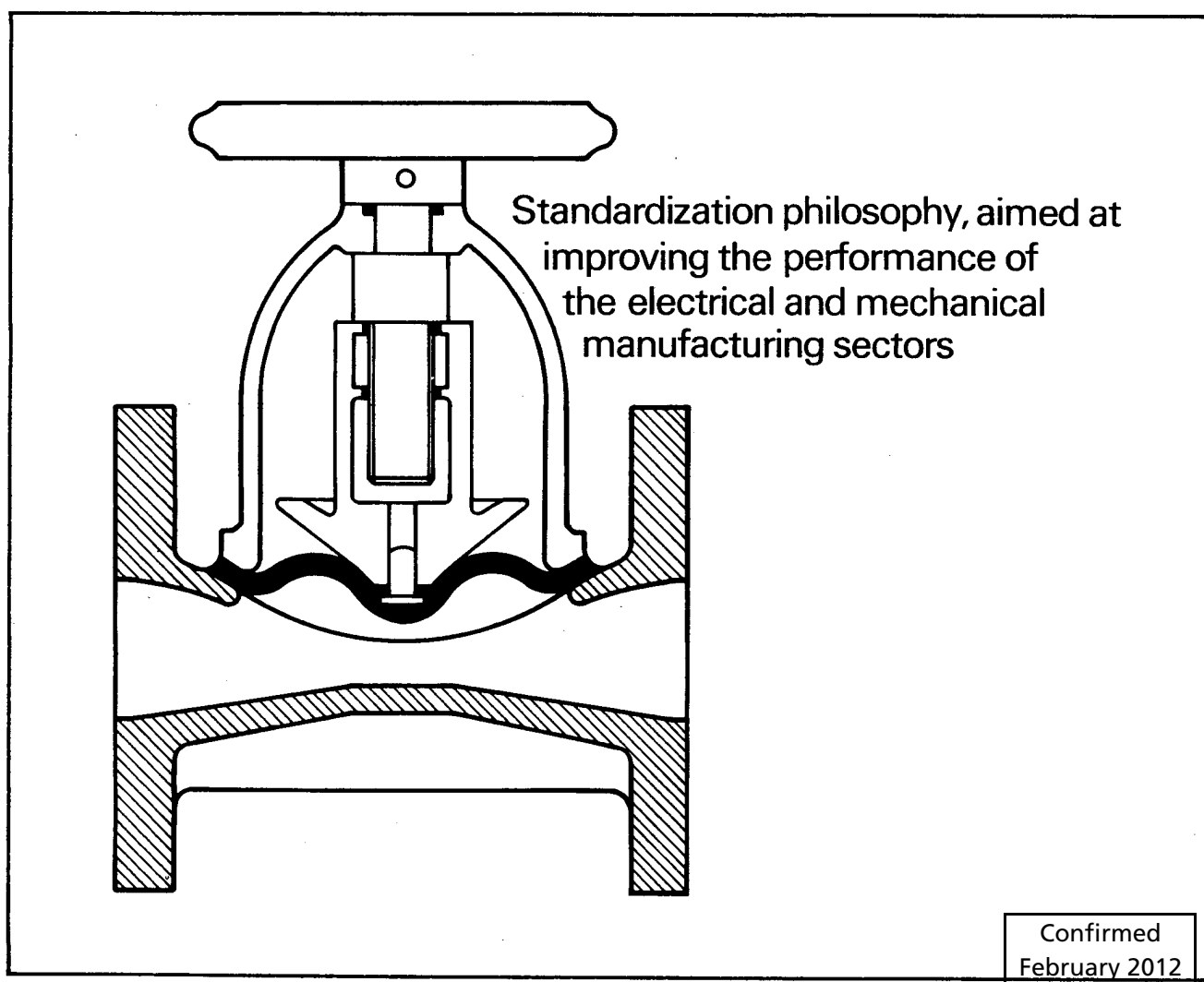


The management of design for economic production



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Foreword to the third edition by the Director General BSI

G B R Feilden, CBE, F Eng, FRS

After the decision in 1965 that the UK would progressively adopt the metric system, BSI initiated the massive task of producing agreed outline programmes for the change in different industries and of preparing the necessary British Standards in metric (SI) units. We began with standards for basic materials and components, all of which have now been published. For the past decade, all new work at BSI has been in SI units.

It soon became clear that the change to metric units gave industry a very important, indeed unique opportunity, to reduce the variety of basic materials and parts that it used. Combined with the opportunities of trade expansion available to us as members of the European Economic Community, the metric change was probably the best opportunity for a new look since the industrial revolution. These opportunities came at a time when trade returns indicated only too clearly that we were lagging behind other industrial nations in our rate of growth and six years after the issue of the second edition of this publication these conditions are still with us.

When Mr Sumner initially suggested to me that a guide should be prepared pointing out the advantages to be gained from taking a fresh look at our industrial practices in the light of metrication, I gave my wholehearted support. The 1973 and 1975 editions of this publication were extremely well received and clearly fulfilled a need. In fact, the author continues to be invited to present papers to numerous institutions, productivity associations and universities in which he has ably and consistently broadcast his message to wider audiences. For British Standards, metrication is indeed a *fait accompli* and this

third edition, whilst retaining the essentials of standardization philosophy, is particularly aimed at improving the performance of the electrical and mechanical manufacturing sectors. The opportunity has been taken to introduce new material on designing for minimum cost, whilst examples of the application of design and standardization philosophy have been retained and up-dated. In addition, the format of the publication has been improved in line with BSI's latest editorial practices.

The UK continues to be faced with both energy and materials crises. The present economic state of our country makes it even more important to apply the approaches advocated by Mr Sumner and his team, to whom we owe a debt of gratitude for the hard work they have put into the original writing and subsequent up-dating of 'The management of design for economic production'. I wholeheartedly endorse the check list for company/organization management given in section eight of this publication and I trust that management will regard the list as somewhat akin to the ten commandments.

As I said in the forewords to both the first and second editions, I commend this publication to management and designers alike as a document to be studied with care and applied with vigour. I believe that it will play a part in helping the UK to improve its economic role in world trade in the last two decades of the twentieth century.



Preface by the author

L Sumner

This publication results directly from a private approach in 1970 to Mr G B R Feilden, then Director General Designate of BSI.

I thought I knew something of the proper approach to the opportunities offered by the change to the metric system and what should be said to engineering management in this context. The control of design processes and the philosophy to be followed were key features, hence my approach to Mr Feilden.

I was by no means confident and told him to 'show me the door' if he thought I was talking nonsense. In fact, he didn't show me the door but installed me as chairman of a small steering panel with instructions to produce this document. My first acknowledgements are, therefore, to the British Standards Institution in general and to Mr Feilden in particular for backing the project.

However, my interest in this goes much further back, to 1959 when, as Chairman of the Naval Manufacturing Techniques Committee, I was involved in an exercise known as 'The cost of accuracy'. I am indebted to Mr A P Peat, then with Baker Perkins Ltd, for producing the first relative cost figures for both materials and machining accuracy. An up-to-date version of some of his work is included in section six.

This work led to more advanced relative cost exercises when an attempt was made to write 'The design rules for economic production and cost control'. Mr R A Head, secretary of the committee, was responsible for coordinating this work which was strongly supported by my then Assistant Director, the late Mr A E Brown. I am particularly indebted to Mr J C Wall, then with Matrix Machine Tools Ltd, to Mr J R Beaton, then Production Director, Brown Brothers Ltd, and to Mr W Balfour, National Engineering Laboratory, not only for the work they did originally for the Naval Manufacturing Techniques Committee, but also for their work under John Wall's chairmanship of a working party of the steering panel to up-date this work, to provide additional information, and to present it in a form suitable for publication. This has, of course, been further up-dated for this third edition and, in particular, contributions have been made by Dr N A Waterman.

All the members of the steering committee, past and present, contributed greatly, even though, in certain instances, some of the work contributed has not been included. These acknowledgements would not be complete without mentioning the help and encouragement that I have received from Mr W H Mayall, formerly of the Design Council, Mr C G Longford, formerly Group Development Director, Newman Industries Ltd and from our untiring Secretary, Mr A J Rayment.

Assistance or permission to use information has also been given by the following:

Mr R F G Morrison, Chairman,
Warren-Morrison Valves Ltd

Mr J A Bachrich, formerly Standardization Manager,
Newall Engineering Co Ltd

Mr W Cowan, formerly Managing Director,
J H Carruthers and Co Ltd

Mr W Turley, Switch Product Manager,
Plessey Connectors Ltd

Mr D R Stewart, Managing Director,
Hytork Actuators

In this, the third edition, the emphasis has changed and although it is pertinent to take advantage of metrication, where this has still to be accomplished, it is of paramount importance that the British manufacturing sector becomes more efficient and greatly increases its ability as a major contributor to the nation's wealth creation. The situation is critical and a marked improvement must be achieved in the next few years if we are to survive as an industrial nation. The Finniston Inquiry into the engineering profession has identified many of the problems but the solutions offered in the form of changed requirements in the education and training of engineers will take a minimum of 15 years to reach fruition, assuming the changes are adopted and are successful. Consequently, it is essential that manufacturing companies help themselves, and this edition is aimed at providing the philosophy, the guidance and the examples to enable this to be achieved. The philosophy must be market-oriented, since efficient manufacture of products that will not sell is self-defeating. Further, if we are to achieve the quick results needed, we must concentrate on improving our current knowledge and the performance and quality in areas of established technology. Advanced technology invariably increases both risk and time. Whereas due account must be taken of this, it only affects a small proportion of companies in terms of manufacture and is essentially long-term.

Clearly, two kinds of engineer are required for this philosophy to succeed and both must be capable of being simply effective. One who can be simply effective in design and the other who can be simply effective in the management of manufacture.

We require engineering designers who can be creative and produce viable design solutions whilst obeying the disciplines of the philosophy, thus giving advantages to the engineering manager for more efficient performance in all the stages that follow.

Above these two kinds of engineer will be the exceptionally effective engineering manager who has the right personal qualities and who is knowledgeable across the wide spectrum of marketing, design manufacture and in a service support.



The management of design for economic production

Standardization philosophy aimed at improving the performance of the electrical and mechanical manufacturing sectors

Gestion des études en vue d'une production économiquement efficace principes de normalisation visant à améliorer les résultats des branches de la construction électrique et mécanique

Die Behandlung der Gestaltung der wirtschaftlichen Fertigung
Normungsgedanken zur Leistungssteigerung auf den Gebieten der Elektrotechnik und Mechanik

0. Introduction

This guide is concerned with making the most efficient use of resources. For that reason it is aimed at both engineering management and designers.

It is a well-known saying that nothing is as constant as change. Change may be necessary because of technological advance, or be compelled by the forces of the market place. Whatever the causes, the art of management in a progressive industry is largely the art of exploiting change to make a profit by continually optimizing the match between resources on the one hand and the needs of the market place on the other. The former must be used as economically as possible, and the latter satisfied as fully as possible; it is in this optimization process that, from the point of view of running an efficient and profitable business, standardization has a major role to play.

It is often said that standardization is inimical to high performance and progress. Anyone holding that view has a fundamental misconception. **Standardization, in its broadest sense, is the discipline of using the minimum number of parts for the maximum number of purposes, produced by the most economical manufacturing processes, of the appropriate quality to give reliable and acceptable performance at minimum (whole life) cost.**

With this broad definition, standardization becomes a very potent tool in producing effective, adaptable products with the maximum economy. It is an essential tool for use when businesses diversify in order to spread the risk over a wider sector of the market, since, if control is not applied, the increased variety of components can undo the beneficial effects.

The application of standardization philosophy will give economies in money, manpower and time, and will lead to increased competitiveness. To achieve this, the threefold aim should be to minimize the number of products to satisfy the market, the number of different parts to satisfy the range of products, and the number of different processes and materials to produce the range of parts.

The economic use of resources does not necessarily mean using less material in a product. In an example of rationalization, the small Triumph saloon cars, Toledo, 1500 and Dolomite were given the same size boot, and the smaller boot of the older Toledo gave place to the common larger one. As a result, it is understood that

the reduction in cost per vehicle was over £100. Thus, unnecessary variety led to the uneconomic use of resources.

'Putting it another way, we have invented a name for a new 'ology', we call it 'totology', defined as the technology for optimizing the overall performance of a manufacturing company or sector by minimizing the number of products, component parts, manufacturing processes and materials consistent with satisfying the reasonable present and foreseeable requirements of the market place'. (See reference 1.)

The standards publications referred to in this document are as follows.

- BS 436 Spur and helical gears
Part 2 Basic rack form, modules and accuracy
(1 to 50 metric module)
- BS 970 Wrought steels in the form of blooms, billets, bars and forgings
- BS 1134 Method for the assessment of surface texture
Part 1 Method and instrumentation
Part 2 General information and guidance
- BS 1400 Copper alloy ingots and copper and copper alloy castings
- BS 1449 Steel plate, sheet and strip
- BS 1452 Specification for grey iron castings
- BS 1470 Wrought aluminium and aluminium alloys for general engineering purposes — plate, sheet and strip
- BS 1474 Wrought aluminium and aluminium alloys for general engineering purposes — bars, extruded round tubes and sections
- BS 1490 Aluminium and aluminium alloy ingots and castings
- BS 2789 Iron castings with spheroidal or nodular graphite
- BS 2870 Specification for rolled copper and copper alloys: sheet, strip and foil
- BS 2874 Copper and copper alloys. Rods and sections (other than forging stock)
- BS 3692 ISO metric precision hexagon bolts, screws and nuts
- BS 4168 Hexagon socket screws and wrench key metric series

BS 4360	Specification for weldable structural steels
BS 4500	ISO limits and fits Part 1 General, tolerances and deviations
BS 4608	Copper for electrical purposes. Rolled sheet, strip and foil
BS 4891	A guide to quality assurance
BS 5750	Quality systems
BS 5760	Reliability of systems, equipments and components Part 1 Guide to reliability programme management
PD 3542	The operation of a company standards department
PD 6481	Recommendations for the use of preferred numbers and preferred sizes
PD 6489	Guide to the preparation of a company standards manual
DD 13	Guide on the assessment of reliability of engineering equipment and parts
DD 16	Guide on the reliability of engineering equipment and parts. Practical examples of DD 10 to DD 15

Section one. The nature of design and costs

1.1 Design

The following material extracted from an editorial in 'Machinery and production engineering', January 1978 by A Barker described, under the title 'Some sacred cows to the slaughter', the experience of a British company which bought a similar USA company in the same line of business.

'Although both were comparable in all important aspects, the US overall performance in general, and profitability in particular, were superior. A detailed study to compare the two companies was an obvious move. In the process, a number of sacred UK cows were led quietly to the slaughter.

The US company must use more up-to-date plant and equipment, it was initially thought. Not so. A higher number of its machines were more than 21 years old, and a lower number were less than 10 years old, than in the British plant. The US company must enjoy a larger and more standardized home market. Not so. Diversity of its products was much the same as in the UK and, if anything, a little worse from the production standpoint. The US workers must put more effort into their hours than those in the UK. Not so. If anything they put in less effort. The US company must be using a different, and more favourable, pricing structure. Not so. It sells its products in world markets at roughly the same price as those made by the UK company, pays its workers approximately twice as much, and still makes more profit.

Four sacred cows believed to account for many of the difficulties of UK manufacturing companies are, therefore, already in the abattoir. Lack of investment in new plant and equipment, lack of a standardized home market, lack of individual worker effort, and disproportionately high wage rates. So what did the survey reveal? First, for comparable products the man-hour element in the US ranged from 70 % to only 48 % of that required in the UK.

A major factor here proved to be 'design for production'. Product designs are continually reviewed from this standpoint, to reduce the number of man-hours required to make them.'

Perhaps this example gives a clue to the problem: design. It is clear that, while all products are aimed at performing particular requirements, it may also be possible to cater for additional requirements without detriment to any particular one. Additional requirements may be catered for through the control of the disposition and make-up of the elements of a product. Consequently, all requirements should be known or anticipated at the formative stage. The word 'requirements' here covers in particular functional needs, and in general such things as quality, reliability, safety, maintainability and a good appearance.

Acceptable levels for all these requirements are necessary at minimum cost. Almost any inter-relationship of product requirements will produce some requirements that tend to augment each other and some that conflict and lead to the well-known statement that 'design is a process of compromise'.

In order to determine whether requirements conflict or augment each other, all the relevant circumstances should be studied carefully. These may be collected into two broad categories: first, the product characteristics determined by customers' operating requirements, dependent upon thorough market analysis; second, the manufacturing requirements with the addition of purchasing, storage and distribution activities as well as the actual processes of manufacture.

One word, cost, reaches right across the second category and indicates the framework within which customers' demands must be met. Clearly, while the excellence of a product will depend upon how well all requirements have been satisfied, it is the superior differences between this product and competing products that may encourage customers to buy. In many cases today, these differences seem slight and have very little connection with basic performance requirements, but they cannot be ignored.

Managements are therefore faced not just with defining all objectives, but also with deciding their relative importance according to agreed market strategies.

The characteristics that determine the nature of a product can be summarized as follows.

- All product functions must be known or anticipated because all are related.
- Conditions that influence costs, i.e. those arising not just when making the product, but also when operating the entire management system, act as a framework within which all product functions must be satisfied.
- The relative importance of each product function must be known, especially in highly competitive markets, because it is the difference between these functions and those of competing products that help to decide sales.

The conditions given in (a), (b) and (c) emerge from the study of the nature of products. They may well be described as the 'static' approach, but they do not meet all the conditions in which good design work involving the philosophy of standardization will flourish. There is also the 'dynamic' approach, which takes account of the forces acting to cause change and the effect of change on the character of the product.

Two recent forces of change were the opportunities of trading in European markets and the opportunity of a fresh start using the metric system. Other forces, such as technological advance, new production methods and feed-back from manufacturing and field experience, create pressures that managements cannot afford to ignore. Neither can they ignore the element of resistance. Almost always there is a resistance to change within an organization due to conservative attitudes that undoubtedly exist. This reluctance, however, should not be overstressed. A number of issues must be faced. The investment required to create change, whether for initial development or for modifying production procedures, tooling and so forth, is a major element of resistance. Existing material and spares stocks can be additional resistant elements. Customers themselves shy away from change.

These issues should be tackled realistically and objectively because reluctance to change is often based on assumptions rather than on realistic estimates. Estimates of the investment required to effect change should be balanced against those of the return it offers.

The assessment of customers' conservatism cannot be properly weighed unless the influence of sales techniques both by the company and by competitors is taken into account. In short, it is no good in any situation to sit back and say that nothing can be done. The one constant factor in industry is that change is inevitable, but it has to be controlled by careful evaluation and it must be anticipated wherever possible and kept under control.

Ideas and innovations are capital upon which the future prosperity of a company may depend. It has been said that good inventions are simple solutions to what have so far been complex problems. However, no one can produce a simple solution unless he is aware of the problem that requires solving. Hence it is necessary to ensure that creative people are properly directed in their efforts and that the feed-back of problems to them is carefully filtered, so that they can concentrate on just a few highly important areas at a time.

It is essential to have an efficient means of recognizing unnecessary change at the earliest stages and to prevent it from going any further. It is also important to recognize that time will lapse between the point where a change begins and the point where it emerges in the changed product. Therefore all the static approach characteristics should be based upon circumstances obtaining when the changed product ultimately emerges.

Neither of the foregoing simple approaches actually gives rise to new product concepts. However, through recognizing the need for new concepts and encouraging their evaluation, enlightened management can promote them, provided that the entire company is working together to the same end. Marketing, design production, finance and buying departments must play their part and must be controlled if the approach is to succeed. Management must encourage close liaison between departments and see that the whole company contributes to the assessment made. New concepts do not just happen; they depend on a wide variety of inputs, such as marketing, production and cost data, technological development, details of competitors' achievements and even apparently unrelated happenings that have been found by experience to influence or forecast events in the market under consideration.

Hence there must be a 'feed-forward' from all departments of a company so that new concepts can be encouraged and

evaluated, and a 'feed-back' not only from all departments of a company but also from the customer's experience. There must be a constant evaluation of the situation throughout the life of the product, not just during all stages of development. As product users become more cost conscious, the 'whole life cost'* of the product will become the important factor and the initial cost will become less important.

A small but important point is that items that are 'common user' must be clearly shown as such and not be given special drawings or titles that would make them special-purpose spares.

1.2 Costs

Product costs only originate in design and the designer has a prime responsibility to ensure that the product gives optimum value for money. The irreducible cost of the product is determined by the designer. A poor design decision may commit a company to many years manufacture of a design which would have been more profitable had the decision been better conceived. Cost is just as much an attribute of the design specification as is performance, appearance, reliability, life, safety, etc., and is an essential factor to be satisfied by the optimum design solution.

A design that fails to meet its cost specification is no better than one that fails to satisfy its performance requirements. Furthermore, when all other factors are equal, the decision by the customer whether or not to buy a product is largely determined by its cost.

Total product cost is the addition of manufacturing cost and selling cost and is shown graphically in figure 1. It can be shown in tabular form as comprising:

Direct materials	recognizable in the finished product
+ Direct labour	efforts recognizable in finished product
+ Overheads	indirect material and labour expense
+ Product introduction costs	tooling, test gear, technical support, excess materials/labour
+ Sales and administration	marketing, servicing, warranty

Total production cost is not constant but varies in direct relationship with technical merit (quality), and any shift in product quality is reflected in total product cost.

For example, if product quality falls there will be a rise in selling costs. The sales force will need to put more effort into their dealings with customers who may be reluctant to buy a product that does not come up to their expectations, even though the quality of that product may still be within its general specification. More complaints lead to more manhours from the marketing and servicing sections of the company. There may be a loss of goodwill which can only be retrieved by extra expense on special discounts, replacements, improved servicing arrangements, etc. All these non-standard expenses reduce overall profitability, but they are necessary if the low quality product is not to permanently damage future business prospects.

*Whole life cost is the first cost plus maintenance and logistic support cost during the product's life minus its disposal value.

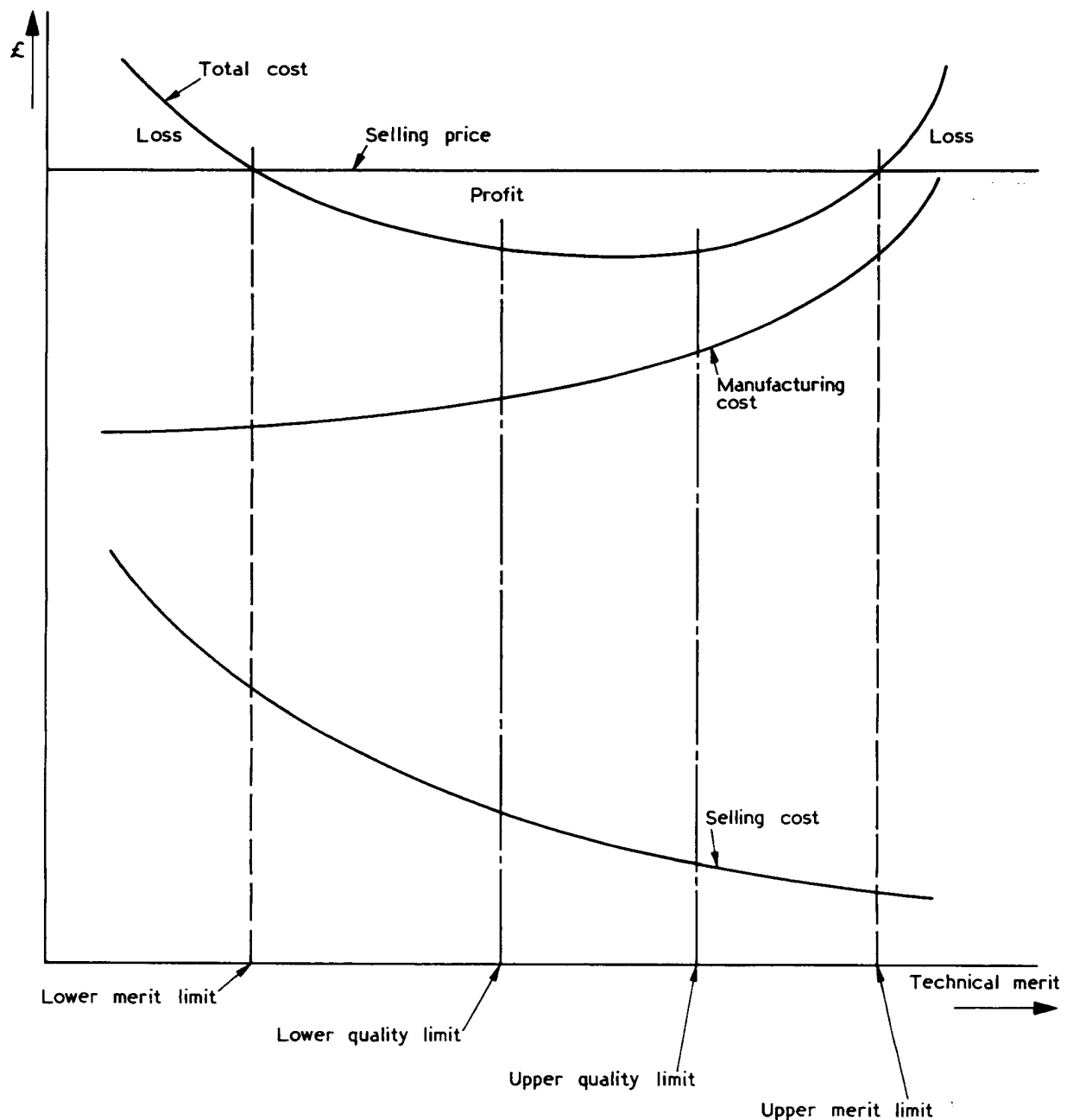


Figure 1. Graph illustrating total product cost

Alternatively, if product quality is allowed to rise unchecked there will be a rise in total cost due to sharply increasing manufacturing expense. An ill-considered increase in quality standards by designers or manufacturing personnel can result in completely acceptable components being scrapped, or sent for rework, quite unnecessarily. A dozen such marginal shifts of quality in a multi-component product will quickly erode the profit margin and produce a total cost greater than the product selling price.

The essence of good design must be the provision of optimum value within the product specification. Any excursion beyond the upper and lower limits of technical merit will rapidly turn a situation of profit into one of loss. Within these limits there must be upper and lower quality limits set to maximize the profit from the product.

Section two. Design, standardization philosophy and management

2.1 Design and standardization philosophy: the economical use of resources

This section enlarges upon the necessity to match the economical use of resources with the needs of the market place.

Firstly, what are these resources? In the broadest terms they are concerned with the deployment of capital and labour, of material and production plant, of design development and marketing which all aim at attracting customers and satisfying their needs. If these needs do not continue to be satisfied, or if a competitor satisfies them better, then the efficiency with which the resources are used is relevant only in so far as it affects prices. The forces of the market place will dictate a rapid change.

Apart from first cost, a customer considers such factors as reliability, the economics of logistic support (spares and ease of maintenance), the adaptability of the product to changed operating requirements, adequate quality level and so on. Thus, for the manipulation of resources, whole life costs must be taken into consideration.

In manipulating resources one can easily identify a number of ideal situations: high production levels to utilize economics of scale, simplicity of manufacture, having the least possible capital tied up in stores, maintaining minimum design and development costs. Equate these situations with those factors high on a customer's list of purchasing priorities, which include first cost, reliability and economics of logistic support, and one major objective for making change profitable is evident: cost effectiveness.

Standardization is the result of the compromise between the opposing forces of customer demand and economic necessity. Consequently, it is now a prime requirement in economic design. Further, it must be a principal aim carried right through a company's operation structure, from boardroom to work-bench.

This fact may be underlined if one looks at a company's objectives from a slightly different though still connected point of view. Management must be concerned constantly with adapting resources to take account of the foreseeable needs of the market place. Obviously resources are not being used economically if they have to be readjusted for each individual demand that is made upon them.

An efficient management tries to regularize procedures and develop set techniques that may be called into play quickly and without fuss. In other words, it must aim at standardization.

In the manufacturing industry this aim depends upon the way in which the products are designed. Unnecessary design variations automatically cause unnecessary variation in the use of production resources, in the purchase and storage of materials and components, and indeed in managerial and design work. Since variations may have crept into a company's products and procedures over a period of years, they are not always easily eliminated unless a significant external influence is brought to bear, e.g. metrication or the need to meet requirements more economically to survive.

'In following a standardization philosophy approach, there is a danger that products might be produced which are too 'general purpose' in their concept to fill a single purpose well. There are two aspects here. One is that the approach demands engineering judgement. Necessary variety is allowed. It is unnecessary variety which must be prevented. The second aspect is that it makes greater demand on designers, who must accept the discipline which this approach imposes and produce a solution which does not inhibit the design.' (See reference 1.)

It is essential that the board of directors of a company establish their product policy, together with procedures aimed at the most economical use of resources consistent with meeting market requirements as fully as possible. To cite an example, Mr G N Bowman-Shaw, Chairman of the Lancer-Boss Group manufacturing fork lift trucks, considers it to be the responsibility of the Board of Directors to lay down the product policy of the company. They decided their future policy in 1966. Two of the key points of their policy were that they were aiming at the upper quartile price range and that the smallest truck

would have a lift capability of 2 tons. They decided that there would be a basic standard truck for each capacity and that variations in requirements must be met by 'add-on' equipment. Because they realised that 'add-on' equipment might not look either right or attractive, they budgeted to employ a stylist to cater for this.

Their policy was reasonably successful until Japanese fork lift trucks were imported in 1972. The challenge was met by introducing a smaller 1 ton capacity truck at the bottom end of the 'upper quartile' price range of products. Then, by putting the prime mover of the 1 ton model into the next larger truck and so on up the range, a new range of cheaper trucks was created without introducing a single major new component or changing the logistic support requirements for the firm's products. This group of companies continues to be highly successful and has recently won its third Design Council Award.

'In general, the management aims should be to ensure that an approach is adopted which includes the following.

1. Ensuring that new parts or sub-assemblies are not introduced when existing ones can be used.
2. Breaking down the design in such a manner that, if new design is necessary, it is not just 'special for purpose' but is likely to have future 'common user' potential.
3. Controlling the number of parts, the selection of materials and processes and keeping all of them to a minimum number.
4. Using creative techniques to ensure that the disciplines of standardization philosophy do not inhibit the design.

The combined effects of this approach sustained over a period of time are bound to have a marked and beneficial effect on the overall performance of a company.' (See reference 1.)

2.2 Standardization philosophy in design

Both the static and the dynamic approaches already mentioned in 1.1 raise questions that managements must ask and answer in relation to standardization philosophy in design. The approach and character vary for different types of products and companies, but no company should think that standardization philosophy cannot be applied to their products and to the processes by which they are produced.

An example is given in 3.3 showing that the maker of one-off equipment can introduce standardization philosophy just as effectively as the maker of large quantity products where a standardization approach appears obvious. The sector comprising 80 % of the British electro-mechanical industry, where a high variety of products are normally produced in short to medium production runs, is most likely to derive the greatest benefits from a standardization approach.

The theoretical absolute limit of standardization is achieved when a company makes a product in which all components are identical and are all produced in an identical manner. However, in product design this ideal situation cannot be reached. There are many products that, having similar functions, must be built in a range of sizes or capacities, while other products that may have a generic similarity perform different tasks. In the first category come such products as motors, pumps, and valves. In the second such products as machine tools, contractors'

plant and electronic equipment. Finally there are products that are dissimilar in character but may contain common features, like constructional techniques, or bought-out components or assemblies.

Variations in products are obviously not being created by manufacturers out of sheer perversity. They arise from real efforts to satisfy customers. Consequently, when given the opportunity to begin anew, the product should be designed and broken down into its elemental components or assemblies in such a way that there is

- (a) **the maximum possibility of multiple use for the elemental components or assemblies; and**
- (b) **maximum flexibility in meeting customer requirements and likely future requirements.**

2.3 The 'building block' principle

The building block principle is now becoming noticeable in some industries. This consists in developing reliable standard components and auxiliaries that have been fully evaluated and documented.

For example, building block concepts have, in conjunction with technical developments, produced the printed circuit board in electronics. The application of standardization philosophy to components and assemblies implies standardization of material purchasing and subsequently that of production processes. Assemblies of parts also become standardized. But the fresh start will not and cannot be simultaneous in all companies and sectors of the engineering industry. It is almost always more advantageous to buy in something that exists and is of known cost, reliability, quality, etc., and that is 'common user', than to design something specially and manufacture it oneself.

There is one example, not British, where two competing internal combustion engine companies agreed to produce completely common engines except for the cylinder head arrangement. Each manufacturer fitted the cylinder head of his own particular design and the result was two ranges of product with over 90 % common parts and with differing performance characteristics to meet both market requirements. The economics of this approach are obvious.

What is needed is a common philosophy among companies as they make the change to designing in metric units. If a suitable part exists, it should be used. If not, it should be designed in such a way that it can be used in other designs. Wherever possible, common components should be incorporated in new designs. Data banks for design selection purposes should be built up on an industrial basis, in which case a classification and codification system must be used to classify components and assemblies by their design characteristics in order to give a quick, efficient service to designers. At first sight trade associations would probably be suitable bodies to sponsor the data banks but there would still be the problem of ensuring that items in one industry were not overlooked, where appropriate, in another.

However, this is preaching the gospel of perfection. Even if data banks are built up on a company basis only, a tremendous amount can be achieved to ensure that the minimum number of parts are used for the maximum number of purposes since in most industries it is fairly clear which items are or can be commonly supplied and which items cannot.

*Beginners all-purpose symbolic instruction code.

Probably the right approach at trade association level would be to carry out commonality studies so that member companies could be made aware of areas likely to be fruitful.

Resources are not being used economically if they have to be manipulated for each and every demand that is made on them, and the threefold theme should be:

- (a) **to have the minimum number of products to satisfy the market;**
- (b) **to manufacture the minimum number of different parts to satisfy the range of products;**
- (c) **to maintain the minimum number of different processes and materials to produce the range of parts.**

2.4 Metrication and international standardization

Although the fact that we export the majority of our products to countries using the metric system was one of the main reasons for deciding to adopt the metric (SI) system in the UK, another extremely important reason is international standardization. The International Organization for Standardization (ISO) has issued some 5000 standards, the great majority of which use metric units, and it is estimated that there will be over 10 000 publications available by the end of the 1980s.

Note, however, that the UK is not merely going metric, but also going international. Consequently it is the national or international standards representing the most advanced state of the art that must be pursued regardless of the units in which they are formulated.

'If these standards happen to be based on imperial units, the proper time to change is when a metric standard of equivalent worth and status is available. There is no excuse for departing from an existing standard to an inferior one of lower status in the metric system. If one does this, then all one does is create new non-standard products in the metric system! In effect, the result will be several abortive changes instead of one effective and, as far as is possible (taking account of technological advances), permanent change.' (See reference 1.)

2.5 Design facilities : use of microcomputers

The microcomputer has two very significant advantages over the mini- or mainframe-computer. Firstly, due to its low cost, small size and extreme portability, it is able to be sited directly at the point of design, cutting out time-consuming travel to and from a terminal. Secondly, it is totally self-contained and completely independent of central data storage units, air-conditioned facilities, technical support groups etc., and also does not rely upon time-sharing. It is always on-line and can be left marking time for long periods without holding up any other person's work and without the designer constantly being reminded that the computer is waiting for further input. This removes any feeling of pressure which may interfere with the concentration of the designer and allows him to devote his entire effort to the problem in hand.

In the design office the personal computer has the following principal uses.

- (a) *Data manipulation.* Most microcomputers have an on-board BASIC* interpreter which simplifies interactive communication between designer and machine.

Software can be easily developed by the designer, or suitable programmes can be acquired from commercial sources. The machine is particularly useful in dealing with complex calculations, especially those where repetitive runs with several interdependent variables are involved; typically, spring calculations where wire size, coil size, active turns, forces and deflection need to be varied in order to establish the availability of standard components. Other applications include gearing, bearing selection, discretionary decision making, critical path project planning, tolerance worst-case analysis, solution of differential equations, vibration analysis, and many more.

(b) *Data storage and retrieval.* The microcomputer backed by a floppy disc drive gives the designer immediate access to a veritable mountain of data which he can add to or update as the necessity arises. By interlinking a number of microcomputers within a design office it is possible to build a data bank that can be sampled at will by any individual machine. Typical contents may include physical properties of materials, cost information, proprietary component availability, standard design data, historical records of current and past projects, preferred sizes of stock materials, etc.

(c) *Pictorial presentation.* The average microcomputer is relatively inefficient as a producer of orthographic drawings and these are best produced in mini- or mainframe-machines. However, it can present quite acceptable graphical information in the form of histograms, dependent variable displays, statistical distributions, trends, etc.

The words computer aided design (CAD) conjure up visions of large units producing working drawings and details from the computer with hardly any human intervention; this is perhaps true of some of our larger and wealthier organizations, but it is not the province of the microcomputer. Nevertheless, as described in (a), (b) and (c) above, the microcomputer has a very significant contribution to make to CAD, and that contribution can be made immediately and at very low cost outlay. It is imperative that design offices embrace the 'chip' now in order to remain competitive and perhaps to gain an edge on competition by the intelligent development of new software material.

2.6 An example of variety prevention : preferred shaft sizes, limits and fits

The standards engineer should give serious consideration, based on his own company products, to providing for his design staff such information as the limited range of preferred shaft and housing sizes based on PD 6481. In preparing these, the number of different limits and fits for selected shaft and housing sizes should be reduced as far as possible.

As a guide to the design engineer, tables 1 to 5 give typical types of fit used in general engineering applications. It is appreciated that different industries may require different limits but the examples given illustrate the type of guidance that can be given to designers, thereby saving detail draughtsmen's time in having to work out the limits each occasion they are applied. The result will be a saving in the following.

- (a) the variety of bar sizes to be stocked;
- (b) the associated tooling required for producing both shafts and holes;
- (c) inspection and gauging equipment;
- (d) the variety of associated accessories, i.e. bearings, oil seals, etc.

2.7 An example of variety prevention : common-user components

A simple example, amongst a variety of common-user components, is machine screws and bolts, from which it is possible, with the introduction of the ISO metric thread, to limit the designer's choice to select list of preferred sizes. A typical example is shown in tables 6 and 7.

It is appreciated that each different type of industry may require its own particular table but the benefits accruing from the prevention of unnecessary variety have a considerable economic impact across the whole of industrial design.

This type of approach, which can be supplemented by the use of code numbers for each part, can easily be adapted for other common-user components which, as well as making economic sense, guide the designer into using variety prevention philosophy.

Table 1. Shaft fits: close slide g5, close running f6, with holes H6

Nominal size		Holes	Shafts			
		Tolerance	Close slide, g5		Close running, f6	
		H6	Shaft tolerance	Extremes of fit	Shaft tolerance	Extremes of fit
Over	Including		g5	g5, H6	f6	f6, H6
mm	mm	mm	mm	mm	mm	mm
3	6	+ 0.008 - 0	- 0.004 - 0.009	+ 0.017 + 0.004	- 0.010 - 0.018	+ 0.026 + 0.010
6	10	+ 0.009 - 0	- 0.005 - 0.011	+ 0.020 + 0.005	- 0.013 - 0.022	+ 0.031 + 0.013
10	18	+ 0.011 - 0	- 0.006 - 0.014	+ 0.025 + 0.006	- 0.016 - 0.027	+ 0.038 + 0.016
18	30	+ 0.013 - 0	- 0.007 - 0.016	+ 0.029 + 0.007	- 0.020 - 0.033	+ 0.046 + 0.020
30	50	+ 0.016 - 0	- 0.009 - 0.020	+ 0.036 + 0.009	- 0.025 - 0.041	+ 0.057 + 0.025
50	80	+ 0.019 - 0	- 0.010 - 0.023	+ 0.042 + 0.010	- 0.030 - 0.049	+ 0.068 + 0.030
80	120	+ 0.022 - 0	- 0.012 - 0.027	+ 0.049 + 0.012	- 0.036 - 0.058	+ 0.080 + 0.036
120	180	+ 0.025 - 0	- 0.014 - 0.032	+ 0.057 + 0.014	- 0.043 - 0.068	+ 0.093 + 0.043
180	250	+ 0.029 - 0	- 0.015 - 0.035	+ 0.064 + 0.015	- 0.050 - 0.079	+ 0.108 + 0.050
250	315	+ 0.032 - 0	- 0.017 - 0.040	+ 0.072 + 0.017	- 0.056 - 0.088	+ 0.120 + 0.056
315	400	+ 0.036 - 0	- 0.018 - 0.043	+ 0.079 + 0.018	- 0.062 - 0.098	+ 0.134 + 0.062

NOTE. In extremes of fit + = clearance, - = interference.

Table 2. Shaft fits: light drive k5, push h5, with holes H6

Nominal size		Holes	Shafts			
		Tolerance	Light drive, k5		Push, h5	
		H6	Shaft tolerance	Extremes of fit	Shaft tolerance	Extremes of fit
Over	Including		k5	k5, H6	h5	h5, H6
mm	mm	mm	mm	mm	mm	mm
3	6	+ 0.008 - 0	+ 0.006 + 0.001	+ 0.007 - 0.006	+ 0 - 0.005	+ 0.013 - 0
6	10	+ 0.009 - 0	+ 0.007 + 0.001	+ 0.008 - 0.007	+ 0 - 0.006	+ 0.015 - 0
10	18	+ 0.011 - 0	+ 0.009 + 0.001	+ 0.010 - 0.009	+ 0 - 0.008	+ 0.019 - 0
18	30	+ 0.013 - 0	+ 0.011 + 0.002	+ 0.011 - 0.011	+ 0 - 0.009	+ 0.022 - 0
30	50	+ 0.016 - 0	+ 0.013 + 0.002	+ 0.014 - 0.013	+ 0 - 0.011	+ 0.027 - 0
50	80	+ 0.019 - 0	+ 0.015 + 0.002	+ 0.017 - 0.015	+ 0 - 0.013	+ 0.032 - 0
80	120	+ 0.022 - 0	+ 0.018 + 0.003	+ 0.019 - 0.018	+ 0 - 0.015	+ 0.037 - 0
120	180	+ 0.025 - 0	+ 0.021 + 0.003	+ 0.022 - 0.021	+ 0 - 0.018	+ 0.043 - 0
180	250	+ 0.029 - 0	+ 0.024 + 0.004	+ 0.025 - 0.024	+ 0 - 0.020	+ 0.049 - 0
250	315	+ 0.032 - 0	+ 0.027 + 0.004	+ 0.028 - 0.027	+ 0 - 0.023	+ 0.055 - 0
315	400	+ 0.036 - 0	+ 0.029 + 0.004	+ 0.032 - 0.029	+ 0 - 0.025	+ 0.061 - 0

NOTE. In extremes of fit, + = clearance, - = interference.

Table 3. Shaft fits: general slide g7, general running f7, with holes H8

Nominal size		Holes	Shafts			
		Tolerance	General slide, g7		General running, f7	
		H8	Shaft tolerance	Extremes of fit	Shaft tolerance	Extremes of fit
Over	Including		g7	g7, H8	f7	f7, H8
mm	mm	mm	mm	mm	mm	mm
3	6	+ 0.018 - 0	- 0.004 - 0.016	+ 0.034 + 0.004	- 0.010 - 0.022	+ 0.040 + 0.010
6	10	+ 0.022 - 0	- 0.005 - 0.020	+ 0.042 + 0.005	- 0.013 - 0.028	+ 0.050 + 0.013
10	18	+ 0.027 - 0	- 0.006 - 0.024	+ 0.051 + 0.006	- 0.016 - 0.034	+ 0.061 + 0.016
18	30	+ 0.033 - 0	- 0.007 - 0.028	+ 0.061 + 0.007	- 0.020 - 0.041	+ 0.074 + 0.020
30	50	+ 0.039 - 0	- 0.009 - 0.034	+ 0.073 + 0.009	- 0.025 - 0.050	+ 0.089 + 0.025
50	80	+ 0.046 - 0	- 0.010 - 0.040	+ 0.086 + 0.010	- 0.030 - 0.060	+ 0.106 + 0.030
80	120	+ 0.054 - 0	- 0.012 - 0.047	+ 0.101 + 0.012	- 0.036 - 0.071	+ 0.125 + 0.036
120	180	+ 0.063 - 0	- 0.014 - 0.054	+ 0.117 + 0.014	- 0.043 - 0.083	+ 0.146 + 0.043
180	250	+ 0.072 - 0	- 0.015 - 0.061	+ 0.133 + 0.015	- 0.050 - 0.096	+ 0.168 + 0.050
250	315	+ 0.081 - 0	- 0.017 - 0.069	+ 0.150 + 0.017	- 0.056 - 0.108	+ 0.189 + 0.056
315	400	+ 0.089 - 0	- 0.018 - 0.075	+ 0.164 + 0.018	- 0.062 - 0.119	+ 0.208 + 0.062

NOTE. In extremes of fit, + = clearance, - = interference.

Table 4. Housing fits: normal k6, interference M6

Bearing outer diameter and housing bore, nominal size		Bearing outer ring tolerance	Housing			
			Normal		Interference	
			k6	Extreme of fit	M6	Extreme of fit
Over	Including		mm	mm	mm	mm
10	18	+ 0 - 0.008	+ 0.002 - 0.009	+ 0.010 - 0.009	- 0.004 - 0.015	+ 0.004 - 0.015
18	20	+ 0 - 0.009	+ 0.002 - 0.011	+ 0.011 - 0.011	- 0.004 - 0.017	+ 0.005 - 0.017
30	50	+ 0 - 0.011	+ 0.003 - 0.013	+ 0.014 - 0.013	- 0.004 - 0.020	+ 0.007 - 0.020
50	80	+ 0 - 0.013	+ 0.004 - 0.015	+ 0.017 - 0.015	- 0.005 - 0.024	+ 0.008 - 0.024
80	120	+ 0 - 0.013	+ 0.004 - 0.018	+ 0.017 - 0.018	- 0.006 - 0.028	+ 0.007 - 0.028
120	180	+ 0 - 0.018	+ 0.004 - 0.021	+ 0.022 - 0.021	- 0.008 - 0.033	+ 0.010 - 0.033
180	250	+ 0 - 0.018	+ 0.005 - 0.024	+ 0.023 - 0.024	- 0.008 - 0.037	+ 0.010 - 0.037

NOTE. In extremes of fit + = clearance, - = interference.

Table 5. Shaft fits: stationary g6, rotating j5

Nominal size		Bearing bore tolerance	Shafts			
			Stationary		Rotating	
Over	Including		g6	Extreme of fit	j5	Extreme of fit
mm	mm	mm	mm	mm	mm	mm
3	6	+ 0 - 0.008	- 0.004 - 0.012	+ 0.012 - 0.004	+ 0.003 - 0.002	+ 0.002 - 0.011
6	10	+ 0 - 0.008	- 0.005 - 0.014	+ 0.014 - 0.003	+ 0.004 - 0.002	+ 0.002 - 0.012
10	18	+ 0 - 0.008	- 0.006 - 0.017	+ 0.017 - 0.002	+ 0.005 - 0.003	+ 0.003 - 0.013
18	30	+ 0 - 0.010	- 0.007 - 0.020	+ 0.020 - 0.003	+ 0.005 - 0.004	+ 0.004 - 0.015
30	50	+ 0 - 0.013	- 0.009 - 0.025	+ 0.025 - 0.004	+ 0.006 - 0.005	+ 0.005 - 0.019
50	80	+ 0 - 0.013	- 0.010 - 0.029	+ 0.029 - 0.003	+ 0.006 - 0.007	+ 0.007 - 0.019
80	120	+ 0 - 0.013	- 0.012 - 0.034	+ 0.034 - 0.001	+ 0.006 - 0.009	+ 0.009 - 0.019
120	180	+ 0 - 0.018	- 0.014 - 0.039	+ 0.039 - 0.004	+ 0.007 - 0.011	+ 0.011 - 0.025

NOTE. In extremes of fit + = clearance - = interference.

Table 6. Select list of preferred sizes of ISO machine screws: socket head cap screws

(ISO metric coarse, grade 12.9, blue-black or chemical black oxide finish (see BS 4168).)

Nominal length, mm	Nominal diameter						
	M3	M5	M8	M12	M16	M20	M24
8	x						
12	x	x					
16	x	x					
20		x	x				
30		x	x	x	x		
40		x	x	x	x	x	
50			x	x	x	x	x
60				x	x	x	x
80					x	x	x
100						x	x
140							x

NOTE. This is a typical in-house standard to illustrate the measure of rationalization which can be achieved in the range of socket head cap screws.

Table 7. Select sizes of preferred ISO hexagon head bolts

(ISO metric coarse, grade 8.8, dull black finish (see BS 3692).)

Nominal length, mm	Nominal diameter						
	M5	M6	M12	M16	M20	M24	M30
25	x						
30	x						
35	x	x					
40	x	x	x				
50		x	x	x			
60		x	x	x	x		
80			x	x	x	x	
100				x	x	x	x
120					x	x	x
140						x	
160							x
200							x

NOTE. This is a typical in-house standard to illustrate the measure of rationalization which can be achieved in the range of hexagon head bolts.