in industrial design and arose from contact between the firm and Sheffield Polytechnic. Through this contact, the Director of

Research is aware of the alternative approach to product design adopted in industrial design studies and believes it has commercial potential. He is attracted by the lateral thinking, as distinct from the sequential thinking of an orthodox engineer. He believes this less-disciplined thinking can yield radical alternatives during brain-storming sessions; visualising and aiming for a final product rather than pre-occupation with the minutae of technical detail. Enthusiasm for the alternative approach is tempered by the view that formal training in industrial design is as yet in an embryo state relative to its usefulness to industry. The experiment with the newly-qualified industrial designer was not an unqualified success. The firm's development engineers are sceptical of the value of the alternative contribution though it is acknowledged that they have trammelled attitudes and modes of thinking which are not easily changed.

The Director of Research identified flair as a necessary quality in an industrial designer. The firm's consultant is a forceful personality; strong in his opinions and with a confidence in approach which is very persuasive. By contrast, the consultant from Pats-centre is a quiet personality but commanded respect at Board meetings because he communicated lucidly through spontaneous drawing.

At the manufacturing subsidiary Moore & Wright Limited, the management recognises industrial design as significant in relation to traditional products. Cosmetic changes have been made to conventional micrometers in order to up-date their appearance.

Another manufacturing subsidiary in the Group, by producing a model of the conventional hacksaw with an ergonomically-designed die-cast pistol-grip handle as an alternative to that with a traditional turned hardwood handle, substantially increased the sales of this product.

However, the engineering manager at Moore & Wright stated that product availability far outweighs industrial design as an issue in successful innovation.[132] In his view, the launch of Micro 2000 was premature, hastened by the knowledge that a competitor, Quality Measurements Incorporated of America, was about to launch a similar product, 'Q-Mike'. (Fig.14) After the publicised launch of Micro 2000, demand for the product exceeded the capacity of Moore & Wright to supply the quantity required. Some of the market was lost to Q-Mike because of its availability even though it was more expensive, had no technical advantage over Micro 2000, and is less attractive visually. At the time, the selling price of Q-Mike was £195, that of Micro 2000 £125.

4.3.6 The Effect of Winning a Design Council Award

The 1978 Design Council Award to Micro 2000 was the first to be received by a product of Moore & Wright or its parent Group. However, the Group management professed greater interest in a Queen's Award for Industry. In 1966, the Group had received a Queen's Award for export achievement. It sought one for technological innovation in respect of the Micro 2000 and received it in 1979. Of all the participants in the Micro 2000 project, those said to be most excited by the Design Council Award were the industrial design consultants.[133]

There is a second design award associated with Micro 2000; the Duke of Edinburgh's Personal Prize for Elegant Design. Formerly, this prize was awarded on the personal recommendation of the Duke to an industrial designer associated with one of the Design Council Awards. In 1978, the rules for this prize were changed so as to make engineers or a design team also eligible. In that year, the prize was awarded to the Micro 2000 project leader, an engineer and the inventor of the sliding glass-block moire-fringe transducer.[134]

The Design Council Award appears to have drawn the attention of the Moore & Wright management to the activities of the Council. Following the award, the firm sent a number of its engineers on a short course in industrial design organised by the Council, with the intention of developing an in-house capability in industrial design.

4.3.7 The Micro 2000 Project : From the Standpoint of the Industrial Design Consultant

The industrial design consultant, an employee of Patscentre, became involved in the project two years after the feasibility study for the product had been undertaken, when Moore & Wright commissioned the full design study. In retrospect, the consultant does not regard the design of Micro 2000 highly but maintains it was the best that could be done with the technology available at the time. The electronic hardware used in the product, e.g. printed circuit board, wired connections, is much bulkier than would be used were the product designed today.[135]

Before the consultant became involved, the project leader had already devised the sliding glass-block transducer as a means of obtaining the micrometer readings and Patscentre engineering personnel had already devised a configuration to embody it in the new product (Figure 15.1). In the consultant's view, however, this configuration rendered the instrument virtually unusable. Though the instrument would be capable of functioning technically in this form, the mode of operation is unrelated to that of a conventional micrometer and would probably be judged by users as too bulky and very ungainly. To overcome these deficiencies, the consultant re-arranged the components of the micrometer along a single axis so as to produce a configuration as shown in Figures 15.2 - 15.4, which he judged as more likely to gain user acceptance. Even so, the consultant's design is bulky for a hand-held product; a compromise between technical development and human use. The Patscentre development engineers would have preferred the various components of the product, i.e. glass blocks, printed circuit board, light-emitting diode, damper, and spring, to be assembled with more space separating them. However, to comply with its description, it was necessary to contain the components in a space envelope that could be gripped in the hand.

During the project, the consultant also played a support role for R & D. The various physical block models he produced were crucial as a means of persuading the Moore & Wright directors to sanction further development of the design. The directors did not understand the details of the electronics in the project; the block models, however, indicated to them the form of the finished product. In the event, the directors were unaccustomed to assessing design models; they were unable to distinguish between design and its representation in a model. Several variants of the design were submitted for approval by them. (Figure 15). One of the fourteen directors strongly influenced the others and he firmly rejected the variant recommended by both the consultant and the Group Director of Research on the grounds that a control-button on the block-model malfunctioned during the presentation.[136]

Taylor provided corroboration on the shortcomings of the Moore & Wright management. The claims of Patscentre on the service it could provide were not fully justified. This caused difficulties during development. However, the weak link in the development chain was not so much Patscentre as Moore & Wright. Employing consultants of this type entails a capacity for penetrating criticism of proposals coupled with detailed knowledge of the firm's own manufacturing capability. At the time, Moore & Wright management did not realise the additional responsibility and accountability required of them by this mode of development. They were not sufficiently professional. They dealt with matters superficially. They asserted and guessed. They did not anticipate likely areas of difficulty in manufacture. As a consequence, there have been changes in the management at Moore & Wright.[137]

The choice of materials for the product was quite straightforward. The consultant proposed a satin finish for the handle but settled for a matt finish because the processing was within the existing capability in the firm. Even though the firm invested heavily in the Micro 2000 project, there were compromises in the design so that the firm's existing facilities could be utilised.

There is a significant discrepancy between the initial target cost of £12.00 for Micro 2000 and its eventual cost. In the feasibility study, it had been overlooked that the magnitude of the closing force for micrometers is specified in a British Standard. To both meet this specification and lessen the consequential impact at the micrometer anvil so as to give the instrument a reasonable life, it was necessary to include a damper in the system. The cost of the damping arrangement accounted for most of the difference between the target and the actual cost.[138]

4.3.8 Subsequent Developments

In 1977, after four years of research, design and development, Moore & Wright launched Micro 2000 as a standard 0-25mm micrometer and as an Imperial 0-1 inch alternative. Market research estimated a market for the product of 10,000 units per annum. In the first year, 15,000 units were sold and in 1978, 30,000 units were sold.[139] The Moore & Wright management were sufficiently encouraged by the market response to embark on the development of a product range based on Micro 2000. By 1981, the product range shown in Table 11 was available. Figure 16 shows the way in which the original design was used to develop the product range. Patscentre and its industrial design consultant were not involved in this development.[140]

Table 11. MICRO 2000 : PRODUCT RANGE

Description	Catalogue No. Imperial	Catalogue No. Metric
	0-1"	0-25mm
Standard model — flat anvils	**M2001**	**M2025**
Ball anvil and Ball spindle	**M2001BB**	**M2025BB**
Ball anvil and Flat spindle	**M2001BF**	**M2025BF**
Flat anvil and Ball spindle	**M2001FB**	**M2025FB**
16mm Pad anvils	**M2001P**	**M2025P**
60° pointed anvil and spindle	**M2001S**	**M2025S**
Half pressure closing force	**M2001LP**	**M2025LP**
Standard model — Flat anvils	**M2002**	**M2050**
Ball anvil and Ball spindle	**M2002BB**	**M2050BB**
Ball anvil and Flat spindle	**M2002BF**	**M2050BF**
Flat anvil and Ball spindle	**M2002FB**	**M2050FB**
16mm Pad anvils	**M2002P**	**M2050P**
60° pointed anvil and spindle	**M2002S**	**M2050S**
Half pressure closing force	**M2002LP**	**M2050LP**
Multi Anvil model	**M2001MA**	**M2025MA**
Multi Anvil with Base	**M2001MAB**	**M2025MAB**
Depth gauge electronic micrometer	**M2001D**	**M2025D**
Adjustable electronic micrometers		
Capacity 0-2" or 0-50mm	**M2002A**	**M2050A**
Capacity 0-4" or 0-100mm	**M2004A**	**M2100A**
Capacity 0-6" or 0-150mm	**M2006A**	**M2150A**
Capacity 6-12" or 150-300mm	**M2012A**	**M2300A**
Micro 2000 stand For 0-1" or 0-25mm models only	**M2000 STAND**	

Source: Moore & Wright Limited

4.3.9 Evaluation

(cf 4.3.3) Evidently Moore & Wright is a firm which has felt the strain of international competition, not only in terms of export but also in the depletion of its share of the home market. However, unlike Gowllands, the firm has the advantage of greater financial resources on which to draw and a Group board of directors which puts pressure on the local management to innovate. The Micro 2000 project indicates not so much a firm seeking to innovate as part of its normal activity to maintain market leadership, more the attempt of a management to prevent further erosion of its business. It is evident that the management is unaccustomed to taking the risks inherent in technological innovation; its capability seems to be limited to organising production, sales and distribution. Nevertheless, it is to the firm's credit that it took the unusual step of engaging consultants to undertake most of the process of innovation on its behalf. The involvement of the Patscentre organisation in the project provides a pointer for other firms which seek to innovate but have not the manpower capable of doing so.

Table 10 illustrates a firm's capacity for complexity in organisation when initiating technological innovation. Almost inevitably, that complexity is a breeding ground for seeds of internecine rivalry between factions at all levels. In these circumstances, unless the control of the product design is at a high level in the organisational structure, it is likely to be a casualty of compromise.

Even though most of the process of innovation was delegated, the management still had the inescapable responsibility of initiating the project following the feasibility study, and its attempt to do this in an organised manner is instructive. It took as a starting point a set of 'design parameters'. However, the parameters do not identify a profile for the product; rather, they are the elements of a general technical specification, concerned with order of accuracy, method of construction, the power source, and testing of components. The only meaningful reference to design is for a displayed, digital reading facility. It is an example of the low level of communication mentioned in 1.5. The management had only a vague idea of what form the new product should take; either it was unable to be explicit or did not consider it necessary to be so. In briefing the innovation consultants, the management resorted to technical detail. This corroborates an issue identified earlier by the users of ophthalmic instruments: a management unaccustomed to thinking in terms of the product. There is a dearth of vocabulary to adequately describe new product proposals. The discrepancy between the projected and actual selling price of Micro 2000 is a further indication of the vagueness with which the management envisaged the new product, the market, and the users.

(cf 4.3.7) Figure 15 illustrates that even though the same components are used, the configuration of a product can be very different if factors other than technical function and production processes are taken into account. When the alternatives are set side by side, those shown in Figures 15.2 - 15.4 seem obvious solutions and that in Figure 15.1 unacceptable. Yet it is not in doubt that the alternative shown in Figure 15.1 was a serious proposal at the time. Whether one attributes the preferred solution to special training in industrial design is debatable; it is not so much that the preferred solution is profoundly expert, more one of attitude towards the problem which enables such a solution to emerge. It seems, however, that for this to happen, a contribution is required from someone who is neither inhibited nor trammelled by responsibilities in either technical development or production.

This example also illustrates the importance of the timing of the design phase in the innovation process. If it is too late, personnel with technical responsibilities in the project are likely to resist forsaking perhaps lengthy and taxing development of a selected configuration in order to accommodate radical change prompted by user considerations. It may even be described as a critical point in the innovation process, when the outcome is based not so much on the merit of the challenge as the relative status of the challenger and the challenged.

The pressure to compromise a design by improvising with existing components or factory facilities is another critical point. It occurred in the Maylite project; it occurred in the Micro 2000 project. It represents perhaps an even stronger challenge than that of change in configuration because the issue usually at stake is investment in new production facilities. Of course, it is a test of resourcefulness and imagination in design to endeavour to use existing production facilities but to make it a pre-condition is to shackle the innovation process. An aid to overcoming this problem is a procedural one: the production of alternative designs with and without the constraint of existing components and facilities, followed by an assessment of the benefits and disbenefits. This procedure is valid only if the management can make a mature assessment of the alternatives. This study shows that it is necessary to test rather than assume maturity.

(cf 4.3.8) The subsequent development of Micro 2000 into a range of related products illustrates in a negative way the need to sustain a high level of managerial control in design if there is to be consistency in aesthetic quality throughout a range. This objective is not an end in itself; if aesthetic quality adds perceived value to one product in a range, it is reasonable to assume that it will do so for the others. During the original Micro 2000 project, Patscentre was the design authority. Moore & Wright did not engage that organisation in the subsequent development of the product range. Even though lessons were learnt from Patscentre during the original project, even though the new product was a commercial success, the old habit of improvising with existing components and finishes - characteristic of much British engineering design - resurfaced in the product range. For example, comparing Figure 17 with Figure 16, it will be seen that the main casting of the conventional product is also used in the new product, even though both the shape and the surface texture are inappropriate. Moreover, the facing on this casting which carries the brand name on the conventional product, rendered superfluous on the new product because the branding appears on the digital display housing, carries 'Micro 2000' in a different letter-face. The overall effect of this and other improvisations in detailing within the product range is to introduce visual muddle where otherwise there could have been a consistently clear projection of elegant high-technology products.

Figures 14, 18 and 19 illustrate diffusion in innovation and the commercial competition which is a by-product of this diffusion. The Figures also illustrate that when comparing products with a similar technical function, the influence of configuration and general appearance is inescapable. Viewed alongside the international competition, Micro 2000 is unmistakably an example of good design; clearly a product of its time, projecting elegance in both concept and realisation. By contrast, the Mitutoyo instrument from Japan (Figure 18) is an example of poor design. The product suggests visually the addition of an electronic calculator to a conventional micrometer. This additive process in design results in visually confusing forms, seen at its worst in machine tool engineering. The dated hammer finish on the Mitutoyo instrument is in conflict with the high-technology inferred by the micro-electronics. The Q-Mike from the United States (Figure 14) is not unattractive and potential users would probably not be deterred from purchasing by its appearance. However, soon after the launch, this product was withdrawn from the market as a free-standing hand-held instrument because the battery-charging system proved to be unreliable. It is a

Figure 13. The 'Micro 2000' hand-held electronic micrometer manufactured by Moore & Wright Limited.

Source: Moore & Wright Limited.

Figure 14. The 'Q-Mike' hand-held electronic micrometer manufactured by Quality Measurement Systems Incorporated.

Source: Quality Measurement Systems Incorporated.

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Figure 15. Block models of Micro 2000.

Source: Patscentre International.

Figure 16. Micro 2000 : product range.

Source: Moore & Wright Limited.

Figure 17. Conventional micrometer manufactured by Moore & Wright Limited.

Source: Moore & Wright Limited.

Figure 18. The Mitutoyo hand-held electronic micrometer.

Source: Mitutoyo (UK) Limited.

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Figure 19. The Microtron hand-held micrometer developed by MMI of Milan.

Source: Microtron Limited.

truism that industrial design is worthless without reliable technology, even if the latter has to be taken for granted in the finished product. The Microtron instrument (Figure 19) is bulky and inelegant when compared with Micro 2000, illustrating that not all products from Italy are of superior design.

The premise that there are national characteristics in modern product design is suspect. Over 60% of Patscentre's industrial design assignments are undertaken for Continental firms, e.g. German, Scandinavian.[141] It is not the quality of design in countries so much as whether individual firms invoke the principles of industrial design in new product development. Continental firms generally have a better understanding of the place of industrial design in new product development than many British firms. The quality of design in products of Japanese manufacture is uneven. However, the dominance of Japanese firms in certain product categories inevitably establishes the design norms in those markets.

4.4 Electronic Colour Scanners

4.4.1 Introduction

The starting point for this case study is the Magnascan 550 colour scanner manufactured by Crosfield Electronics Limited of London (Figure 20). In 1967, the firm received a Queen's Award to Industry for technological innovation in printing, in 1972 for the development of the Magnascan colour scanner, and in 1973, 1976, and 1979 for export achievement. In 1978, the Magnascan 550 received a Design Council Award.

The evidence comprises that obtained from the published literature,[142] from the firm, from the industrial design consultant involved in the Magnascan project, and from a manufacturer in direct competition with Crosfield Electronics.

4.4.2 The Firm

Crosfield Electronics manufactures colour scanners and press controls for the printing industry. These are high-technology products which utilise electronic circuitry, automatic control devices, computers and lasers. In the field, the firm is a market leader. It holds 60% of the world market in colour scanners and 85% of the production is exported.[143]

The firm is a member of the De La Rue Group and has approximately 900 employees, of whom 150 are design and development staff. There are sales and service subsidiaries in Austria, France, West Germany, Italy and Switzerland. To give an indication of the financial resources, a recent set of trading results for the Group is shown in Table 12.

TABLE 12. DE LA RUE GROUP TRADING RESULTS

Results for the year to 31 March	1983 £'000	1982 £'000
Sales		
UK	54,353	52,220
Export (including sales to overseas Group companies)	123,387	115,648
Overseas (after adjusting for inter-company sales)	48,166	35,628
	225,906	203,496
Trading profit before interest	20,545	13,394
Interest receivable less payable	2,107	1,937
Trading profit	22,652	15,331
Share of profits of associated companies	8,996	6,606
Profit before taxation	31,648	21,937
Taxation—		
United Kingdom	845	(1,645)
Overseas	6,839	4,258
	7,684	2,613
Under/(Over) provision for taxation in previous years	73	(1,559)
Advance corporation tax (ACT) written off	3,687	6,056
	11,444	7,110
Profit after taxation	20,204	14,827
Minority interests	1,915	1,380
Profit attributable to The De La Rue Company p.l.c., before extraordinary items	18,289	13,447
Extraordinary items	(3,222)	(806)
	15,067	12,641
Dividends	8,959	8,418
Retained earnings	6,108	4,223
Earnings per Ordinary share-net basis (before extraordinary items)	48.0p	35.3p
Earnings per Ordinary share—nil distribution basis (before extraordinary items)	57.7p	51.2p
Trading profit as a percentage of Sales	10.0%	7.5%

Source: De La Rue Company

4.4.3 The Magnascan System

Electronic colour scanning has undergone significant development and is accepted today by the printing industry as a rapid method of producing high-quality colour separations, a crucial stage in colour printing. The Magnascan range of products, manufactured by Crosfield Electronics, is a manifestation of that application. The principles of the system are described below.[144]

Prior to the introduction of direct electronic colour scanners, the colour separation process in printing was accomplished by optical methods which were lengthy and required the services of highly skilled cameramen and retouchers. In contrast, users of electronic colour scanners are able to carry out the colour separation process and the screening of all four basic colours simultaneously. The scanner produces automatically four colour-separated half-tone film images to the required dimensions which are then used in the preparation of printing plates. Besides a reduction in the time required to prepare the half-tone film images and a reduction in the need for skilled re-touchers, the main advantage of this electronic process is the improvement achieved in the picture quality. The image is scanned and reproduced directly and does not pass through a photographic lens.

The input to the system is a normal colour transparency, taken by a photographer with a camera. The output is a set of four colour separations on a single piece of photographic film which then forms the input to the colour printing process. The system is shown diagrammatically in Figure 21. The colour transparency to be scanned and the unexposed film are first mounted on two rotatable drums, 2 and 11 respectively. A small spot of light (1) is then projected from the inside of the transparent analysing drum. The light passes through the transparency into an optical system (3) which splits it into red, blue and green components and then projects it on to three photo-multipliers. The electrical outputs from the photo-multipliers are passed to a computer (4) which carries out the functions of colour correction, tone correction, black printer generation and undercolour removal. To manually override the computer in order to make localised adjustments, the appropriate colour channel is selected by the operator with the colour selector switch (5). The output of the computer (6) controls the brightness of a spot of light projected on to the unexposed film (10).

The analysing and exposing drums are coupled together and rotate as one. Each time the drum rotates, one scanned line of the picture is stored electronically and is played back during either the same or the following revolution to the exposing lamp at a different speed, depending upon the enlargement required. The slower it is played back, the greater the degree of enlargement. The play-back is controlled digitally to avoid circumferential distortions. The axial movements of the analysing and exposing optics are provided through lead-screws, driven by two separate servo-motors which rotate at different speeds, depending upon the enlargement required.

The main feature distinguishing the output side of the Magnascan 550 from earlier machines is the provision of a double exposing head. Together with appropriate signal buffer storage, this enables four colour separations (cyan, yellow, magenta and black) to be produced in a single scanning pass.

4.4.4 Technological Innovation and the Business Strategy of the Firm

To maintain its market leadership, the firm deploys technological innovation offensively. A strategy of the firm is to couple technological advance to product-cost objectives. It aims to incorporate the most advanced technology in its products while at the same time applying rigorous costing procedures. The firm is highly selective in its marketing, aiming at the technically-sophisticated sector where there are relatively few competitors. Buyers in this sector are prepared to pay more for superior performance if this brings cost benefits or higher profit-margins in high quality colour printing. The firm's policy, therefore, is to allocate technical performance, reliability, and quality of the machine output higher priority than lowest selling price.[145]

Apart from the risks inherent in rapid technological change, there are other kinds of uncertainty with which the firm has to contend. A particularly difficult problem is to establish with an acceptable level of certainty the value customers place on a projected technological advance. Though customers in this market are big spenders, their demands are rigorous. For instance, it is customary for prospective buyers to scrutinise the accuracy of colour registering under 15X magnifiers. To reduce the level of uncertainty in new product development, the following procedure has been instituted. Through market research, an estimate is made of the price customers are prepared to pay for a particular technical facility which is not yet available on the market. R & D personnel then undertake a feasibility study with the aim of providing this facility related to a product-cost objective. The project is allowed to proceed only if an adequate margin ensues between the estimated product cost and an acceptable selling price. The tendency is for R & D costs to escalate and for customers to revise downward their level of investment, so if there are doubts about achieving an adequate margin, the project is abandoned.

4.4.5 The Place of Product Presentation in Technological Innovation

Product presentation is said to be rated highly by the firm.[146] Customers in this sector of the market have been conditioned by the foreign competition, e.g. Japanese and West German firms, to expect a high standard of external appearance coupled with high-quality internal and exterior finishing and detailing. Though irrational, a high-quality exterior infers commensurate technical quality and therefore is regarded as an important sales aid not only for the product manufacturer but also for the customer's business.

At this firm, product presentation extends beyond the product to include the environment in which sales of the product are negotiated. At the firm's premises, there has been considerable investment in what is described as a product display centre. The centre comprises a carpeted suite of well-appointed viewing rooms, equipped with comfortable high-quality modern furniture, back-projection systems, and illuminated display panels, where customers are brought to inspect the firm's products and to evaluate technical performance with their own test material.

Though product presentation is regarded as a significant consideration in this firm, industrial design is the element most likely to be subjected to a cost-reducing exercise if the product cost-objective is in danger of being exceeded. In this firm, industrial design is regarded almost literally as the casing which packages the product. Savings can be effected in the cost of casing materials, forming and finishing without lowering the technical specification of the product. Moreover, the casing is an element which can undergo modification quite independently of the rest of the product.

Even though the firm received a Queen's Award to Industry for technological innovation in 1967, it was not until 1975 that it engaged the services of a professional industrial designer. The then newly-appointed Technical Director of the firm, influenced by his previous experience with the Honeywell Group, believed that a totally professional approach to the development of the firm's products must include a professional approach to appearance design.[147]

It is said that the firm's work load in industrial design does not warrant a full-time appointment. The employment of consultants also enables the firm to change its industrial designers at will. Moreover, it is felt that an industrial designer who has the flair the firm requires would not have enough scope if he were confined to designing only the firm's products. Flair is seen as a significant quality in an industrial designer, and as the firm accumulates experience in industrial design, so its ability to identify flair is heightened. Currently, the firm engages the services of more than one consultancy although only one is given responsibility for the design of a particular range of products. The consultant is briefed by the Technical Director and thereafter liaises with the Chief Engineer.

At Crosfield Electronics, a stage is reached in the development of a new product when a so-called A-model is produced. This is a model which demonstrates the performance and production feasibility of the technical aspects of the product. The A-model is followed by a B-model which in effect is the A-model plus proposals by the industrial designer for the product casing. The run-up to the B-model includes the provision of coloured perspective illustrations which enable the Board of Directors to visualise and approve the proposed external appearance of the finished product. Approval is followed by the provision of a full-size detailed mock-up which accurately simulates the appearance and handling characteristics of the finished product. The significance of this stage of the development is that it enables the Board of Directors and the marketing executives to pass judgment on these features before production costs are incurred. The responsibility of the consultant extends to determining sources of supply of the switches, push-button controls, and other accessories which form part of the external design of the product and where there is a need for visual coordination.

The consultant also plays a role in extending the life-cycle of the firm's products. When sales of a particular model begin to decline, it is normal practice to introduce technical improvements, the object being to prolong the life of the product. To visually emphasise the improved technical specification, changes in the external appearance of the product are also introduced.

During the Magnascan 550 project, there was interaction between the engineering design department and the consultant insofar as the latter provided the design of the product casing for the completed engineering design. However, an engineer was responsible for the ergonomic design of the controls. This aspect of the design is seen as requiring a level of knowledge and expertise which the consultant does not possess. It entails producing control systems which are compatible with the existing skills of printing machine operators. In the light of experience, it is now recognised that product development would probably be more efficient if there were early interaction between engineering design and industrial design and to this extent interaction is growing.

Difficulties had been experienced due to the lack of interaction between the consultant and the production engineering function. It seems that the consultant was not sufficiently aware of costs related to material forming. Initially, the intention had been to produce the casing as plastic mouldings but tooling proved to be too expensive. Sheet-steel pressings were adopted as the alternative but the form design remained essentially the same. The readiness of the engineers to implement the consultant's proposals notwithstanding their inappropriateness to sheet-steel pressings had resulted in a high-cost casing. On the credit side, however, the consultant deliberately introduced accentuated gaps between adjacent panels on the outer casing of the Magnascan 550. This not only produces an attractive visual effect but also widens alignment tolerances and reduces assembly times. The consultant also provided a solution to the production problem of labelling controls in the language of the country to which a particular unit is destined. Words are replaced by symbols. The operator is provided with a key to the symbols which in practice he quickly memorises.

The interaction between the consultant and the sales and marketing personnel was confined to the design of the product; the design of the sales literature was not discussed. Sales and marketing personnel assessed the consultant's proposals and the final decision on the colour scheme for the product rested with the sales personnel.

The place of industrial design in the firm is now considered from the standpoint of the consultant.

4.4.6 The Place of Industrial Design in the Firm : from the Standpoint of the Industrial Design Consultant

Contrary to the evidence of Salmon, industrial design consultants were said to have been engaged by the firm prior to his appointment as Technical Director at Crosfield Electronics in 1975.[148] On the strength of work done for another division of the firm, the consultant Woodhall was engaged to work on the Magnascan 550 project in 1974. Pentagram, a consultancy which operates internationally, had been ousted on the instructions of the Managing Director of Crosfield Electronics. The industrial design of an earlier Magnascan model undertaken by Pentagram (Figure 22) had attracted unfavourable comment from potential customers for the product. The appearance of this machine was regarded as unattractive; it did not adequately project either the technological innovation the machine embodied or an appropriate image of the firm manufacturing it. Even so, Pentagram had proposed a similar appearance for Magnascan 550 and this was said to have precipitated its disengagement from the project.[149] To the extent that the engineering of Magnascan 550 had already been finalised when the new consultant became involved, leaving very limited scope for aesthetic manoeuvre, he regarded his participation in the project as unsatisfactory.

Since the initial involvement with Crosfield Electronics in 1974, this consultant's practice has expanded. It now employs five industrial designers, seven engineering designers, and seven model-makers. This increased capability has enabled a higher level of participation in projects at Crosfield Electronics. For instance, the consultancy has facilitated the transfer of technology between different groups, e.g. between the lasergravure and the scanner development teams.

In contrast to its very limited involvement in the Magnascan 550 project, the consultancy now participates during the formative stages of projects. For instance, in the Magnascan 570 project, a development of Magnascan 550, it participated in the development of the product concept. The complete system comprises a scanner, a computer-disc store, and a digitising table, and the consultancy was given the task of visually unifying these elements. During the engineering development of the scanner element, the consultant proposed reversing the positions of the analyser and the developer relative to the cylinders (Figure 23). This re-arrangement enables an operator to change cylinders on the machine more easily than on previous models and represents a significant improvement in ergonomic design. The consultancy now develops the designs of the outer casings of new products to the prototype stage. However, the sales personnel at Crosfield Electronics are still the arbiters of the colour schemes for new products. This is said to create problems for the consultancy; subjective decisions by sales personnel are sometimes in conflict with the aim to create a corporate identity for the firm's products.

The consultancy now operates at a variety of levels in the Crosfield organisation; on the one hand, presentations are made to the Board of Directors and on the other, there is liaison with detail draughtsmen.

4.4.7 Technological Innovation in Electronic Colour Scanners : From the Standpoint of a Competing Japanese Firm

The firm, Dainippon Screen Manufacturing Company, began in 1868 as a small engraving and printing business in Kyoto, Japan. The present Company was incorporated in 1943. Today, there are 1300 employees in home and overseas operations, 150 of whom are engaged in R & D activities. Wholly-owned subsidiaries operate in the United States, the United Kingdom, the German Federal Republic, Singapore and Taiwan.

The firm manufactures various types of equipment used in graphic art reproduction. The products include electronic colour scanners, industrial process cameras, film processors, contact printing equipment, and proof presses. In addition to their use in the printing industry, the firm's products are also used in the textile, medical equipment, office equipment, automobile, and shipbuilding industries. In 1980, the firm's sales amounted to 32,724 million yen (£65.5 million) and yielded profits of 2,185 million yen (£4.37 million). Twenty three per cent of the firm's output was exported. Its products are sold in over sixty countries.[150]

The firm's aims are: to achieve balanced growth in all aspects of its operations; to develop new products to meet the requirements of targeted user segments; to utilise expertise in graphic art reproduction in the diversification of products for a wider range of industries; to expand further the network of overseas subsidiaries;

to establish assembly and manufacturing facilities overseas, staffed principally by nationals of the host countries.

An important element in the success of the firm is attributed to the direct marketing of products and the provision of close technical support for users. Close contact with the market - in Japan and overseas - enables the research activity to be directed towards fulfilling specific user needs. Close technical support enables users to achieve the best possible results from the equipment and systems they have purchased.[151]

The firm's R & D activity has three specific objectives: the development of new applications of existing technologies in graphic art; the development of new cost-saving technologies for graphic art; the development of new products jointly with firms in related industries. Through R & D, the firm has developed technological skills in three principal fields: high-precision ruling, optics, and image information processing. Resources allocated to R & D are equivalent to 3% of the firm's total sales. The management believes that its commitment to R & D has been one of the major factors in establishing a key position in its markets. The resulting new products and production technologies have produced a steady growth in the volume of sales per employee.

It is said that high-quality colour printing is now very competitive and as a result, the scanner market has become distorted. A standard scanner is capable of high productivity but this has not resulted in higher throughput for the user. To a large extent, it simply means that the delivery times of finished work are now very short, which alone does not warrant the high investment required to purchase a standard scanner. However, the possession of a scanner is now a prerequisite for contractors tendering for business in high-quality colour printing. As a means of overcoming this dilemma, the firm identified the need for a basic model in addition to a standard model.[152]

The firm had introduced its first (standard) scanner in 1975 (Figure 24). By 1980, the firm's sales of electronic colour scanners of all types were valued at 7,832 million yen (£15.7 million). or 23.9% of the firm's total net sales. A factor accounting for the rapid growth in sales was the introduction of a basic model (Fig.25), more compact and lower in price than the standard model, and which meets the requirements of a large number of small and medium-sized firms in the graphic art industry. It is said that the market for basic models is as yet largely unexploited both in Japan and elsewhere. Electronic scanning technology can also be used to reproduce patterns in textile and chinaware production. The firm is engaged in the development of models for these industries.

Global sales of the standard model - that which competes with the Magnascan 550 manufactured by Crosfield Electronics - are 180 units per annum at a unit price of approximately £135,000. This represents a global market share of 18%.[153]

In 1970, the firm's sales staff identified industrial design as an aid to commercial success and pressed the management on the issue.[154] Since then, the firm has engaged both in-house industrial designers and consultants; in-house personnel are regarded as essential for continuity while consultants provide periodic injections of outside knowledge. The industrial designers report to the Chief Engineer in the firm but also have access to higher levels of management. The management perceives industrial design as having a dual role: making operation of a machine more convenient for the user and developing its appearance.

Following the representations by the sales staff, the management now recognises product presentation to be important on three counts. Firstly, scanners have become status symbols in the graphic art reproduction business so users demand good-looking products. Even though users do not fully understand scanning technology, they wish to be seen to have advanced equipment. Secondly, good appearance serves to stimulate a potential user's initial interest in the product. A well-finished good-looking product infers, albeit irrationally, commensurate technical quality. Thirdly, there is a requirement to introduce new products frequently. Industrial design plays a part in new product development by providing each new addition to the product range with a distinctive appearance.

The various models of scanner manufactured by the firm do not relate to one another visually. This has occurred because the same design team is not responsible for all the models. Each manufacturing unit has its own design team with a high degree of autonomy and the parent Company does not have a policy of corporate identity. It is said that for scanners, corporate identity has no commercial significance because each customer purchases only one scanner.[155]

4.4.8 Evaluation

(cf 4.4.2) On a number of counts, this firm and its products contrast markedly with both Gowllands and Moore & Wright. The latter are traditional firms which have recently adopted high technology as a means of overcoming problems in trading. By contrast, for Crosfield Electronics, high technology is its raison d'etre, reflected in the number of trained manpower engaged on research and development. Moreover, its products and in particular the colour scanner, are not modern versions of traditional products in common use among a particular professional group, as in the case of Gowllands and Moore & Wright, but entirely new highly-specialised industrial processing machines. They emerge from developments in electronics and laser technology, entailing a capability to handle the uncertainty attendant upon technological innovation at a high level of investment. The physical size of the product is quite different; whereas the Maylite ophthalmoscope and the Micro 2000 micrometer are hand-held instruments, the Magnascan 550 colour scanner is a free-standing machine comparable in size to a turning lathe. There is contrast in the selling prices of the products: Maylite : £5.40; Micro 2000 : £125; Magnascan 550 : £130,000.

And whereas the output of both Maylite and Micro 2000 is measured in thousands of units per annum, the output of Magnascan amounts to only a few score. Moreover, Crosfield Electronics is an acknowledged leader in technological innovation; the Design Council Award is a recent addition to an impressive record of Queen's Awards for technological innovation and export achievement.

(cf 4.4.5) It is evident, however, that whereas Crosfield Electronics is very sure-footed in high-technology, it is much less so in industrial design. The adoption of 'good design' seems to have arisen from the need to keep up with international developments in this respect rather than a deep-rooted conviction about its relevance to this product category; this is reflected in the role and status of industrial design within the firm. The way in which industrial design is perceived by the management is revealing: literally an envelope in which to package the technological hardware, capable of an independent existence so that its cost can be reduced if necessary within the equation of the overall product cost objective. Designing is seen not as a starting-point to form a link between user and machine but as a sub-set of the engineering of the product; a role limited by the trammelled view of design held by the engineering department. Moreover, the industrial design contribution is contrived, which resulted in a mismatch with material forming and therefore a source of inefficiency during development.

(cf 4.4.6) The way in which the industrial design consultancy which services Crosfield Electronics has developed is revealing.

Its engagement as a sub-function of engineering prompted the formation of its own engineering section so as to be less peripheral in the development process; a business objective rather than a design one. The go-between function, facilitating technology transfer between departments in Crosfield Electronics is not so much a bona-fide role of industrial design, more the attempt of a consultancy, only tenuously connected to the firm's main activity, to enhance its standing with the technical personnel. To the credit of the consultancy, its persistence produced positive results; winning the confidence of the technical development personnel resulted in improved level of dialogue which in turn provided opportunities for suggesting improvements to the configuration of the machine.

(cf 4.4.7) The evidence obtained from the Japanese firm of Dainippon is revealing. Evidently a commercially successful firm, it is comparable in size and output to Crosfield Electronics. However, unlike the latter, its thrust in R & D is directed more at product and market diversification. The market analysis which led to the development of a low-cost 'people's' scanner to complement the expensive standard machines which compete directly with the Magnascan range shows opportunism in innovation.

Industrial design has an established if relatively minor role within this firm's innovation strategy. Like Crosfield Electronics, the industrial designers report to the chief engineer, a further indication that it is an instrumental role, supportive of the engineering rather than determining the product profile. The attitude of the management towards corporate identity (i.e. producing a range of products which are related visually and part of the stock-in-trade of industrial design in other fields) is a disarming piece of oriental logic from which a lesson can be learnt. In the final analysis, unless customers have a use for more than one of the firm's products, corporate identity has no market significance whatsoever.

Overall, the role of industrial design in innovation in this field is a minor one and evidently there are good reasons why this is so. The products are highly specialised items of machinery used by operatives in an industrial processing context. The operatives do not regard them as items of personal equipment, the choice of which is influenced by self-esteem, which can be said of, for instance, an ophthalmoscope or a micrometer. Indeed, the operators of colour scanners are not the purchasers; to that extent, appearance does not influence user choice. Conversely, the purchasers are not the operators so personal preference related to appearance is not critical. Because there are many control-settings on a colour scanner, good ergonomic layout contributes to operational efficiency; there is some evidence to indicate that an industrial designer can make a contribution in this field but cannot be justified on these grounds alone. Whilst some control over the appearance of the products is necessary simply because visually cohesive forms do not emerge automatically from the technology, it is not a critical factor for success or failure in innovation; customers who buy this category of equipment can verify the technical performance by

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Figure 20. The 'Magnascan 550' electronic colour scanner manufactured by Crosfield Electronics Limited. Source: The Design Council.

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Figure 21. The Magnascan system.

Source: Crosfield Electronics Limited.

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Figure 22. The 'Magnascan 460' electronic colour scanner manufactured by Crosfield Electronics Limited.

Source: Crosfield Electronics Limited.

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Figure 23. The Magnascan 550 electronic colour scanner: relative positions of analyser, developer and cylinders.

Source: The Design Council.

Figure 24. The DS SG-701 electronic colour scanner manufactured by Dainippon Screen Manufacturing Company.

Source: Dainippon Screen Manufacturing Company.

Figure 25. The DS SG-1000 electronic colour scanner manufactured by Dainippon Screen Manufacturing Company.

Source: Dainippon Screen Manufacturing Company.

objectively testing the quality of the output. Nevertheless, there is an indication that even though industrial design has a minor role, the firms have identified the need for a contribution which they cannot obtain from engineering designers or draughtsmen.

4.5 Combined Scanning Micro-interferometer & Microdensitometer

4.5.1 Introduction

The starting point for this case study is the M86 combined scanning micro-interferometer and microdensitometer manufactured by Vickers Instruments of York (Figure 26). The instrument received a Design Council Award in 1975. The evidence in the case study comprises that obtained from published literature, from the Research Director at Vickers Instruments, and from the industrial design consultant involved in the project.

4.5.2 The Firm

Vickers Instruments is a subsidiary of the Vickers Group of Companies. Formerly, Vickers Instruments traded as Cooke, Troughton & Simms Limited, an amalgamation of the firms Thomas Cooke, Edward Troughton, and James Simms. These firms began as scientific and mathematical instrument makers in the seventeenth and eighteenth centuries.[156] In 1915, Vickers Limited - principally a manufacturer of armaments at the time - acquired Thomas Cooke & Sons in order to have a facility for the production of optical gunsights.

Currently, Vickers Instruments has 800 employees and an annual turnover of £3-5 million. Vickers Group sales are currently valued at £391 million annually.

4.5.3 The M85 and M86 projects

Scanning integrating microdensitometry is a technique which extends quantitative biochemistry to the cellular level. It is a means of localising and precisely measuring the activities of specific enzymes or the amounts of DNA in cell nucleii and individual chromosones; localised effects of potentially toxic substances or of drugs can be studied; variations in the amount of light-absorbing proteins, cytochromes, haemoglobin or chlorophyl can be determined. Traditionally, specialists in this field have largely confined their interest to either the study of DNA distribution within cell populations employing the Feulgen staining techniques or to the localisation and measurement of a wide range of proteins, enzymes, carbohydrates or nucleic acids. However, methods are now available for the estimation of hormone levels in blood plasma or organ effluent by cytochemical determination of specific chemical changes within selected cells or regions of organs.

Scanning integrating microdensitometry overcomes some of the difficulties encountered in earlier techniques.[157] The amount of light of a specific wavelength absorbed by passage through a specimen is directly proportional to the quantities of specifically stained or naturally absorbing chemical substances within the sample. However, a direct measurement of absorbance is only proportional to the chromophore quantity if the staining distribution is entirely homogeneous and the specimen is of uniform thickness throughout the sample area. In general, biological preparations are highly irregular in shape, size, thickness and also in distribution of the light-absorbing chromophores which are often concentrated within fine granular deposits. By scanning microdensitometry the absorbance measurements can be conducted over the whole of the specimen area of interest within a very large number of sample elements. Each element is small enough to virtually eliminate distributional error. By summing all the individual values, a true value for total specimen absorbance is obtained.

The direct relationship existing between refractive index and solution concentration allows precise assessment of the dry mass of living and prepared biological material by interferometric methods. Dry mass, and other parameters proportional to optical path difference may be determined by measurement of the phase shift induced in a coherent light beam passing through the specimen relative to the specimen background. The integration of many such phase shift (optical path difference) measurements required to account for specimen heterogeneity or area irregularity has, in the past, proved to be impractical for routine determinations because of the very tedious and time-consuming procedures entailed. However, the use of scanning methods coupled with automatic measurement and integration of optical path difference at a specific wavelength produces complete dry mass determinations rapidly and with precision. Individual spot optical path difference measurements can also be made, producing a value directly proportional to dry mass thickness or refractive index at the point measured.

Vickers Instruments, which specialises in instrumentation related to the fields just described, first developed a scanning microdensitometer. This product, the M85 Scanning Microdensitometer, was launched in 1969 and was commercially successful.[158] (Figure 27). A combined scanning microdensitometer and microinterferometer was subsequently developed out of this successful instrument by utilising a laser-operated phase modulator invented by Smith,[159] in collaboration with the Department of Human Biology & Anatomy at the University of Sheffield, and with the aid of a grant from the then Science Research Council. The enhanced product, the M86 Scanning Microinterferometer and Microdensitometer, was launched in 1975. (Figure 26).

As a scanning microdensitometer the instrument automatically measures integrated optical density of microscope specimens with diameters down to 0.3 microns and optical densities within the range 0 - 1.3 at any wavelength within the visible spectrum. An indirect masking system simplifies the isolation of irregular shaped and sized materials and, under standard conditions, eliminates the errors in integrated density which might arise from the edge effect apparent with masks positioned in the photometer beam.

As a scanning micro-interferometer, the instrument can measure the dry mass of living cells with a speed of operation which allows significantly large numbers of cells to be measured in a very short period of time. A phase-modulated laser beam is made to scan the biological specimen in an interference microscope system. (Figure 28). The optical retardations produced by the specimen are measured photometrically and automatically integrated during a scan of five seconds to give a digital reading proportional to the total protein content of the selected feature.[160] More specific examples of application of the instrument are its use for fundamental genetic studies at the Institute of Cell Biology, Soviet Academy of Sciences, Moscow; its use to measure the very low amount of hormone present in babies at the Mathilda and Terence Kennedy Institute of Rheumatology, Hammersmith; its use in the study of plant hybridisation at the University of Leicester. The market for this type of instrument is said to be expanding as a consequence of the emphasis in recent times on the monitoring of the health of workers in hostile industrial environments, e.g. asbestos processing plant.

4.5.4 Technological Innovation at Vickers Instruments

The market for general purpose scientific instruments is intensely competitive because, it is said, Japanese and Korean firms plagiarise designs and secure price advantage by utilising low-cost labour in manufacture. To circumvent this problem, the firm's policy is to direct its main effort at the high-technology sector of the scientific instrument market where there are relatively few competitors.

Users in this market sector, e.g. Universities, research institutes, are said to be less price-conscious. The firm also seeks to protect its position in the market through the extensive use of patents. Competition in this market sector is said to take a particular form stemming from the specialised nature of the instruments. Scientific laboratories tend to use a single make of instrument for a particular application to avoid having to retrain laboratory personnel. Therefore, the strategy at Vickers Instruments is to be the first in the field with an instrument that fulfills a particular user-laboratory requirement, embodying in it the most up-to-date technology; the aim is to be the sole supplier of a particular type of instrument. The market for the instrument is expanded by developing succeeding generations from the original, incorporating improvements stemming from user feedback and subsequent developments in technology. One of the design aims in the succeeding generations is to utilise the user-skills developed in the first-generation instrument. This provides laboratories with an incentive to continue with the same make of instrument.

In this market, the take-up of a new product is slow, demanding patience of the innovator. The users are mainly personnel in the Universities and research institutes and most sales result from personal recommendations and research workers publishing results obtained with the new instrument. A failure of general management to understand this market characteristic can result in premature withdrawal of a new product before its take-up has had a chance to be established. In this connection, it is necessary for the firm to provide an efficient after-sales service. This measure reduces the risk of unserviceable instruments lying unused in laboratories; only those which are operating have the potential to generate further sales.[161]

The above strategy is said to have disadvantages. The resulting production volume is low and unit costs are high, and inevitably there is a problem of low cash-flow. To compensate, the firm maintains an interest in intermediate-volume markets and thereby more fully utilises its production-process facilities such as investment casting plant, which also improves the cash-flow.

Product presentation plays a part in the firms innovation strategy. Technically excellent lash-ups are said to be unacceptable to users in this sector of the market. Good quality finishing, refined cohesive forms, and unified products infer, albeit irrationally, careful attention to all the technical details of an instrument. At exhibitions, a corporate resemblance in the firm's range of products is an aid to professional display and projects visually the technical quality of the instruments. Moreover, the majority of users tend to under-utilise the instruments relative to their total capability. In these circumstances, non-technical features such as simplicity of operation, ease of maintenance, and overall appearance are significant in attracting users and gaining acceptance of the instrument.

To deal with this aspect of innovation, the firm's research director initiated in 1958 a long-term policy of integrating industrial design into the product development programme. Initially, the policy was unpopular with the in-house engineers and some members of the Board of Directors. However, it is said that the policy is now widely accepted in the firm because of the increasing importance of product presentation in this sector of the market and the realisation that achieving corporate resemblance between products of this type is a long-term process.[162]

Industrial design services at Vickers Instruments are provided by a consultant. The present consultant has been associated with the firm since 1963. At that time, the Vickers Group acquired Baker Limited, the managing director of which became the Group Marketing Director. This new Vickers subsidiary already employed the services of an industrial design consultant and on the recommendation of the new Group Marketing Director, Vickers Instruments also engaged his services.

During his extended period of association with Vickers Instruments, the consultant has acquired a working knowledge of the general operating requirements of the instruments developed by the firm. This enables him to participate during the formative stages in new product development. The consultant's participation in the M86 project followed the pattern of his involvement in other Vickers Instruments projects. His interaction begins, not with the firm's research scientists but the engineers; nevertheless, he reports directly to the Research Director.[163]

Immediately after the essentials of the new instrument were explained to him, the consultant designed a basic configuration for the product.

This tentative proposal was in the form of simple outline sketches, intended primarily to obtain immediate feedback from the in-house engineers. This proposal was followed by the production at the consultant's premises of paper and card models to delineate the configuration more precisely and to show the proposed positions of controls and indicators. At this formative stage, the in-house engineers also produced a model for comparison with the consultant's proposals.

During subsequent development of the new product, the consultant paid periodic visits to the firm to review progress. One of his functions is to arbitrate when there is a difference of opinion within the development team about non-technical details in the instrument form. His disinterested opinion is seen as relieving the project leader of appearing to favour particular members of the development team and this makes for better cooperation. For this and other reasons, the personality of the consultant is regarded as significant. He has to be acceptable personally to members of the development team, and this acceptance stems largely from his ability to understand engineering problems on the one hand and his flair for creating style in new products which reflects a sound understanding of production processes on the other.

The consultant's ability to link innovations in style to the economics of production is seen as a particularly significant contribution. In this respect, his association with other firms, e.g. International Computers Limited, is regarded as advantageous. Through his outside connections, his awareness of changes in stylistic trends ensures that new products launched by Vickers Instruments are not prematurely outdated in appearance. In the case of the M86 instrument which was launched in 1975, the opportunity was taken to update stylistic features and the colour scheme. Due to a number of factors, the selection of appropriate finishes for a new product is a particularly difficult problem. Paint finishes for the instruments must meet an exacting technical specification: chip-proof so that the general appearance does not deteriorate in use; acid-resistant to counter corrosion by laboratory reagents; consistent in colour. The consultant's colour proposals are difficult to implement because the production volume of this category of instrument is low, i.e. approximately 15 units per annum. A typical requirement for paint is 200 litres per annum, which suppliers regard as a nuisance when the technical specification is coupled with a colour specification unfamiliar to them. In the event, the final decision on colour schemes is made by marketing personnel, who select from alternatives offered by the consultant.

Since his appointment as consultant to Vickers Instruments in 1963, the consultant's involvement in projects has gradually lessened, with a corresponding reduction in his fees. Initially, there were difficulties in persuading the in-house engineers to accept an industrial design consultant as a participant in the development team and a harmonious working relationship ensued only after a fairly lengthy period of gestation. In time, the consultant 'trained' the engineers to understand the objectives of industrial design relative to new product development programmes; the problem areas were identified and dealt with as issues rather than personal clashes.

Total development costs for the M85 and M86 instruments over a period of nine years were within the range £50,000 - £100,000, with the consultant's fees amounting to less than 10% of this budget and on a reducing scale for the reason stated above. When the selling price of the M86 instrument was £10,000, the cost of industrial design features amounted to about £1,000.

4.5.5 The effect of winning a Design Council Award

For reasons stated earlier, winning a Design Council Award has had no direct effect on sales of the product but there were a number of benefits. The public recognition of achievement inferred by the Award boosted the morale of the design and development team. The production workers at the firm were said to be pleased to be associated with an award-winning product. The publication of a report on the Award in the Group house journal, Vickers News, and the press coverage initiated by the Design Council[164] were said to have had some public relations value. Its value to the innovation thrust in the firm was that the Award featured in the Annual Report of the Company, bringing the achievement to the notice of the Group Main Board. This provided useful support when subsequently application was made for Group investment in the firm's new product development programme.

4.5.6 The M86 Project from the standpoint of the industrial design consultant

Vickers Instruments is located in the science of microscopy. There is a certain prestige in being connected with this science. The firm's strength in the market rests not so much on optics, more on linkages and movements. With this in mind, the Board of the firm does not really have a design policy; rather, it looks for breakthroughs in technology related to the firm's perceived position in the field of microscopy. The Research Department initiates new product development and the Research Director presents proposals for new products to the Board. On occasion, the consultant[165] has personally assisted the Research Director in this respect. The Engineering Department in the firm is charged with translating the ideas of the Research Department into hardware and the Research Director has the authority to overcome resistance arising in the Engineering Department.

The consultant regards it as necessary to have the personal backing of the directors because for him status is relevant to the promotion of industrial design within a firm. If the directors are lukewarm or apathetic about industrial design, personnel with lower status in the firm take their cue from those at the top of the hierarchy and erect obstacles for the consultant. He sees the extreme case of this situation in the position of the in-house industrial designer, who has little opportunity to design and is attacked by others in the firm for the little he does. With only limited opportunities for developing outside contacts, he becomes desensitised and soon begins to think his contribution is unimportant. By contrast, a consultant has the freedom to criticise a firm and its products; the in-house industrial designer does not have this freedom. (The general validity of this point is discussed in 4.5.7)

Industrial design related to capital goods has a particular attraction. A consultant can be involved in a dozen capital goods projects during the period when the engineers in a firm are wholly engaged in a single project. In these circumstances, the consultant is very likely tc be ahead of the engineers in design thinking. The consultant maintains he has an aversion to the ethos of the in-house engineering drawing office. Engineers perceive design mainly in terms of dimensions and specifications, are at their happiest and most secure when manipulating mathematical formulae. They think of design in terms of centre-lines whereas he thinks in terms of related forms. The engineers also believe they are resourceful when improvising with components from existing products, even though doing so may ruin the visual effect of the new product.

However, the consultant maintains he prefers the firm's engineers to propose the initial arrangement of the new product; this provides him with the degree of constraint he says he needs. From this arrangement he then tries to design a well-proportioned shape for the product; where possible, he offers a choice of shapes to encourage the development team to participate in the decision-making. Successful industrial design rests on subtleties in detail; it is about getting rid of raw edges, producing visual organisation in the product, and achieving visually satisfying proportions in the elements. Usually, these subtleties are not immediately apparent to the engineers.

The consultant maintains he does not subscribe to post-Bauhaus conventional wisdom which asserts that in design, form should follow function, that an industrial designer should use the technical configuration as the starting point and design outwards to the surface of the product. His approach is to lessen the dominance of the technical design. He designs inwards; how far he penetrates depends upon the particular product. His premise is that with this approach he addresses the product in the same way as the user. In doing so, he maintains he is refuting some industrial design cliches. The forms of the Modern Movement looked functional but really they were a reaction against ornament. Currently, there is a reaction against plainness so ornament and decoration are again in vogue. However, there is a danger in becoming too intellectual about industrial design; its main value is in its emotional appeal. Purchasing is by habit an emotional experience, strongly influenced by the appearance of the product. The purchase of specialised professional equipment is inseparable from the purchase of products generally; the same habit persists even if a rational explanation follows to justify the purchase.

Because the M86 scanning micro-interferometer and microdensitometer is intended to be operated by laboratory technicians, the consultant wanted the finished product to seem cosy and friendly. In this respect, he does not think the design has succeeded; visually, the product is too formidable, too vertical. The reason for the configuration is that the M86 comprises an existing product (the M85 microdensitometer, Figure 27) and an added-on laser facility. The binocular head is also an existing component. In the consultant's view, the later version of the microdensitometer, launched in 1980, is of much better design. It has a low profile, giving the operator an unobscured general field of vision (Figure 29); a cantilever feature gives the instrument an interesting dynamic appearance. In contrast to the M86 project, with the M85a project the consultant was able to start from the beginning again and design a new configuration for the product.

The consultant's contribution is at a variety of levels. He introduced Vickers Instruments to the modular concept in microscopes, regarded by the firm as a significant breakthrough in design. He showed the firm how to manipulate the visual proportions of a product by means of surface texture and graphic devices. He dissuaded the firm from its preference for hammer-finish on its products and introduced in its place black anodising. It was difficult to secure approval for this change because hammer-finish has the advantage of being cheap. However, a significant disadvantage relative to laboratory apparatus is that the paint coverage in the depressions of hammer-finish is inadequate as a barrier to corrosive substances. He introduced the firm to bonding techniques as an alternative to mechanical fastenings. The production engineers in the firm at first asserted that the proposal was impractical and to convince them it was necessary to show that the techniques were already being used by another client-firm. Fluted control knobs is a feature introduced by the consultant and is said to add significantly to the distinctive character of Vickers Instruments.

The Board believes one of the consultant's contributions has been to 'train' the firm's engineers in product design.[167] Initially, it was envisaged that after five years his services would be no longer required. Even though he enjoyed a good rapport with the Research Director and the new Managing Director has commented that the products to which the consultant has contributed sell well, his relationship with the firm is now not as strong as it used to be; consultations are less frequent. In the consultant's view, because Vickers Instruments has been adversely affected by the recession, the firm is mistakenly reverting to its former position of isolation in design. After twenty years of 'training' the engineers, for a variety of reasons the firm still needs an industrial design consultant; to champion the product as a whole rather than only the mechanism it embodies; to counter the tendency to improvise in the detailing; to husband the development of visual quality; to promote the unexpressed needs of the user.

4.5.7 Evaluation

(cf 4.5.2) Vickers Instruments is part of the second largest Group in the sample and with a continuous lineage in the manufacture of scientific instruments dating from the seventeenth century. In a sense, therefore, this firm has a long tradition in the field of technological innovation, which currently has the financial backing of a large Group. It is to be expected that the firm would reflect maturity both in policy-making and managerial procedures relative to innovation in a way which perhaps the relatively young firm of Crosfield Electronics would not. To some extent this is true and is particularly noticeable in the role that engineering has in the firm. Though in manufacturing terms Vickers Instruments is in a particular category of engineering products, it is reflected in the management structure that the engineering function is strictly instrumental relative to innovation emerging from research proposals. (cf 4.5.6)

(cf 4.5.4) While the supremacy of the research function within the structure of the firm is firmly established, the operations executed within that structure are nevertheless subject to internal pressure and the risk of true objectives being deflected by prejudice stemming from a limited view of innovation harboured by engineering personnel remains. The ability to resist this adverse pressure ultimately depends upon the level of awareness, attitude, and resoluteness of key individuals within the firm. Evidently the engineers at Vickers Instruments resisted the introduction of an industrial design consultant into the development team, contending that they were capable of whatever contribution he could make. In effect, this resistance challenged a policy decision, which then became the subject of negotiation between the research and engineering functions in the firm. Inevitably, the outcome was a compromise, the consultant ostensibly having a training role in exchange for a limited and diminishing tenure of engagement with the firm. Herein lies a situation which is of fundamental significance to innovation and from which a number of consequences flow. The practical contribution of the consultant - eliminating raw edges of metal from the instrument profile to suggest solidity, applying surface texture and graphic devices to improve the visual proportions of the instrument, introducing fluted control-knobs to provide good tactile quality - has no intellectual significance. Indeed, the contribution may seem trivial when juxtaposed with the technical contribution that the instrument makes to the science of microscopy. However, to rank the elements of a project, with the intellectual as superior and the practical as inferior, is to misunderstand the nature of innovation; it is to deny that technik, a practised empirical contribution rooted in art, instinct, and tacit knowledge rather than science and theory, has a role in the creation of all man-made objects, including high-technology scientific instruments. Moreover, it is to compound this misunderstanding to contend that because the visible outcome of technik is readily understood by everyone, it can be executed by anyone, including engineers. That is to ignore the influence of a creative guiding mind with a set of objectives quite different from those of the majority of engineers (e.g. related shapes rather than connecting centre lines); it ignores the value of the project in hand of contemporaneous experience in making a similar contribution to a number of other projects while the engineers are engaged solely on one. (cf 4.5.6)

(cf 4.5.6) It is because of its apparent propensity for being misunderstood that the status of industrial design in a firm assumes a particular significance. Arguments about relevance and validity with personnel of middle-management status are circumvented when industrial design has the personal backing of the directors. However, personal backing is inevitably associated with not only the task in hand but also the individuals concerned and on a number of counts is evidently more workable in a firm when the industrial designer is a consultant rather than an employee. The freedom to voice criticism of a firm's products to its Board, the freedom to make outside contacts, and the freedom to undertake commissions for other firms are not the prerogative of an in-house industrial designer yet they are germane to his professional confidence and to the success of the task he undertakes.

(cf 4.5.4) As in the case of Crosfield Electronics, evidently Vickers Instruments tries to avoid intense direct competition by seeking to achieve a technical monopoly in an instrument category and by directing its efforts at markets where the level of competition is relatively low. It is another example of a passive attitude towards competition, vulnerable to the initiatives of rivals on the offensive and not conducive to devising tactics for outwitting them. The idea that the firm should face the situation squarely and adopt an aggressive attitude to markets does not seem to have occurred to the management even though the consultant provides some useful indicators. (cf 4.5.6) The acceptance that there is an element of emotion which influences choice in the purchasing of any product, however scientific or technical in content, permits of another dimension in new product development. Comparison of the microdensitometers in Figures 27 and 29 is instructive. It shows that a bold approach to design which takes as its starting point basic human considerations (e.g. the need for the product to be 'cosy and friendly') rather than technical parameters can transform a dull item of laboratory equipment into an elegant instrument with strong user appeal, and therefore greater likelihood of commercial success, given that the technical function it performs is in demand.

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Figure 26. The M86 combined scanning micro-interferometer and microdensitometer manufactured by Vickers Instruments.

Source: The Design Council.

Figure 27. The M85 scanning microdensitometer manufactured by Vickers Instruments.

Source: The Design Council.

Figure 28. The interference microscope system.

Source: Vickers Instruments.

Figure 29. The M85a scanning microdensitometer manufactured by Vickers Instruments.

Source: Vickers Instruments.

It seems incredible that Vickers Instruments, having deployed industrial design so effectively, instead of building on this approach, should in the current recession revert to its former practice of perceiving design as a sub-set of engineering. It is also an indication of the conservatism and protectionism in engineering circles.

4.6 Stereoscopic Microscopes

4.6.1 Introduction

The starting point for this case study is the Stereo Three microscope manufactured by Ealing Beck Limited of Watford (Figure 30). The instrument received a Design Council Award in 1976. The evidence in the case study comprises that obtained from published literature, from the Executive Director - Design of Ealing Beck Limited, and from the industrial design consultant involved in the project.

4.6.2 The Firm

The firm was established in the mid-nineteenth century by two instrument makers, Richard and Joseph Beck, to manufacture custom-built microscopes. The firm claims to have manufactured the first microscope incorporating compound achromatic optics.[168]

Gradually, the firm's range of products expanded to include camera lenses, binoculars, telescopes, and other optical instruments.

During the two world wars, the firm was engaged on military contracts and responsible for the design and manufacture of a number of secret devices. Following World War II, the firm reverted to the manufacture of optical instruments for use in research and educational institutions and also contributed to defence contracts as a sub-contractor for Hawker Siddeley Dynamics. It designed and manufactured optical devices for the orbital satellite UK2. It specialises in the vacuum-deposition of gold and aluminium, a process employed in the manufacture of components for optical instruments designed to withstand the severe environmental conditions encountered by ballistic missiles and space-vehicles. The firm claims to uphold a tradition of research and innovation in both optical instrument design and production processes. Currently, the firm manufactures or markets over 3,500 items comprising components and finished products.

In the post-World War II period there have been changes in the ownership of the firm. R & J Beck was first acquired by Griffin & George Limited, manufacturers and distributors of scientific equipment and laboratory apparatus. In 1968, Griffin & George Limited hived off R & J Beck to the Ealing Corporation of Cambridge, Massachusetts, a scientific instrument marketing enterprise. Prior to its acquisition by Griffin & George, R & J Beck had been a principal supplier to the Ealing Corporation. Currently, there are 170 employees at the Watford Works of Ealing Beck.[169]

4.6.3 The Stereo Three Project

Until a few years ago, clinical laboratories were the main purchasers of low-power stereoscopic microscopes and their requirement for the examination of biological specimens tended to determine the configuration of these instruments. In the electronics industry, particularly in the manufacture of micro-miniature components, there is also a requirement for stereoscopic microscopes for inspecting laminated substrates in integrated circuits and for viewing a magnified image whilst assembling miniaturised circuits. The electronics industry was perceived by the firm as the growth market for stereoscopic microscopes.[170] The firm therefore concentrated on establishing this industry's requirements. Consultation took place with leading firms in this field, i.e. Ferranti and Marconi. They provided information about the desired product configuration, e.g. binocular vision to reduce operator fatigue when working for long periods, a stand-off viewing position to enable spectacles to be worn by the user. Following this consultation, the management of Ealing Beck was confident it had formulated an appropriate product specification.

To combine a high standard of optical performance with a three dimensional effect, a new optical system was devised for Stereo Three. Objective lenses providing three levels of magnification are mounted in an adjustable turret in the microscope head. A parfocal system enables the object being viewed to remain in sharp focus at each level of magnification. The optical system also enables a large working clearance to be provided between the object and the microscope head, necessary for users carrying out manipulations or manufacturing processes whilst viewing a magnified image (Figure 31). A choice in the range of magnification is offered: X5, X10, and X20; X10, X20, and X40; X20, X40, and X80. A convergence angle of 10^{o} in the binoculars provides the stereoscopic effect.

To complement the new optical system, a range of stands with a choice of illumination systems was developed for Stereo Three. For some industrial applications there is a cold cathode light source which gives bright even illumination over an area outside the object. For viewing low-contrast laboratory specimens, there is a small intense light-source conducted to the base of the stand from a remote-control unit by a fibre-optic guide. For viewing biological specimens, base illumination is transmitted through the object.

In addition to those already mentioned, Stereo Three has a number of design features which improve operator comfort and reduce fatigue during long periods of observation. Each eye-piece has a focussing top-lens to enable the object image to be in focus with both eyes. The microscope head is reversible relative to the focussing unit to suit the operating convenience of the user. (Figure 31). The controls of the instrument are ergonomically designed.

However, very soon after its launch, the Stereo Three microscope became obsolescent because of developments in the design of microscopes which more closely suited user needs in the electronics industry. The replacement of conventional dual eyepieces by a biocular eyepiece (Figures 32 and 33) gives the user greater freedom in the viewing position which greatly reduces eye-fatigue. The management at Ealing Beck expected Stereo Three to have a life of about twenty years but sales began to decline rapidly after only two years. Indeed, the volume of sales declined to such a level that manufacture was no longer viable and production of the Stereo Three microscope ceased in 1978. Total output of the product had been approximately 500 units.

4.6.4 Technological Innovation at Ealing Beck

The firm has a tradition of research and innovation, sustained by its involvement in the military, defence, and aerospace contracts referred to earlier. However, successful innovation in clinical laboratory microscopes has proved to be elusive. During the 1960s, the firm felt the brunt of Japanese competition; it was unable to match the technical sophistication at the selling prices quoted by the Japanese firms. As a consequence, the firm decided to develop new products which would meet the needs of other market sectors. One result of this decision was the design and development of a student microscope, launched in 1968. It was a commercial success; over 30,000 units were sold. The firm had high hopes of Stereo

Three but its commercial failure has prompted a further revision of marketing policy. The firm has withdrawn microscopes from its general catalogue and instead is now a sub-contractor in this field.[171] During the last two decades, product presentation is said to have assumed increasing importance in the markets the firm supplies.[172] For example, Figure 34 gives an indication of the level of presentation in other makes of stereoscopic microscope. Previously, the Ealing Beck management felt able to deal with product presentation using its own (engineering) manpower but the intensity of competition is now such that it believes a contribution from an industrial design consultant is required.

The Stereo Three project was not, however, the first occasion on which the firm had engaged an industrial design consultant. During the 1960s, when the firm was a subsidiary of Griffin & George, there had been an unproductive experience with a consultant. He had been engaged to design a microscope eye-piece. The insignificance of the result did not warrant either the lengthy period of its development or the fee it entailed. Largely as a consequence of this experience, the firm's in-house design and development engineers were unenthusiastic when the management once again proposed engaging a consultant.

The firm's commercially successful student microscope launched in 1968 attracted the attention of the then Council of Industrial Design, the predecessor of the Design Council. The product was put on display at the Design Centre in London. This contact with the Council engendered renewed interest in industrial design in the firm's management and the managing director was particularly enthusiastic. After lengthy consultation between the management and the in-house engineers, it was decided to engage a consultancy on the development of new products or new models of existing products. (Many of the items manufactured and marketed by the firm are mechanical components which have no aesthetic potential). The Council assisted the firm in the selection of a consultancy.

Initially, there were difficulties in the working relationship between the in-house engineers and the consultants. For instance, the consultants' aversion to visible fastenings on the external surface of a product irritated the engineers. Subsequently, however, the engineers' scepticism gave way to a productive working relationship with a high degree of interaction between the parties.[173]

For the Stereo Three project, the management gave the consultants a wide-ranging brief to couple distinctive appearance with improved and more economical methods of manufacture which exploit new developments in materials. In the event, the configuration of Stereo Three, including such detail as the working clearance between the object and the microscope head, emerged from a market research survey. The firm had already produced a stereoscopic microscope; Stereo Three was to be a new model, aimed particularly but not exclusively at the electronics industry.

Many features of Stereo Three are the result of interaction between the in-house engineers and the consultants rather than the work of individuals working in isolation. Nevertheless, some features can be identified as the contribution of the consultants. They paid particular attention to the ergonomic requirements and handling characteristics of the product, resulting in some innovation of a minor order.

The management wanted Stereo Three to have a crisp angular external form which suggested precision in manufacture and accuracy in use. The usual means of creating this appearance in product casings is through the use of metal die-castings or plastic injection-mouldings. However, tooling costs are relatively high for both of these processes and their use is usually confined to items produced in large quantities. The consultants created essentially the same character in the external forms for Stereo Three by the use of metal sand-castings and hand-laid fibre-glass mouldings, both of these processes being appropriate to the (batch) production of the microscope.

On the Stereo Three project, the cost of engaging the consultants was 10% - 15% of the total development costs.[174]

4.6.5 The Effect of Winning a Design Council Award

The Design Council Award boosted the morale of the in-house design and development staff. The Board members of the parent company were impressed; previously they had been critical of the design and of the low volume of sales of the product.

After receiving the Award, the Stereo Three microscope attracted the attention of those involved in the promotion of good design. Journalists and authors of textbooks sought permission to use the product as an example of design which integrates visual elegance, ergonomics, and modern manufacturing techniques. The firm also received requests for the product to be included in design exhibitions at home and overseas. Ironically, to meet this exhibition requirement and the sales of the product which invariably result, the firm manufactured a batch of fifty units, even though by then the product was regarded as a commercial failure and general production had ceased.

4.6.6 The Stereo Three Project : From the Standpoint of the Industrial Design Consultants

The consultancy involved in the Stereo Three project tends to be commissioned by manufacturers of professional equipment; medical instruments, laboratory apparatus, business machines, and telecommunications equipment. Even if superficially these product categories seem diverse, there is a certain similarity in the way the projects are handled by the consultancy.[175] However, it is said that more significant than product category is the particular client-firm; the way it perceives its role in economic terms as a producer and employer and the way it perceives industrial design as a facet of its activities. In this connection, the management of Ealing Beck perceives industrial design primarily as a means of improving the appearance of a product. Industrial designers employed for this purpose only have a minor influence; like draughtsmen and technicians, their role is instrumental.[176]

The firm of Ealing Beck is essentially engineering-orientated, with production engineering having a significant influence on its policy and operations. Operationally, research and development, engineering design, and production engineering in the firm are not discrete activities. Moreover, the firm does not have a developed marketing department. Sales personnel in the firm have a low status relative to engineers. The consultancy operated only with the consent of the firm's engineers. During the period of the commission, a consultant was based on the client's premises for one day per week alongside engineering draughtsmen, with whom there was frequent informal consultation. Contact with employees of higher status in the firm was brief albeit significant; the Technical Director, the Chief Draughtsman, the Production Engineer.

The consultancy became involved in the Stereo Three project by chance. At the time, it was working on another project for the firm which was subsequently abandoned. The brief for the Stereo Three project was to give shape to a system already devised. The configuration of the product had been determined by in-house engineers. The firm's engineers were considering using vacuum-formed plastic sheet for the microscope-head casing. The consultants persuaded them to use a fibre-glass moulding instead, which is visually more solid and structurally more rigid. The consultancy also arranged for mouldings of an appropriate quality to be manufactured by a subcontractor with which it had collaborated previously. Ealing Beck had already decided to use iron sand-castings for the microscope base. The consultants' contribution was to introduce accentuated gaps between adjacent castings, not only to accommodate minor misalignments of components which would otherwise detract from the overall appearance of the product but also to widen dimensional tolerances, thereby eliminating the need for costly machining of metal sand castings. The accentuated gaps also aided the dissipation of the heat generated by the microscope lamp, besides strongly delineating the external form of the product. The consultants introduced smooth large-diameter matt-black nylon control knobs on the microscope as an alternative to the customary small-diameter knurled chromium-plated metal knobs. It was argued that the nylon knobs not only enhance the appearance of the product but also provide functional advantages; the material is warm to the touch and the larger diameter provides more sensitive control. Moreover, the colouring pigment for the nylon is included in the material formulation so no finishing is required. It was said that only with difficulty were the consultants able to convince the firm's engineers on the significance of visual accuracy in the form and finishing of physical models.

4.6.7 Subsequent developments at the firm relative to industrial design

It was asserted that on reflection timing proved to be crucial for the Stereo Three microscope; the firm was one year too late with the launch.[177] However, the opinion of a successful competitor in this field is that market success derives in part from a firm's microscope being integrally fitted to the bonding and probing machines used in the earlier stages of electronic microcircuit manufacture. Users tend to purchase the same make of stereoscopic microscope for microcircuit assembly and inspection as that which forms part of the bonding and probing machines. Because these machines are mainly of American manufacture, the sector of the stereoscopic microscope market related to the electronics industry is dominated by American firms.[178]

Though Stereo Three was a commercial failure, the management of Ealing Beck did not regard the project as a total loss. Through the project, the firm gained new experience in production techniques and use of materials which was subsequently applied to other projects. In the Stereo Three project, a fresh approach had been taken in new product development which has had a lasting effect in the firm.

Since the Stereo Three project, the industrial design consultants have been engaged jointly by Ealing Beck and the Scientific Instrument Research Association (SIRA) on the development of another new product. The consultancy has also been engaged separately by SIRA.

4.6.8 Evaluation

(cf 4.6.3) Though the Stereo Three microscope received a Design Council Award, the product was a commercial failure. A conclusion to be drawn from this case, therefore, is that in technological innovation related to scientific instruments, good design - as inferred by the Award - does not ensure commercial success. Whilst there are strong indicators from the evidence presented in other sections that good design is <u>one</u> of the factors influencing commercial success in technological innovation, that factor is not sufficient in itself to overcome shortcomings in the firm's management of innovation. Moreover, uncertainty and its attendant risks are constant factors in innovation, and adverse influences from this source may render impotent factors such as good design which under more favourable conditions may have contributed to commercial success.

(cf 4.6.4) Uncertainty and risk muddy the waters in innovation. When industrial design is consciously introduced into a project against a background of opposition from in-house engineering staff, it could be a casualty in the event of commercial failure of the new product. To its credit, Ealing Beck did not make industrial design the scapegoat for the commercial failure of Stereo Three but continued to deploy it on projects and even aided its diffusion by introducing the consultancy to the Scientific Instrument Research Association. (cf 4.6.7). However, this may not be so much resoluteness in innovation management, more a consequence of design being represented on the Board of the firm, which is atypical.

(cf 4.6.3) With the wisdom of hindsight, it is possible to suggest alternative action in the firm's management of innovation which may have avoided the commercial failure of Stereo Three. From the evidence, failure of the product can be attributed to two principal causes. Firstly, Stereo Three was rendered obsolete by the introduction of microscopes with a bi-ocular eyepiece. Secondly, the firm's market intelligence should have indicated that there was already in existence a firmly-established mode of provision for stereoscopic microscopes for the electronics industry based on the incorporation of particular makes of microscopes in processing equipment; the likelihood of Ealing Beck successfully challenging this oligopoly was extremely remote. (cf 4.6.7). Failure due to inadequate market intelligence will not be pursued because it is outside the scope of this study, even though its significance may render further analysis of this case of academic interest only. Nevertheless, failure attributable to obsolescence is relevant to the study; the introduction of a bi-ocular eyepiece into stereoscopic microscopes is an advance in microscope design rather than microscopy. When the two types of eyepiece are compared, the superiority of the bi-ocular form is so obvious it leads one to conclude that had the firm's enquiry into user needs been more penetrating and more imaginative, the preference for bi-ocular viewing could have been anticipated. (cf Figures 32 and 33). Moreover, the physical discomfort associated with binocular viewing for lengthy periods is so well known that had the designers in any event taken as their starting point the basic needs of the user (as suggested by London in the previous case study), it would have entailed little imagination on their part to realise that an alternative to the binocular mode of viewing would represent a significant improvement in design. Assuming the adequacy of the instrument's stereoscopic performance, the primary problem to be solved by design was user fatigue and its consequential effect on working efficiency. As it is, Stereo Three is an example of design in which the configuration was determined largely by engineering and technological considerations. (cf 4.6.6)

In these circumstances, one must seek an underlying explanation rather than simply attribute mistakes to dumb ignorance. Though the firm has a long-standing reputation in the field of optics, it is evident that this relates largely to technical components rather than complete products with a user interface. (cf 4.6.2). When compared with product innovation, component innovation is less demanding, even if technically complex; there are fewer variables and there is less uncertainty. Moreover, though the design content in technical components is within the competence of engineering designers and draughtsmen, their formal training does not automatically equip them to also design products with a user interface. Therefore, when engineering personnel whose experience is rooted in component design are in control of the design of a new product with a user interface, there is a likelihood that they will inappropriately apply the conventions and habits of the one to the other.

(cf 4.6.4) The tacit admission by the management that the requirement for external assistance in design was a consequence of the

Figure 30. The 'Stereo Three' microscope manufactured by Ealing Beck Limited.

Source: Ealing Beck Limited.

Figure 31. The Stereo Three microscope: working clearance and reversibility of head.

Source: Ealing Beck Limited.

Aston University

Illustration removed for copyright restrictions

Figure 32. The 'Vision TS-1' stereoscopic microscope with bi-ocular eyepiece.

Source: Finlay Microvision Company Limited.

Aston University

Illustration removed for copyright restrictions

Figure 33. The Stereo Three microscope in use.

Source: The Design Council.

Aston University

Illustration removed for copyright restrictions

Wild. (Switzerland)

Source: Wild.

Aston University

Illustration removed for copyright restrictions

Kyowa. (Japan)

Source: Finlay Microvision

Figure 34. Stereoscopic microscopes: other makes.

pressure of competition is instructive. It infers that in less competitive times, deficiencies in design were less critical relative to success or failure. For this firm, therefore, the role of industrial design in technological innovation is a consequence of heightened levels of competition. In the event, in the face of resistance from the engineering staff, the management fudged the issue. Rather than take a bold user-orientated approach to design, the role of the industrial designers was limited to that of refining the form of a technical configuration devised by the engineering staff (cf.4.6.6). It is a further example of policy decisions on innovation being negotiated, not in a constructive atmosphere aimed at increasing the likelihood of success of a new product but rather to accommodate the uneasiness and hostility of a reluctant engineering staff who feel threatened by change in working procedures even though these are intended to prevent the total eclipse of the firm.

4.7 Gas Chromatographs

4.7.1 Introduction

The starting point for this case study is the F.30 gas chromatograph manufactured by Perkin-Elmer Limited of Beaconsfield. (Figure 35). The instrument received a Design Council Award in 1974. The evidence in the case study comprises that obtained from the published literature, from the Product Line Manager at Perkin Elmer Limited, from a competing firm, and from industrial design consultants involved in this field.

4.7.2 The Firm

Perkin-Elmer Limited is the British subsidiary of Perkin-Elmer Incorporated of America. The corporation, which has subsidiaries throughout the world, was founded during the 1930s and initially specialised in optics. Later, its operations expanded to include the manufacture of scientific instruments. During the post-war period there was further diversification into electronics because of the increasing importance of electronics in scientific instruments. Currently, two-thirds of the corporation's business is in optics and one-third in scientific instruments. It is a market leader in scientific instruments. It supplies 80% of the world market atomic absorption apparatus, 50% of the interferometers, and 40% of the gas chromatographs. Of the 16,000 employees in the Perkin-Elmer Corporation, 800 are employed in the United Kingdom.[179]

4.7.3 The F.30 Project

Chromatography can be defined as a technique for the separation of a mixture of solutes in which separation is brought about by the differential movement of the individual solutes through a porous medium under the influence of a moving solvent.[180] The Russian biologist Tswett is said to have invented the technique in 1906. Initially, it was regarded only as a laboratory curiosity. The technique was re-invented by Kuhn, Winterstein and Lederer in 1931, who applied it to the resolution of plant carotene into its components. A period of rapid development followed. The technique of gas chromatography dates from the work of A.T.James and A.J.P.Martin in 1952. It is said that no other discovery has exerted as great an influence and widened the field of investigation in organic chemistry as much as Twsett's chromatographic analysis. Research in the field of vitamins, hormones, carotinoids, and numerous other natural compounds could never have progressed so rapidly and achieved such great results had it not been for this method, which has also disclosed the enormous variety of closely related compounds in nature.[181] Today there is almost no field of chemistry or biology which does not use chromatography in some form. It is used not only as an analytical technique in laboratories but also for industrial process control in the manufacture of food, petrochemicals and other commodities.

A gas chromatograph is an instrument which identifies both the molecular weight and the intensity of each substance contained in a complex chemical mixture. It is especially useful for analysing organic mixtures, which are difficult to analyse chemically in any other way.

The principles on which the gas chromatograph is based are simple. The liquid mixture to be analysed is injected into the instrument and vaporised at temperatures up to 500°C while a regulated supply of carrier gas is passed through the vaporiser. The gas stream carries the sample through a temperature-controlled chromatographic column, which is a tube containing a thin film of non-volatile liquid on an inert support with a large surface area. Different components of the mixture travel through the column at different speeds, depending on the 'partition ratio' between the stationary liquid and the carrier gas. As they leave the column, the components pass through a detector which converts the gas composition into an electrical signal which is fed into a potentiometric recorder. The resulting 'chromatogram' provides both qualitative and quantitative information about the sample, although in practice a gas chromatograph is normally used only as a quantitative instrument.

During the early 1960s, when gas chromatographs were first used in industry, it was the custom for users to make up their own instruments from standard items of laboratory apparatus. In 1964, Perkin-Elmer launched its F11 gas chromatograph. The standard of technical performance of this instrument and its competitive selling price were such as to dissuade users from the effort of making up their own instruments. The F11 was a commercial success. Approximately 6,000 units were sold, said to be very high for this category of scientific instrument. The firm claims that through the F11 it created the market for commercially produced gas chromatographs.

By the end of the 1960s, gas chromatography was being widely applied in industry and the operation of gas chromatographs was no longer confined to specialists. Perkin-Elmer identified the need for a gas chromatograph which was simply a tool, capable of being operated without the special knowledge and skills previously associated with gas chromatography. The F.30 project was set up to meet this need.[182]

The F.30 gas chromatograph was developed specifically for ease of operation so that even an unskilled operator can obtain accurate and reproducible results. For example, the controls on the front panel are arranged in a logical sequence and in clearly defined groups to reduce the possibility of error. There is also a 'systems check' on the front panel, comprising a row of lamps which remain lit until the various temperatures and gas flows exactly match the instrument settings. (Figure 36). When all the systems are stabilised, the lamps extinguish and a 'ready' lamp indicates that the chromatograph is ready for the next sample or, alternatively, a start signal is transmitted to an automatic sampling accessory.

The elements of the F.30 are housed in two separate cases; the oven and its associated injectors and detectors in the upper case and the electronics in the lower. The two cases are hinged together to facilitate easy access to the electronics. A pneumatic stay assists in lifting the heavy oven and also acts as a safety device. (Figure 37).

The outer casing of the F.30 is made of sheet steel. On the front panel of the casing, extruded aluminium bezels are attached by means of spring latches for easy removal, providing ready access to the detector manifold and injectors. An aluminium alloy trim is easily removed for replacement of the push-buttons and digital switches.

Alternative foreign language panels can be fitted. By means of an interchangeable plate behind the front panel, different injection systems can be incorporated without altering the overall appearance of the product.

The F.30 has a number of special technical features. Digital circuitry provides a high degree of precision in re-setting parameters with a consequent improvement in the accuracy of the analysis. The flow sensor, an electrical measuring system for the gas flow, simplifies both the initial flow setting and the re-setting of a previously-used flow rate. (Re-setting is particularly important if the instrument is being used in conjunction with an automatic date-handling system). A carrier-gas make-up system maintains a constant flow of the carrier-gas to the detector irrespective of the gas flow through the column. This eliminates the need for re-calibration of the detector when the gas flow is changed and thus reduces the possibility of error. A hot-wire detector bridge is controlled at constant resistance rather than the more usual constant current or voltage. To provide reproducible results under conditions of varying ambient temperature, all the pneumatic and electronic components are thermostatically controlled.[183]

The F.30 was launched at the Pittsburgh Scientific Instrument Exhibition in 1971. It is claimed that at the time, there was no other product on the market which could match the F.30 for accuracy and reproducibility of analytical results, simplicity of operation, and overall elegance. The product was said to be five years ahead of its time in concept and performance.

The estimated total cost of development of the F.30 was £200,000 (1971). The selling price of the unit was £2,200. (1974).

4.7.4 Technological Innovation at Perkin-Elmer

Technological innovation is part of the firm's business strategy. As indicated in 4.7.3, the firm claims to have created the market for commercially-produced gas chromatographs.

Innovation in this field presents special problems of communication because the new product development is astride a number of disciplines. Because the users of the instruments are chemists, Perkin-Elmer employs chemists as marketing representatives. The R & D personnel are electronics engineers and physicists. The technical design of the instruments is undertaken by mechanical engineers, and industrial designers also make a contribution. A project team is led by a Product Line Manager. The team has two branches : R & D and marketing. New technical concepts emerge from the R & D branch which then makes innovation proposals for evaluation by the marketing branch. It is within the discretion of the Product Line Manager whether or not to include an industrial designer in the project team. There are difficulties in coordinating the activities of the team; not only are mechanical engineers and industrial designers prone to disagreement but also mechanical engineers and electronics engineers.[184]

The management of the firm holds that the successful marketing of scientific instruments calls for discernment in presentation; that elegance in scientific instruments has commercial and professional utility. In an era when conducted tours of Company premises are an established part of salesmanship and public relations, industrial laboratories also serve as show-places viewed by visiting dignitaries, prospective customers, and the wider public. The head of a laboratory who invokes elegance as one of his purchasing criteria is able to project a modern efficient image in his department which not only serves the firm's wider objectives but also enhances his personal reputation within the firm.

In spite of what scientists may assert to the contrary, it seems that the approach to the purchase of professional scientific instruments is very similar to that of private motor cars. Purchasers are influenced initially by the external appearance, the external finishing, and other non-technical features, then proceed to justify preference and pride of possession by alluding to the technical specification. Like motor cars, scientific instruments are used well within their maximum capability by the majority of users. For instance, it is said that when an instrument is capable of registering readings with various orders of accuracy, the lowest order of accuracy is the setting most commonly used.[185] Within any particular instrument category, most of the competing makes have an ample technical specification. In this respect, most scientific instruments are over-designed technically and selection based on the manner of presentation is not so irrational as may first appear.

The scrutiny of technical specifications is more rigorous than in the case of private motor cars because the purchasers are more able to expertly assess them but the psychology of product presentation is held to be a strong determinant in the ultimate choice of make.

Industrial design is seen as the means of transforming anonymous technical hardware into elegant marketable products with a strong corporate identity. Many purchasers are influenced by the reputation of the manufacturer so an aid to commercial success is the ability of the product to project a distinctive Company image.[186]

Almost from its inception in the 1930s, the American parent firm engaged the services of an (American) industrial design consultancy, Eliot Noyes. This association, which stemmed from the personal acquaintanceship of the principals, developed into a lasting partnership. From the outset and under the influence of Eliot Noyes, Perkin-Elmer cultivated a strong corporate identity, projecting an image of high quality in its products. Contemporaneously, the Eliot Noyes consultancy grew in stature to become one of the foremost in the United States. Besides Perkin-Elmer, the Mobil Oil Corporation, International Business Machines, and the National Aeronautics and Space Administration are among its clients.[187]

In Perkin-Elmer Incorporated, the consultancy has access to the highest level of management. All designs are subject to the approval of the consultancy. It seems that the consultancy has the authority to insist that foreign subsidiaries of Perkin-Elmer, including the British firm, conform to this arrangement. At the British firm (Perkin-Elmer Limited), for the F.30 project the industrial design contribution was at two levels: through occasional interaction with American consultants from Eliot Noyes and from an in-house industrial designer.

The consultants are highly regarded at Perkin-Elmer Limited. The consultancy has accumulated experience in ergonomics related to scientific equipment. Its external designs for instruments with an operator interface are said to 'read' very easily. Well-tried principles are applied to the lay-out of instrument panels and the grouping of controls. The elegant form solutions reflect a knowledge of material-forming processes and the economics of production engineering and are admired by the production engineers. Control switches, indicator dials and similar accessories are carefully selected in the quest for visually-coordinated products. With the potentiometer controls on the F.30, for instance, the mode of operation was changed to fit in with the visual concept. The colours and standard of finish on all Perkin-Elmer scientific instruments, in whatever country produced, are specified by the consultancy.

The Product Line Manager for the F.30 regarded the consultant as a great asset in the project team: his wide experience of coupling aesthetic sensibility with engineering feasibility; the confident sureness of touch; the capacity to generate enthusiasm in the rest of the team for his aesthetic objectives; his common-sense; his receptiveness; his firmness; these qualities were said to bring sparkle and dynamism to the team work. By contrast, the in-house industrial designer in the same team was regarded with much less enthusiasm. He adopted a precious attitude towards the shapes he created, in the manner of an artist. His sketch proposals could be implemented only in terms of uneconomical methods of production and because of the high status of industrial design in Perkin Elmer, the production engineers felt obliged to do so. Production difficulties ensued; costly forming and craftsman-like hand-finishing. For the rest of the team, the industrial design content of the project, as dealt with by the in-house designer, became a wrangle and a source of inefficiency. Against this, it was said that the Perkin-Elmer management are fastidious about the quality and standard of finish of the products. Units are rejected if they are blemished by the slightest scratch. At the time, the in-house industrial designer had other responsibilities in the firm besides product design: exhibition design, interior design, and graphic design. This in-house post has since been discontinued.

The cost of industrial design services for the F.30 project was estimated at £15,000 (1971). The fees the consultancy obtains from Perkin-Elmer were described as very high by British standards. In the United States, consultants charge the large corporations high fees but are considered to give good value for money.

4.7.5 The Effect of Winning a Design Council Award

The Award was said to have had value as a selling aid rather than as a direct influence on sales. It impressed the management of the (American) parent corporation, with favourable reflections on the management of the British subsidiary. It boosted the morale of the project team. The citation for the Award, however, caused some dissension. The Design Council judges, in stating they were impressed by the technical features of the F.30, the ease of access for servicing, the high standard of detailing, and the overall appearance of the product, named only the in-house industrial designer.[188] This displeased the rest of the project team on two counts. They felt the Council should have given credit to the project team as a whole. Moreover, it was said that the Eliot Noyes consultant had a greater influence on the product than the in-house industrial designer.

4.7.6 Pye-Unicam : A Competitor of Perkin-Elmer

4.7.6.1 The Firm

Pye-Unicam is a subsidiary of the Pye Group which in turn is part of the Philips Group. Prior to the merger with Philips, the Pye Group - centred on Cambridge - had various subsidiaries engaged in the manufacture of scientific apparatus, business machines, and consumer electronics. Following the merger, the Pye Group was reorganised so as to be more compatible with Philips' operations. Some Pye companies were merged with their Philips counterparts, others were closed down. In the field of consumer electronics, for instance, Pye was highly innovative during the 1960s, developing a colour television system and a flat-screen receiver, with an in-house industrial design facility to transform them into finished products. However, Pye failed to maintain this momentum when faced with the first competitive thrust in consumer electronics from Japanese firms. Its demise in this field is attributed largely to its failure to keep in touch with changes in purchasing preferences in its markets. Implicitly, Pye's designs were intended to appeal to a middle-aged middle-class medium-price market. Mistakenly, it was assumed that these users' preferences were static and uninfluenced by trends in other sectors of the market. One consequence of the merger with Philips was the phasing out of the Pye in-house industrial design facility at Cambridge.[189]

In the field of chromatography, Pye-Unicam had a better reputation in the market than Philips so chromatographic development and manufacture was concentrated on the former, which was designated a World Supply Centre for the Philips organisation. Within the Philips Group, Pye-Unicam is also an autonomous profit centre. Pye-Unicam as a whole has 1,000 employees of whom about 12% are engaged in development. Besides chromatographs, Pye-Unicam manufactures equipment in the fields of spectrometry and electro-chemistry. In the chromatography section, there are 130 staff; 75 development personnel and 55 supporting staff.[190]

4.7.6.2 Technological Innovation at Pye-Unicam

The firm attempts to make 5-year projections of the technical facilities in chromatography customers are seeking. The price customers are prepared to pay for a facility is a vital element in a projection. The advent of micro-computing and data-processing has significantly affected projections in recent times. Only a few years ago, in order to maintain sales the firm found it necessary to keep the price of a gas chromatograph below a ceiling of £1,000; that was said to establish the order of costing for the product.[191] With the advent of data-processing, however, first American and later British customers were prepared to pay £5,000 for a gas chromatograph with this added facility. It is said that customers in the United Kingdom are generally slower to respond to technological advances and more sceptical than their American counterparts. For instance, many potential customers for gas chromatographs in the United Kingdom first regarded micro-processors as a gimmick.[192]

Within the project team, there are three levels of development personnel; the Senior Study Group, the Junior Development Group and the Productionising Group. Having identified the customers' technical requirements, the Senior Study Group is allocated six months to draw up the product specification and to identify the technologies to be developed. The latter will probably have been anticipated in broad terms. This is said to be a critical stage in innovation; inter-related decisions on product concept, product cost, technological alternatives, and the amount of mechanical engineering required must be capable of implementation within the terms of the product specification. The Junior Development Group is allocated 12 months to develop the specification into a design. The Productionising Group is allocated 12 months to carry out its task. Inevitably, the activities of these groups overlap.[193]

Commercial success is linked to the time interval between concept and launch. New technology in this field has a currency of about seven years. Therefore, the two-and-a-half years which elapse between the start of a project and the launch of a new product, as detailed above, leaves only four-and-a-half years to recoup investment and realise a profit. Product price, level of investment, and profit margin are geared to this equation. An over-run in development is at the expense of product life. With this in mind, there is a firm policy of freezing the specification at a particular point in the project; to make additions as a result of technological developments during the tenure of the project can adversely affect other elements in the package and produce a confused specification. Moreoever, without the constraint of freezing the specification, a project is prone to become an on-going hobby of development personnel. It is accepted that the firm's products are intrinsically obsolescent, a feature of all high-technology manufactures.[194]

The United States market for gas chromatographs is ten times that for the United Kingdom. Therefore, American manufacturers begin with the advantage of potentially greater home sales. Whereas 3,000 units are typically produced for a British product, the comparable quantity for an American product is 5,000 units. This difference in market potential encourages American manufacturers to invest more in development. The Pye-Unicam share of the United Kingdom market for gas chromatographs is 40%.[195]

It has been the policy of Pye-Unicam for at least twenty years to pay close attention to the visual quality of its products. Industrial design is one of the firm's established norms in the innovation process, probably a spill-over from its pioneering work in domestic radio receiver design.[196] Contiguous with this tradition, the views of the Senior Study Group on industrial design in relation to gas chromatographs transcend those of the hired consultant. A new product is required to communicate sympathetically with the user: generally convenient in its arrangement; easy to operate; ergonomically correct. The product is also required to project a distinctive image of the firm which the user will equate with high quality.

In the early chromatographs, the manually-set controls gave the user an immediate visual indication of the state of the sampling. This facility was lost when chromatographs became automatic and the processing of data internalised. With the advent of the visual display unit (VDU), however, intermediate data is again visible. In early chromatograph design, banks of push-buttons and indicators made control-panels visually complex. With new circuitry and microprocessor technology, control panels are now much simpler.

Design transfer is a significant factor in this field. For instance, the advent of membrane-controls in electro-chemistry significantly affected instrument design. This form of control eliminates the long-standing problem of corrosive chemicals in the proximity of conventional push-buttons. The membrane-control also presents a wipe-clean surface, enhances the colour-coding, and provides more flexibility in the graphic arrangement of controls. Moreover, membrane-controls have set a new stylistic trend with symbolic connotations of technological change. The advent of modular systems in instrument design is also a significant development, not least because it has been accompanied by the development of display-panels which are visually modular. Now, more than ever, functionally related sub-system packages must also relate visually in dimensions and form. This has resulted in some standardisation in design. For instance, many Pye-Unicam instrument chassis are now designed to be contained within a standard Philips casing, permitting a degree of interchangeability between systems. The size of instruments generally has increased and to reduce their visual bulk, Pye-Unicam transposed its two-tone, light-grey/dark-grey house colours.

The industrial design consultant contributes at a number of levels. In the early stages of a project he contributes at Senior Study Group level. He presents preliminary sketches to show alternative forms for the new product. He produces physical models for presentations to the Board of Directors as an aid to obtaining approval for the development and productionising phases of the project. He also contributes at the detailing level to ensure that his intentions are correctly interpreted by the engineering draughtsmen. There is subtlety in both the comfortable operation of equipment and in the projection of an image, which ultimately depends upon dimensional precision.

The management has recently acted on the need to make engineering design contiguous with industrial design. As a radical measure, it has detached the in-house engineering designers from their traditional habitat, the engineering drawing office. Instead, every engineering designer now works as a member of a project team and the drawing office is simply a central servicing facility of engineering draughtsmen. With this new arrangement, the industrial design consultant interacts directly with an engineering designer on matters of configuration. The firm's engineering designers are also encouraged to contribute to those aspects of design concerned with maintenance and access, e.g. re-arrangement of the layout of the gas chromatograph oven to effect easier access.

In his role as a stylist, the consultant is expected to put his personal stamp on the product.[197] Until 1980, the style of Pye-Unicam gas chromatographs was that of Upjohn, a former senior partner in the consultancy London Associates. (cf. 4.5.6). The style of Stokes, another partner in the same consultancy, is now becoming established. Concurrently, a gradual change of image, as reflected in the graphics applied to the products, indicates the growth in the influence of Philips. There has been pressure from the Philips headquarters for Pye-Unicam to use the central industrial design facilities at Eindhoven in Holland rather than independent British consultants. This pressure has been resisted on the grounds that lines of communication would be longer and less responsive to the needs of Pye-Unicam. Moreover, if the necessity arises, it is easier to replace a consultant than an in-house industrial designer. Also, a consultant is remote from the day-to-day problems in development and his contact with the wider world is another factor in his favour. He brings to the team a detached viewpoint when there are internal differences of opinion about design. There has been pressure from the Philips headquarters to involve the consultants in the presentation of information in the firm's sales brochures. This has been resisted on the grounds that the Pye-Unicam management is familiar with the problems of brochure design and the existing graphic design sub-contractors have achieved a high standard of presentation. It is realised, however, that a distinctive identity for Pye-Unicam will be retained by Philips only so long as it has significance in the market.

The consultant works within constraints laid down by Philips. For instance, colours, graphic symbols, letter-faces, and some of the panel controls (e.g. push-buttons, switches) are specified so as to be visually compatible with other products in the Philips range. There are regular consultations (i.e. two or three meetings annually) between representatives from Philips headquarters and the consultancy. These consultations are about stylistic trends generally and about changes in form. It is an exchange of views; these are said to be indications that the style of Pye-Unicam has influenced that of Philips.

At Pye-Unicam, the cost of industrial design in a gas chromatograph is typically 10% of the total product cost for the keyboard and 5% for the casing. Packaging to ensure that the instrument is delivered in pristine condition is typically 1.5%. Therefore, at 15%, the cost of industrial design in an instrument is of the same order as that for various technical features. If the product cost objective is exceeded during development, the cost of achieving the desired level of visual quality in the instrument is scrutinised. The cost of engaging industrial design consultants on a project is in the range £3,000 - £4,000, said by the Pye-Unicam management to be lower than average.

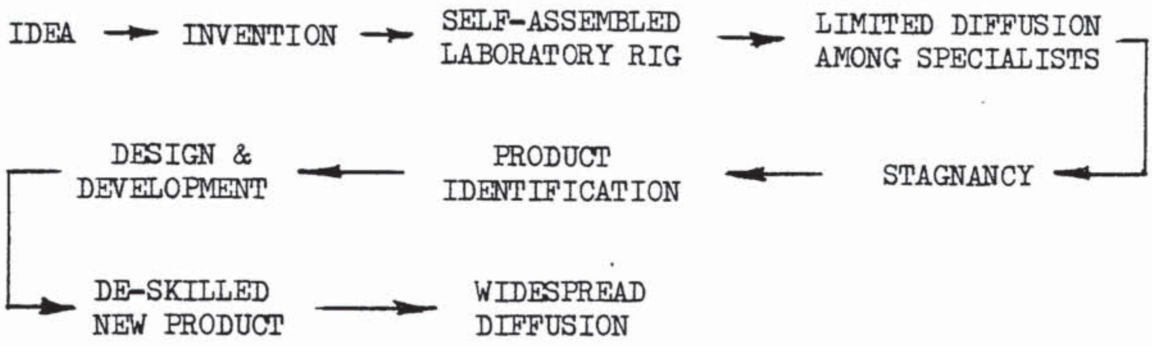
Figure 38 shows the Pye-Unicam PU 4500 gas chromatograph, the equivalent of the Perkin-Elmer F.30.

4.7.7 Evaluation

(cf 4.7.3) This case provides an example of the way in which good design can act as a catalyst in technological innovation. A scientific discovery, such as gas chromatography, though developed into an analytical technique, may in respect of the apparatus remain as a self-made rig in laboratories even though it has the potential to be developed into a marketable instrument package. Perkin Elmer identified this potential in gas chromatography and through good design even extended its application beyond the domain of scientific laboratories into the industrial sphere, enabling unskilled operators to perform tests which previously required scientific skill. In doing so, the firm created from an established scientific principle a market for a new scientific instrument. The usual sequence in technological innovation is:

IDEA → INVENTION → DEVELOPMENT → LAUNCH → DIFFUSION

In the case of gas chromatography, the sequence was:



Lest this case be regarded as an isolated example, the Airstream anti-dust safety helmet manufactured by Racal Electronics provides another example of technological innovation in which good design acted as the catalyst.[198] The original invention emerged from the Safety in Mines Research Establishment but, obtaining no response from the National Coal Board, the patent lay dormant. Racal, seeking to diversify its operations and enter the growing market of safety equipment, identified both product potential and poor design in the original invention and through good design developed a new product with a much wider application than that originally envisaged by the inventor. Rothwell et al[199] have also encountered good design acting as a catalyst in technological innovation.

(cf 4.7.4) This case also gives an indication of the way in which a large American corporation deploys industrial design in technological innovation. Though Perkin Elmer Limited is a British firm under the terms of the Companies Act - and therefore eligible to have its products considered for a Design Council Award - it is essentially an operating subsidiary of an American corporation which strongly influences its management and methods. Unlike the indigenous British firms considered in the other case studies, which have adopted industrial design recently as a means of fending off competition, it has been a norm in this corporation since the 1930s. Indeed, the firm's early association with the consultant Eliot Noyes indicates a pioneering role in the peculiarly American approach to industrial design which influenced product design and the merchandising of goods generally all over the world. Eliot Noyes, along with a small number of other entrepreneurial industrial designers, is credited with literally giving shape to many products regarded as characteristically American, which in turn has shaped the image of the United States. These entrepreneurs also conceived the idea of corporate identity, and developed it to the point where the design of a corporation's buildings, interiors, vehicles, uniforms, stationery, packaging, and all the paraphernalia of merchandising were visually coordinated in order to project a consistent public image favoured by the management.

The extent of this design activity is such that both the expenditure by the corporations and the income of the consultancies is much greater than is to be found in the United Kingdom. This has a number of consequences. Industrial design features prominently in policy. The consultancies have access to the highest executive levels in the large corporations and thereby strongly influences their management of design. There is close centralised control of the presentation of products; for instance, the authority of the Eliot Noyes consultancy to specify the colour and finish of Perkin Elmer products worldwide contrasts markedly with the situation at Crosfield Electronics (4.4) and Vickers Instruments (4.5), where sales or marketing personnel choose colours from alternatives submitted by the consultant. However, evidently all American firms are not organised in the manner of the large corporations or have a similar view of industrial design. Though Ealing Beck Limited (4.6) is the subsidiary of an American corporation, its deployment of industrial design is very parochial when compared with Perkin Elmer.

(cf 4.7.4) Though the suggestion that the purchasing of scientific instruments such as gas chromatographs is in some respects similar to that of private motor cars may be treated with scepticism if not disbelief, there are positive indications that Perkin Elmer, a market leader, considers this to be the case. The centralised control of product image, the seconding of industrial design consultants from the United States for project assignments in Britain, the fastidious inspection of the finished product before despatch, not only resembles motor industry practice but also indicates the seriousness with which the imagery of scientific instruments is treated and the backing in investment it receives.

Figure 35. The F.30 gas chromatograph manufactured by Perkin Elmer Limited.

Source: The Design Council.

Figure 36. The F.30 gas chromatograph: detail of controls and 'systems check'.

Source: The Design Council.

Figure 37. The F.30 gas chromatograph: detail of upper and lower cases.

Source: The Design Council.

Aston University

Illustration removed for copyright restrictions

Figure 38. The PU4500 gas chromatograph manufactured by Pye-Unicam Limited.

Source: Pye-Unicam Limited.

Though Pye-Unicam is now an operating subsidiary of a multi-national corporation, it has British antecedents which Perkin Elmer Limited has not. There is a similarity with Perkin Elmer insofar as it has employed industrial designers since the 1930s, even if the approach then reflected that of the European Modern Movement, and therefore had its origins in fine art rather than the unashamedly commercial approach adopted in the United States. These distinctions in approach are no longer apparent. Moreover, whilst the management of Pye-Unicam has a measure of autonomy in design relative to the parent organisation which the British subsidiary of Perkin-Elmer does not have, it is evident that the pressure to conform to policies on design formulated at the centre are growing. (cf 4.7.6.2).

(cf 4.7.6.2) The long experience of Pye-Unicam in integrating good design into its activities shows in the clear distinction the management makes between design and engineering draughtsmanship, in the confident handling of industrial design in the innovation process, and in the readiness to exploit the use of new visual forms which emerge from technological developments. Moreover, the well-defined procedures in the management of innovation provide a workable model for firms still at the stage of trying to convince engineering staff of the need for good design rather than simply draughtsmanship.

4.8 Linear Accelerators

4.8.1 Introduction

The starting point for this case study is the SL75-20 linear accelerator manufactured by MEL of Crawley (Figure 39). The machine received a Design Council Award in 1978. The evidence in the case study comprises that obtained from the published literature, from the Technical Manager of the Particle Accelerator Group at MEL who was also the project leader for the SL75-20 project, from a design engineer involved in the project, and from firms who compete in the same field.

4.8.2 The Firm

The firm was founded in 1935 as Radio Transmission Equipment Limited. In 1949, it was constituted in its present form under the name of Mullard Equipment Limited. (MEL). At about this time and working in cooperation with the Telecommunications Research Establishment, the firm constructed a 3.5 MeV linear accelerator for the Atomic Energy Research Establishment at Harwell. In 1977, MEL became a subsidiary of Philips Electronics and Associated Industries, the multinational corporation which has its headquarters in Eindhoven, Holland. Philips is organised into Main Industry Groups and functionally the Linear Accelerator Division of MEL is within the Medical Systems Group. The Linear Accelerator Division is designated by Philips as an International Supply Centre for radiation therapy equipment and as such supplies the various national marketing companies of Philips throughout the world.

Philips is a design-orientated corporation with a large centralised in-house industrial design facility (i.e. professional designers, studios, model-making shops) at its headquarters. In this respect, Philips is similar to the other major Continental manufacturers of electrical goods, e.g. Siemens, A.E.G. In turn, these major manufacturers are similar to those in the motor vehicle industry; in both industries, industrial design has long been accepted as a significant element in the marketing of products. The scale of the activity and the requirements of secrecy in respect of new models warrants an in-house facility.

Industrial design staff at Philips headquarters are available to take part in projects at manufacturing subsidiaries such as MEL. It is within the discretion of a project leader to include in his team either an industrial designer from Philips headquarters or an independent consultant.[200]

The total number of employees at MEL in Crawley is 2,000. In the Linear Accelerator Division there are approximately 200 employees, comprising 100 research and development staff and 100 administrative, commercial and servicing staff.[201]

4.8.3 The SL75-20 project

Radiotherapy is used to treat cancer and can result in a cure if the malignancy is detected at a very early stage. Radiotherapy is also used to alleviate pain in terminal cases of cancer. The SL75-20 linear accelerator, when launched in 1973, was the first machine in the world to provide in one unit a choice between X-ray therapy for the treatment of tumours deep within the body and electron therapy for the treatment of tumours at intermediate and superficial depths.[202]

The SL75-20 project had its origins in earlier machines manufactured by the firm. The SL48 linear accelerator (Figure 40) was launched in 1953. Many units were installed in hospitals both in the United Kingdom and Continental Europe. The model was in production until 1971.[203] Anticipating increased sales of this product, the firm initiated development on a new model in 1960. A fresh appraisal of the SL48 by a new project leader concluded that the machine was unsuitable for modern X-ray therapy techniques.[204] For instance, the walls of modern hospital treatment rooms containing X-ray equipment are constructed of barium-filled concrete two metres thick. The entrance to such a room has a barrier in order to trap stray X-rays. (Figure 41). The bulky SL48 model entailed the provision of a large (and therefore expensive) treatment room. The requirement was for a more compact machine which would reduce the overall cost of the installation.

The SL48 also had operational limitations. Due to its configuration and great height, the arc of rotation of the treatment head was limited to 220 degrees. This prevented the X-ray beam from being completely rotated about its target; to achieve uniform penetration, the patient had to be re-positioned during treatment. Moreover, the bulk and configuration of the machine was awesome to the patient, inducing tension during treatment.

A new product specification emerged from this appraisal. The new model was required to be more compact and operable through an arc of 360 degrees; accurate in alignment so that the angle of incidence and the focal point of the X-ray beam could be maintained during treatment and be reproducible during subsequent treatments; sealed to prevent the leakage of X-rays; simple to install and easy to service; suitable for current and anticipated therapeutic techniques; ergonomically compatible with the therapist and less awesome to the patient. The new design based on this specification was designated the SL75 model. A prototype was built and installed for field testing in a Rotterdam hospital. Special installation equipment was designed to obviate the need for expensive lifting gear and to enable the machine to be manoeuvred along corridors and in confined spaces in hospitals.[205] The production version of the SL75 (Figure 42) was launched in 1964 and became the first generation of the current series of this machine. The model was in production until 1970.[206]

Technically, the SL75-20 model, which superseded the SL75, is a travelling wave accelerator. The electrons acquire their energy from a radio-frequency field travelling through an accelerating wave-guide. The initial phase velocity of the field is equal to that of the electrons emitted from an electron gun and increases along the wave-guide, accelerating the electrons to 20×10^6 electron volts. After accelerating, the electrons are turned through 90^{o} by an electro-magnet and either directed on to a heavy target to produce X-rays or passed through a thin metal window for electron therapy. A collimator in the treatment-head restricts the beam to a cone and motorised heavy metal diaphragms adjust the field to the required rectangular shape. The radio-frequency power is supplied by a 5 megawatt magnetron, the frequency of which is servo-controlled for optimum accelerator performance.

The hardware comprises a horizontal accelerator assembly mounted in a gantry-arm projecting from a rotatable annular drum, a treatment table, a positioning-control unit, and a number of ancillary units. The gantry-arm containing the irradiation-head can be rotated through 360° with ample clearance between the patient and the treatment-head. Both the treatment-head and the treatment-table can be rotated and the height of the treatment-table is adjustable. The axes of rotation of the treatment head, the gantry-arm and the patient turntable intersect within a sphere of 4mm diameter. By locating the tumour at the centre of the sphere - the isocentre - and using several intersecting beams, damage to surrounding healthy tissue is minimal. High dose rates enable treatment times to be short. Rapid-positioning facilities enable a large number of patients to be treated daily.[207]

Safety for both patient and operator is an important consideration in the design of radiation therapy equipment. Besides specific safety devices on the SL75-20, the controls are deliberately arranged logically and ergonomically to reduce the possibility of error in operation. Access to potentially hazardous areas of the equipment is guarded. To prevent the maximum radiation dose being exceeded, there are two independent dosimetry channels; the system was developed in collaboration with the Department of Health and Social Security to comply with its safety requirements and those of other countries. The duration of irradiation is indicated on a timer; as soon as the preset limit is reached, irradiation is automatically terminated, regardless of the preset dose limits. A built-in select-and-confirm routine is intended to prevent inadvertent repetition of treatment; the treatment conditions have first to be selected then confirmed by a second operation before treatment can be started. Fail-safe interlock devices are intended to prevent the system from being operated with incorrectly set parameters. A safety switch on the positioning control unit is a means of preventing inadvertent operation during the setting-up procedure. The treatment head is fitted with a touch-guard which automatically stops irradiation and all gantry and table movements if an obstacle is encountered.

The SL75-20 is a commercial success. The selling price of the basic unit is £300,000 (1978). Units are now in use at leading radiation therapy centres throughout the world. Their record of performance, safety and reliability is said to set a standard for the industry.[208]

4.8.4 Technological Innovation at MEL

The total world market for linear accelerators of all types is about 150 units per annum. Within this total there are machines of various specifications and capabilities so it is not strictly a competitive market. Of this total, MEL supplies 30 units per annum - 10 units per annum of three types - representing a market share of about 20%. The market leader is the Varian Corporation of America. Other competitors are Siemens of West Germany and CGR of France.[209]

The strategy of the Linear Accelerator Division at MEL is to compete in technical performance rather than price; it seeks to develop and market products which out-perform those of its competitors. Because of the low-volume production, unit costs are high. To overcome this impediment, MEL markets a basic unit with a range of optional extras available, e.g. computer interfaces, automatic data-recording facilities. The introduction of microprocessors has given a boost to development; work is now proceeding to miniaturise many of the optional facilities.[210]

Industrial design is seen as making a significant if limited contribution to innovation in this field. It is said that the significance of appearance in this category of equipment has been brought about by the peculiar conditions prevailing in private medicine in the United States and the particular attitude of the large corporations in the United States towards industrial design.[211] Private medicine in the United States is competitive. One aspect of the marketing of private medical services in the more lucrative sectors is the provision of visually impressive equipment to appeal to the fee-paying clientele. For this reason, American manufacturers of this category of equipment pay a great deal of attention to product presentation and this influences the pattern of development in the market generally. (Figures 43 and 44).

A new product takes between two and three years to develop and is expected to have a life of approximately seven years. The external form of the product must be acceptable stylistically towards the end of its life. This requirement interacts with technological alternatives. The configuration of a particular technological system may be more compatible than another with respect to stylistic trends. Consideration of this issue takes place during the initial stages of the project; balancing the cost of development of alternative technological configurations, their comparative performance, and ease of maintenance against the projected value of a particular stylistic form. It is a consultative issue, not to be overstated. In the Linear Accelerator Division at MEL, machine form is a parameter in new product development; its priority relative to others depends upon the particular project. In all cases, however, fashionable extremes in both form and colour are avoided; the quest is for timeless elegance.[212]

Nor in a broader perspective should the significance of presentation in this product category be exaggerated. In the United Kingdom, for instance, where the Department of Health and Social Security is the principal purchaser, the imagery and appearance of medical equipment is not a dominant issue. Moreover, in institutional medicine, hospital physicists represent the determining influence in the choice of equipment within this category. Although medical practitioners and hospital administrators are also involved in the choice of equipment, the hospital physicist is the expert on the technical performance of radiation therapy equipment and the other parties lean heavily on his advice. He tends to be demanding with respect to technical specifications and technical performance and is less influenced by appearance. Nevertheless, with linear accelerators, the quantity and scale of the hardware is considerable and a requirement is that the product must not be awesome to the patient.[213]

For the SL75-20 project, the industrial designer was assigned to the team from Philips headquarters in Eindhoven. As indicated above, at an early stage in the project he took part in discussions about technological alternatives and the implications for machine form. However, it was decided for the patient's peace of mind to keep the bulk of the machine out of sight, behind a partition. Therefore, the casing which houses the rotatable annular drum and the gantry arm is the only visible element. (Figure 39). He produced design proposals in the form of sketches and three-dimensional models for this casing, aiming to achieve elegance in shape, refinement in colour, and compatibility with stylistic trends. In developing these design proposals, he liaised closely with the production engineering department because there are particular production problems related to manufacturing a small number of units. Modern machine form is usually perceived as the crispness of line associated with mass-produced precision die-castings and plastic injection mouldings, for which the expensive tooling is amortised over a large number of units. A similar crispness of line was sought in the SL75-20 through the use of hand-laid fibre-glass mouldings for the casing, with the manufacturing advantage that the moulds were relatively inexpensive to produce and capable of modification at modest cost during the currency of the product.[214]

The industrial designer made a contribution to the design of the control panels of the machine. There is a long-standing problem of integrating bought-in standard dial indicators into control-panels; they are much cheaper than custom-built equivalents but in many instances the external designs are outdated or inappropriate to the new machine form being developed. When electronic digital indicators became available it was thought at first that this innovation would eliminate the problem but in practice was found not to be universally popular with users. For many readings, a user requires and prefers simply a visual indication of a condition rather than a numerical value.[215] The trend now is towards the use of video display units in control panels (Figure 45). These are capable of incorporating the facility of a dial-indicator display without the disadvantages of the standardised dial-indicator hardware. To this extent, the design of control-panels now entails interaction with electronics engineers.

The ergonomic design of the controls was undertaken not by the industrial designer but a consultant from the Institute of Perceptual Observation at the University of Eindhoven. Proposals from this source were tested by potential users of the machine, with whom it is the custom to consult during the design phase of a project.

The industrial designer dealt with the application of graphics to the product. It was said that graphics are a means cf updating the appearance of a product swiftly and cheaply.

4.8.5 The Effect of Winning a Design Council Award

The Design Council judges were impressed by a number of features of the SL75-20: the configuration and the precision engineering, a combination enabling the pre-planned treatment of the patient to be given accurately; the high quality of the associated electronic engineering makes for reliability; the high aesthetic quality of the machine and the associated control equipment reassures the patient; the good design of the couch.[216]

The Award has not directly influenced sales of the product; rather, it is an aid in sales promotion. The firm published a special sales brochure to draw attention to the Award. It was said that the Award boosted the morale of the development team.[217]

4.8.6 Evaluation

With the possible exception of the Magnascan 550 colour scanner, the hardware of the products considered so far is in the category of light engineering. The linear accelerator, however, is an item of heavy engineering, traditionally regarded as the least susceptible to the influence of industrial design. The earliest version of the product (Figure 40) manifestly suggests that this is so; visually, it resembles a howitzer or a heavy overhead travelling crane. When a new product comes into existence, the hardware is in effect a crystallisation of the ideas and intentions of those who conceived it and, to some extent, a measure of their capacity to control the influences that ultimately shaped it. With this in mind, the immediate impression induced visually by the SL48 linear accelerator is one of intimidation yet it is most unlikely that those who developed this machine deliberately set out to intimidate patients undergoing medical treatment. Dismissing malice from the suite, therefore, other explanations must be sought to account for the inappropriateness of the form: most probably, the configuration was determined by considerations of technical function and mechanical convenience only; perhaps the appearance of the machine was not perceived as an independent variable; certainly the visual impact of the machine on the patient was not identified as a factor which should have influenced the configuration.

(cf 4.8.3) The inference is, of course, that there is not an inevitability about the configuration and appearance of new science-based products. It is part of the design process to first identify all the factors - technological, operational, psychological, ergonomic, and aesthetic - that should be included in the general specification of the new product then manipulate them to achieve balance and harmony in the configuration and form which seems to the user both inevitable and right. Nor should this comprehensive approach to product design be regarded as an end in itself - good design for its own sake. It is evident from the more liberal specification for the SL75 model of the linear accelerator, the replacement for the SL48, that the objective was commercial; to increase the sales potential of the product, not through a programme of complex technological development but simply by designing a new configuration for the existing technology more appropriate to its use. Comparison of the SL75 model with the SL48 (Figures 42 and 40 respectively) graphically confirms that the configuration and appearance of a new science-based product are susceptible to manipulation in this way.

(cf.4.8.4) This case confirms evidence presented in the previous case study: American corporations are capable of mounting formidable competition in markets for professional high-technology equipment through an emphasis on industrial design. Moreover, it is instructive to compare Figures 39, 43 and 44, showing the MEL, Varian and Siemens linear accelerators respectively; to note that each of these three technically-similar products has its own distinctive ambience; to note that an unlikely social factor, American private medicine, can have this kind of influence on machine form. It indicates that there is a social dimension to some categories of technological innovation, the neglect of which at the conceptual stage places an avoidable handicap on the commercial success of the finished product.

This case also provides more evidence of the interaction that is possible between technological developments and industrial design. Figure 45 illustrates the effect that microprocesser technology can have on the design of control-consoles.

Figure 39. The SL75-20 linear accelerator manufactured by MEL-Philips.

Source: The Design Council.

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Illustration removed for copyright restrictions

Figure 40. The SL48 linear accelerator manufactured by MEL.

Source: MEL-Philips.

Aston University

Illustration removed for copyright restrictions

Figure 41. The SL75-20 linear accelerator: layout of treatment room.

Source: MEL-Philips.

Aston University

Illustration removed for copyright restrictions

Figure 42. The SL75 linear accelerator manufactured by MEL.

Source: MEL-Philips.

Illustration removed for copyright restrictions

Figure 43. The 'Clinac' series linear accelerator manufactured by the Varian Corporation of America.

Source: Varian Corporation.

Figure 44. The 'Mevatron' series linear accelerator manufactured by Siemens Aktiegesellschaft.

Source: Siemens AG.

Figure 45. The SL75-20 linear accelerator: detail of treatment control console. The new console incorporates microprocessor technology to simplify treatment preparation and to improve the presentation of essential information. Traditional switches, knobs and meters have been superseded by a video display unit and an alpha-numeric keyboard.

Source: MEL-Philips.

CHAPTER 5

CONCLUSIONS

5.1 Introduction

This study suggests that in technological innovation the factors of form, configuration, overall appearance, and the detailing which delineates them appear to have a positive influence on success. The likelihood of commercial success is greater when these factors are consciously and expertly controlled; the medium for controlling them is termed industrial design. Conversely, the likelihood of failure is greater when these factors are not consciously controlled; when the ensuing features of a product are the chance result of other activities and considerations in the development process. Alternatively, the likelihood of failure is greater when these factors are consciously albeit inexpertly controlled. In many but not all instances, these factors and the ability to control them are variables independent of the technical design of a product; a product is capable of functioning technically even though effective control has not been exercised over the industrial design. This issue is not one of absolutes; there are degrees of control, control at various levels of detail, and degrees of expertness in designing ability. The evidence suggests that the likelihood of success is greater when it is the deliberate policy of the innovator to maximise the potential inherent in these factors.

5.2 Levels of Activity in Technological Innovation

Braun indicates that many classifications have been proposed, both to describe the importance of innovation and the area of activity.[1] Technological innovation can also be characterised as a phenomenon in which activity takes place at a number of levels. The form and patterns of these different levels of activity are not necessarily similar. An understanding of technological innovation will be enhanced if the form or a pattern can be identified at each level of activity. For example, the Sappho project[2] sought to identify patterns for success and failure in innovation at a particular level of activity. Stripped of the qualifying statements which accompany the results, the patterns which emerged from the Sappho project are shown in Table 13.

TABLE 13. THE SAPPHO PROJECT : PATTERNS FOR SUCCESS AND FAILURE IN INNOVATION

Success	Failure
Close attention to user needs.	Insufficient attention to user needs.
Senior personnel in charge of the project.	Personnel in charge of the project lacking in seniority and authority.
Outside technical help is utilised.	Outside technical help is not utilised.
Efficient management of the project.	Inefficient management of the project.
Close attention to marketing.	Insufficient attention to marketing.

This pattern of factors provides guidance for the organisation and management of technological innovation and contributes to reducing the uncertainty in new product development. However, the pattern provides only very general guidance. For instance, it does not provide guidance on the selection of subjects for technological innovation; it provides only tenuous guidance on the composition of the hardware which is the physical manifestation of an innovation. That is not to underrate the value of the Sappho project at the level of strategic planning in business activity; for those engaged in the practical activity of new product development, however, the Sappho pattern has very limited value. To use an analogy from physical science, the Sappho result is a macro-pattern; to more fully understand and manipulate the 'chemistry' of innovation, patterns need to be identified at other orders of detail. After all, the ultimate commercial success of technological innovation is measured by the profitable sale of distinctive new products with unique selling features. There is a need, therefore, for an extended theory of innovation which provides guidance at other levels besides that of strategic planning. This would enable a variety of factors such as industrial design to be introduced which might otherwise be discarded as inconsequential. By classifying such factors with others at the same order of detail, it may be possible to identify a more comprehensive <u>structure</u> of patterns for success and failure in innovation.

5.3 Communication between Innovator and User

In the models of innovation at the macro-level, the subject is treated as a 'black box'. A user, however, perceives innovation as a particular new product; partly as an object which performs a specific function and partly as an article offered for sale.

The more firmly the object is established as a product-type, the more the user perceives it in terms of its accepted description with the function subsumed in its archetypal image. For example, the user perceives private mechanical transport not so much in terms of the complex electro-mechanical assembly it actually is but rather as a motor-car with an external form and a brand name. Conversely, a user with no knowledge of professional electro-mechanical equipment may perceive what is in fact a linear accelerator as an anonymous machine which performs an obscure technical function. Depending upon the product-type, therefore, appearance has one or more basic roles relative to the user. With established product-types, appearance is part of the visual vocabulary of object recognition and has many uses which are taken for granted in daily life. With new or unfamiliar product-types, appearance is part of the mechanism of comprehension. Uncertainty in technological innovation is therefore reduced if the appearance of a new product is consciously and positively designed to facilitate recognition and comprehension rather than allow it to be the chance result of technical development. This may be stated as a hypothesis:

> In technological innovation, a new product is more likely to be commercially successful if it is visually comprehensible to the user; conversely, a new product which is visually incomprehensible to the user is more likely to fail.

An obstacle to good communication between innovator and user is the former's intense familiarity with the new product acquired during development which is not shared with the latter. There is the same type of obstacle between author and reader; the former writes using a store of knowledge and awareness of the subject unavailable to the reader. The practised author learns to externalise his greater knowledge and awareness to a level appropriate to the needs of the reader. The case study on ophthalmic instruments demonstrates that industrial design can be a medium for better communication between the innovator and the user. When the user has the opportunity to choose between competing products with a given technical performance, the efficacy of this communication between innovator and user significantly influences the choice.

5.4 Design and Company Organisation

The development of the role of design in technological innovation is inhibited by its aggregation with engineering. Models of innovation related to scientific instruments and other science-based products allocate a central role to engineering but make no specific reference to design;[3] it is either assumed or inferred that design is a subset of engineering. The case studies illustrate that in practice design is rarely a discrete activity; rather, it is an adjunct to engineering. It is the implications for organisational control which are significant. In firms, design is typically controlled by the engineering function even though all engineers are not designers.[4] Almost inevitably, therefore, design has come to be regarded as an activity supportive of engineering. Since the preoccupation in engineering - in theory, practice and education - is with technical function and performance, the approach to design is typically dominated by considerations of this nature. However, this study has shown that for success in innovation related to science-based products used for industrial and professional purposes, user considerations must be paramount and they transcend simply engineering considerations. The likelihood of success in innovation will be enhanced if design is allocated a role closely identified with the total needs of the user and discrete from the engineering function. Moreover, when the design function is discrete, the scope for innovation within a given operation is increased. With user requirements continuously in view, small albeit significant improvements in design detail can be initiated which may not be technical in character.

It is apparent from this study that the customary hierarchical organisational structure in British manufacturing firms lessens the potential for successful innovation. Power of decision in firms normally rests not with those who have a proven record of achievement in creating new products but with those who have ascended the organisational structure and are remote from design activity. Moreover, the creative detailing in product design on which commercial success in competitive conditions is dependent is customarily delegated to technicians, whose outlook and achievements are necessarily limited. This is in marked contrast to the organisation of science. The success of scientific advance, in physics for instance, is due to the direct creative participation of the most able and eminent in the field; it is normal for the advances to be the work of leaders, and rests largely upon their ability to conceptualise on the one hand and to both codify and manipulate the complex detail of natural phenomena on the other. The evident benefit to innovation when the principal of a manufacturing firm participates directly in the detail of new product development, e.g. Robert Stephenson, suggests the need for a radical reappraisal of company organisation in manufacture. (cf 2.3).

5.5 Good Taste and Innovation

It is apparent from this study that in certain product categories and where competitive conditions prevail, good taste in design can be a factor for success in innovation. Therefore, where relevant, an innovating firm should aim to be at least as discriminating in design as the most discriminating user of the product. The level of discrimination is likely to vary with the product category or field of application; this is an aspect of market intelligence. The indications are that in the category of scientific instruments used for professional purposes, users have a high level of discrimination, which has implications for product design. For instance, in the case study on ophthalmic instruments, it is evident that the discrepancy between the taste of users and that projected by British manufacturers has been a factor in the decline of the industry. (cf 4.2).

5.6 Innovation, Industrial Design and International Competition

It is evident from this study that international competition adds a further order of complexity to the structure of patterns for success in technological innovation. When an innovating firm has captive markets for its new products or when it has technological supremacy in the markets it serves, the management can with impunity concentrate on the technical facility-versus-product cost equation to reduce uncertainty to an acceptable level of risk. The situation is transformed, however, when a firm is obliged to innovate against a background of international competition under conditions of free trade and comparable levels of technological competence in the rival firms. In these circumstances, it is prudent to assume that in a comparatively short time - within the projected currency of a new product - there is a likelihood that competing products will be launched, providing users with the opportunity to choose between makes which have similar technical specifications. It is evident that in certain product categories, e.g. ophthalmic instruments, when users are able to choose between makes, design strongly influences their choice. Moreover, this influence is strong enough to transcend considerations of loyalty to home-produced goods.

British firms seeking to identify the factors which bring success to Japanese firms should note the close attention given to progressive improvement in the standard of industrial design. There is a tradition of good design within the Japanese culture, notably in fabrics and porcelain, and this is now being applied to engineering products. For instance, it is common knowledge that when Japanese firms first launched private motor vehicles on European markets, the general appearance and detailing were poor compared with the indigenous makes. There is no longer that discrepancy; the design of Japanese cars is now comparable with that of the European counterparts. It is evident that the policy of improving products through design has been extended into categories of scientific instruments.

5.7 Recent Government Initiatives

5.7.1 Since this study began, there have been a number of initiatives by the British government and its agencies which in effect corroborate the findings. Industrial design is now officially recognised as having a significant role to play in economic recovery generally and in technological innovation in particular. The recent government initiatives are summarised below and cross-referenced to the appropriate sections in this study.

5.7.2 On 25th January 1982, the Prime Minister invited 70 people to a seminar at 10 Downing Street. The briefing notes describe the occasion as a discussion on product design and market success.[5] The object was to bring together at the highest level politicians, academics, industrialists and designers to air issues of concern and to make proposals for future action. The guest list for the seminar is shown in Table 14. Of the eight individuals listed under the heading 'designers', five are industrial design consultants. In the list as a whole, fourteen individuals are members of the professional organisation, the Society of Industrial Artists and Designers. The seminar dealt with three topics, each with a different chairman: the importance of design (the Prime Minister); purchasing power and its influence on design (the Chairman of the Design Council); preparing for the future (Parliamentary Under-Secretary of State at the Department of Industry and Minister responsible for the Design Council).

The Parliamentary Under-Secretary of State later gave an assessment

TABLE 14. SEMINAR ON PRODUCT DESIGN AND MARKET SUCCESS AT 10 DOWNING STREET : GUEST LIST

Government ministers
Patrick Jenkin, Secretary of State for Industry
John Biffen, Secretary of State for Trade
Nicholas Ridley, Financial Secretary at the Treasury
Kenneth Baker, Minister for Industry and Information Technology
Paul Channon, Minister of State with responsibility for the Arts
William Shelton, Parliamentary Under-Secretary of State at the Department of Education and Science
John Wakeham, Parliamentary Under-Secretary of State at the Department of Industry

Designers
David Carter, DCA Design Consultants
Diarmuid Downs, Ricardo Consulting Engineers
TP Dukes, WS Atkins, consulting engineers
Kenneth Grange, Pentagram
B Hiscock, Fraser Nash, engineering design consultants
Dick Negus, Negus & Negus
Nick Butler, BIB Design Consultants
James Pilditch, AID

Representative bodies
Design Council
Sir William Barlow, Chairman
Keith Grant, Director
Mervyn Unger, Deputy Director

SIAD
Eddie Pond, President
Michael Sadler-Forster, Director
Royal Society of Arts
Ian Hunter, Chairman
Alex Moulton, Master, Faculty of RDIs
Crafts Council
Victor Margrie, Director
Jean Muir
David Mellor

Industry and commerce
Zach Brierly, Z Brierly Limited, engineering design consultants
Terence Conran, Chairman of Habitat
Sir Frederick Page, Chairman and Chief Executive, Aircraft Group, British Aerospace
Peter Lewis, Chairman of the John Lewis Partnership
EC Hewitt, Technical Director of Davy Loewy, heavy capital goods manufacturers
CV Chester-Browne, Managing Director, Vickers Design and Projects
Zandra Rhodes
M Kimberly, Managing Director of Lotus Cars

Universities and polytechnics
David Bethel, Director of Leicester Polytechnic
Professor L Finkelstein, Professor of Measurement and Instrumentation at the City University
Professor JH Horlock, Vice Chancellor of the Open University
Professor Lionel March, Rector of the Royal College of Art
Sir Hugh Ford, Emeritus Professor of Mechanical Engineering at Imperial College

Other notable advocates of design
Viscount Caldecote, Chairman of Delta Metals, and former Chairman of the Design Council
Dr Bryan Lindley, Director of Technology at Dunlop
David Penny, President of the Institute of Mechanical Engineers
John Wesley, Director of the Cranfield Product Engineering Centre
Dr Paul Freeman, Director of the Computer Aided Design Centre
Professor Frank Height, Professor of Industrial Design at the RCA

British Standards Institution
Admiral DG Spickernell, Director-General
Miss GM Ashworth, Secretary

House of Lords
Lord Reilly

Members of Parliament
Marcus Fox, Conservative
Michael Brotherton, Conservative
Christopher Price, Labour
John Lee, Conservative
Jocelyn Cadbury, Conservative
Richard Page, Conservative
Gerry Neale, Conservative

Officials
Department of Industry
Perry Goodman, Deputy Chief Scientific Officer, and head of the branch responsible for relations with the Design Council
AL Thomas, a Principal in the same section
Michael Harrison, Senior Press Officer
Department of Trade
RC Foster, Industrial Adviser
DR Coates, Senior Economic Adviser
Treasury
A Allan, a Principal in Industrial Policy Group
Department of Education and Science
RH Stone, Assistant Secretary, Office of Arts and Libraries
CR Walker, Under Secretary, Further and Higher Education Branch
Cabinet Office
Dr R Nicholson, Chief Scientist
D Wright, Personal Private Secretary to Sir Robert Armstrong
10 Downing Street
Ian Gow MP, Parliamentary Private Secretary to the Prime Minister
Willie Rickett, a Private Secretary to the Prime Minister
Liz Drummond, Press Officer to the Prime Minister
Andrew Duguid, a member of the Policy Unit

Source : Society of Industrial Artists & Designers of the seminar.[6] The government is said to have identified a number of issues on which it is seeking to make progress. Firstly, it will try to persuade British businessmen to adopt a much wider concept of design than they have at present. Many firms could benefit from either a non-executive director with design experience or a full-time director with prime responsibility for design.(cf 4.6). There is also a need for designers with a wider outlook and sufficient understanding of finance and marketing to be capable of full membership of company boards. (cf 2.6). Courses in business studies should - but at present do not - include elements of design. The government's aim is to promote a greater awareness in both designers and non-designers of their relative importance to each other. For incentives, the government is considering assisting firms financially and providing tax relief, using the Design Advisory Service of the Design Council as the gatekeeper. Secondly, Britain trains more industrial designers than any other country in the world yet employs relatively few of them and many work abroad. (cf 2.6). The government believes this is partly because the designers adopt a 'professional' attitude in the sense of being specialist rather than part of a management team. Though designers have an enormous amount to contribute, some wish to distance themselves from the ordinary business world, preferring to be freelance consultants rather than line managers. The government is seeking to persuade industrial design consultants to regard themselves not as a remote profession but as an integral part of industry. The British tax system has so far favoured consultants levied under Schedule D; the government recognises that to attract high-calibre in-house designers, there must be the incentive of comparable tax relief. Thirdly, the government will try to persuade educationalists that design should be taught in schools at the basic level much more than is done at the present time.

5.7.3 In June 1982, the Department of Industry allocated £3 million - £1 million per annum for three years - to enable innovating firms with 60 - 1,000 employees to engage design consultants for up to 15 man days free of charge and for a further 15 days at half-cost. In April 1983, the allocation was increased from £3 million to £10 millions.[7] This Funded Consultancy Scheme is administered by the Design Advisory Service of the Design Council. Apart from its intrinsic value as an aid to design improvement, it is a significant indication of growing support for design in government circles. This stems largely from the Prime Minister, whose latent interest was regenerated at a Schools Design Prize ceremony in 1981. Her enthusiasm gave rise to the idea of the seminar on design at Downing Street at which a series of proposals and actions was established, one of which was the basis for the Funded Consultancy Scheme.[8] By November 1982, funds from the Scheme had been disbursed as follows: 31 projects involving industrial design consultants; 35 projects involving engineering design consultants; 3 projects involving clothing and footwear design consultants.[9]

5.7.4 In December 1982, it was made known that the Department of Education and Science in association with the Design Council had earlier commissioned a research project to identify the skills, knowledge and attitudes industry requires from industrial designers and the extent to which these requirements are being fulfilled.[10] (The inference was that they are not being fulfilled). The research report concludes that neither industrial design nor the training of designers are the greatest obstacles to market success and a high volume of exports. It found that there are five requirements for success: identifying a market opportunity; competitive pricing; quality and performance; delivery; aesthetic appeal. It is suggested that a firm can capture or maintain a market share with adequate performance in all of these requirements; to be really successful, however, it has to be excellent in at least one of them. In all five requirements, British firms were found to be comparable with most overseas competitors but there is an absence of excellence in any of them. The report also concludes that because the present climate in British industry is so anti-cultural, Britain is unlikely to improve its competitive position with design-led innovation.

5.7.5 On 28th September 1983, an exhibition entitled 'Design and the Economy' was opened at the Design Centre by the Secretary of State for Employment and coupled with the simultaneous publication of a study by Rothwell, Schott and Gardiner,[11] sponsored by the Industrial and Commercial Finance Corporation, the London Enterprise Agency, the Scottish Development Agency, and the Welsh Development Agency. The stated purpose of the study is twofold: to present the case for a dramatic improvement in product design and to indicate to senior management the means of achieving the best commercial results from design.

The above study is complementary to this one and on a number of counts both vindicates the approach adopted and corroborates some of the findings. Indeed, Rothwell initiated an exchange of correspondence on the subject during 1982 and in the above study cites the (published) preliminary[12] to this study. Rothwell et al maintain that all the evidence points to poor design and a failure to innovate as the major causes of Britain's loss of both export and home markets. It is stated that though the importance of price factors in market competition is well known, it is less widely recognised that the quality of goods is equally important, accounting for approximately 50% of the trade in many markets. (cf Chap.4). Stress is laid on the importance of case studies in which factors for success in innovation and design are discussed in relation to the experience of particular firms and their products; if the relative decline and economic difficulties of the British economy are to be overcome, it can only be achieved through success by individual firms. It is also stressed that the lessons from case studies may seem obvious; the obvious in theory, however, is not necessarily easy to practise. There is a need for management to look beyond their day-to-day problems and question accepted practices based on conventional wisdom.[13]

A number of specific issues are corroborated by the findings of Rothwell, et al. Firstly, they found that many would-be innovators have produced designs that are technically adequate but which fail to meet the needs of potential customers; determining user needs and satisfying them through good design is at the core of successful innovation.[14] (cf 4.6.8). Secondly, they found that many buyers prefer superior quality goods and do not necessarily allow price to determine their choice; reliability, after-sales service, aesthetic appeal, ease of use, and technical superiority are of prime importance to buyers.[15] (cf 4.2.9). Thirdly, they found that the role design plays in industrial innovation is: translating user needs into a set of functional specifications; translating functional specifications into a functioning device; linking product design to the manufacturing process; making product design user friendly; enhancing reliability; establishing high serviceability in use. They also state that the design and innovation processes are so interlinked as to be inseparable.[16] (cf 4.5.6). Fourthly, they found that though design is essential to the translation into commercial use of even a major technological breakthrough, it is in the subsequent incremental innovations that the influence of good design on competitiveness can most easily be detected.[17] (cf 4.2). Fifthly, they found that though a firm may employ design consultants to assist in the creation of a new product, it also needs in-house design expertise to capitalise on the external contribution. In successful Japanese firms, for instance, those skilled in design are present at all levels in the organisation and the focus of their activity is the satisfaction of user needs.[18] (cf 4.5.6). Rothwell et al also provide another example of the phenomenon identified by the case study on gas chromatographs: to innovate by applying industrial design to existing technology.[19] (cf 4.7.7).

5.8 Epilogue

Finally, this study may be likened to the mapping of virgin territory at the stage when the outlines are being plotted. Others are engaged in this activity in adjacent areas, notably Roy[20] and Walsh[21]. The general features have been delineated, a basis from which the work of producing the contours and other details of the topography may proceed.

THE END

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