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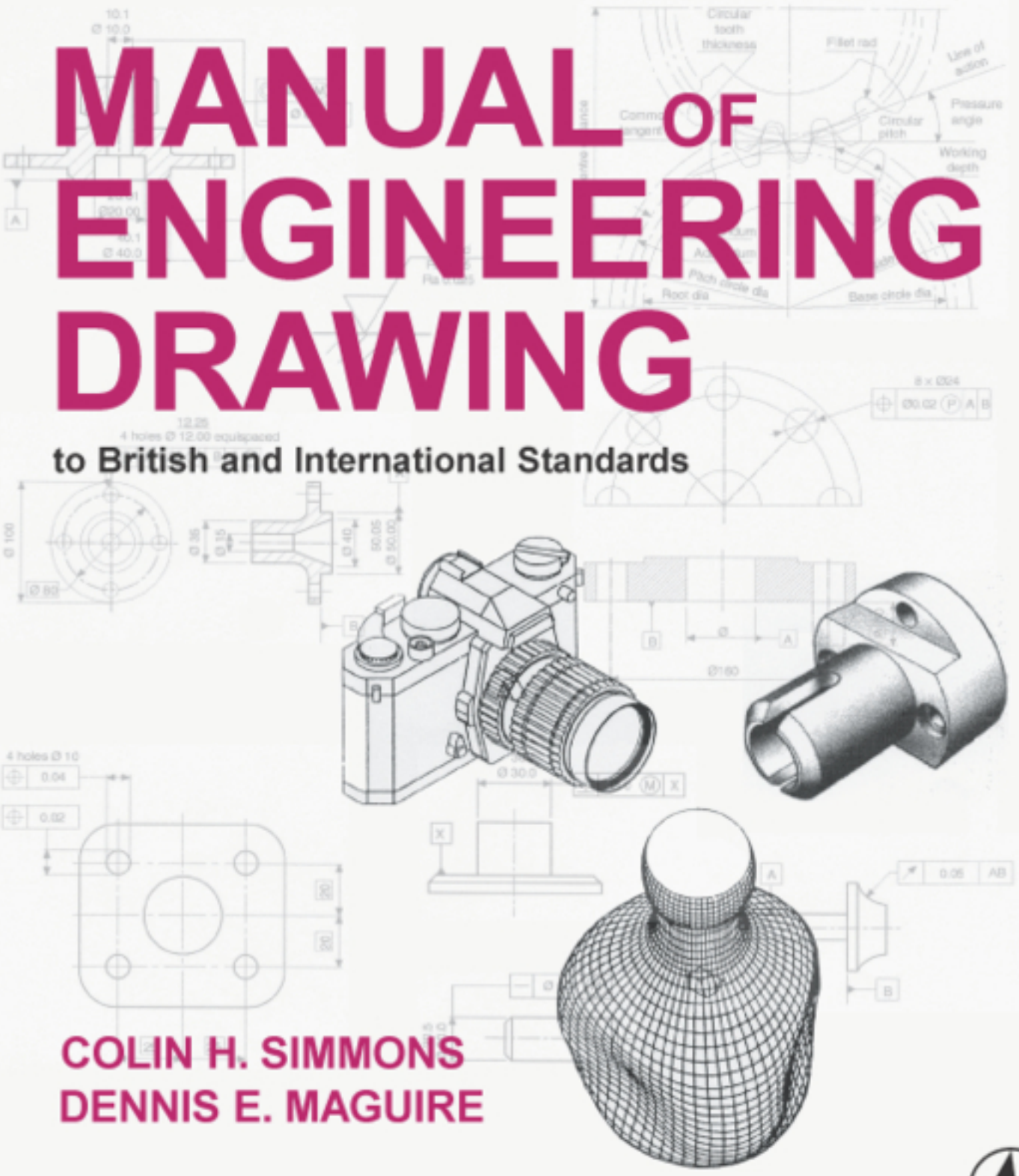
SECOND EDITION

MANUAL OF ENGINEERING DRAWING

to British and International Standards



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Newnes

Manual of Engineering Drawing

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Second edition

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Preface

This latest edition of *A Manual of Engineering Drawing* has been revised to include changes resulting from the introduction of BS 8888. British Standard 308 was introduced in 1927 and acknowledged by Draughtsmen as THE reference Standard for Engineering Drawing. The British Standards Institution has constantly kept this Standard under review and taken account of technical developments and advances. Since 1927, major revisions were introduced in 1943, 1953, 1964 and 1972 when the contents of **BS 308 Engineering Drawing Practice** was divided into three separate sections.

Part 1: General principles.
Part 2: Dimensioning and tolerancing of size.
Part 3: Geometrical tolerancing.

In 1985, the fifth revision was metricated.

During the period 1985–2000 major discussions were undertaken in co-operation with International Standards Organizations.

The general trend in Engineering Design had been that the designer who was responsible for the conception and design of a particular product generally specified other aspects of the manufacturing process.

Gradually however, developments from increased computing power in all aspects of production have resulted in progressive advances in manufacturing techniques, metrology, and quality assurance. The impact of these additional requirements on the Total Design Cycle resulted in the withdrawal of BS 308 in 2000. Its replacement BS 8888 is a far more comprehensive Standard.

The full title of BS 8888 reflects this line of thought.

BS 8888. Technical product documentation (TPD). Specification for defining, specifying and graphically representing products.

It must be appreciated and emphasized that the change from BS 308 to BS 8888 did not involve abandoning the principles of Engineering Drawing in BS 308. The new Standard gives the Designer a vastly increased number of tools at his disposal.

It is important to stress that British and ISO drawing standards are not produced for any particular draughting method. No matter how a drawing is produced, either on an inexpensive drawing board or the latest CAD equipment, the drawing must conform to the same standards and be incapable of misinterpretation.

The text which follows covers the basic aspects of engineering drawing practice required by college and university students, and also professional drawing office personnel. Applications show how regularly used standards should be applied and interpreted.

Geometrical constructions are a necessary part of engineering design and analysis and examples of two- and three-dimensional geometry are provided. Practice is invaluable, not only as a means of understanding principles, but in developing the ability to visualize shape and form in three dimensions with a high degree of fluency. It is sometimes forgotten that not only does a draughtsman produce original drawings but is also required to read and absorb the content of drawings he receives without ambiguity.

The section on engineering diagrams is included to stimulate and broaden technological interest, further study, and be of value to students engaged on project work. Readers are invited to redraw a selection of the examples given for experience, also to appreciate the necessity for the insertion and meaning of every line. Extra examples with solutions are available in *Engineering Drawing From First Principles* using AutoCAD, also published by Butterworth-Heinemann.

It is a pleasure to find an increasing number of young ladies joining the staff in drawing offices where they can make an effective and balanced contribution to design decisions. Please accept our apologies for continuing to use the term ‘draughtsmen’, which is the generally understood collective noun for drawing office personnel, but implies equality in status.

In conclusion, may we wish all readers every success in their studies and careers. We hope they will obtain much satisfaction from employment in the absorbing activities related to creative design and considerable pleasure from the construction and presentation of accurately defined engineering drawings.

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Our final thanks go to our patient and understanding wives, Audrey and Beryl, for all their typing and clerical assistance since we started work in 1973 on the first edition of *Manual of Engineering Drawing*.

Chapter 1
Drawing office management and organization

Every article used in our day-to-day lives will probably have been produced as a result of solutions to a sequence of operations and considerations, namely:

1 Conception
2 Design and analysis
3 Manufacture
4 Verification
5 Disposal.

The initial stage will commence when an original marketable idea is seen to have a possible course of development. The concept will probably be viewed from an artistic and a technological perspective.

The appearance and visual aspects of a product are very important in creating an acceptable good first impression.

The technologist faces the problem of producing a sound, practical, safe design, which complies with the initial specification and can be produced at an economical cost.

During every stage of development there are many progress records to be maintained and kept up to date so that reference to the complete history is available to responsible employees.

For many years various types of drawings, sketches and paintings have been used to convey ideas and information. A good recognizable picture will often remove ambiguity when discussing a project and assist in overcoming a possible language barrier.

British Standards are listed in the British Standards Catalogue and the earliest relevant Engineering Standards date back to 1903. Standards were developed to establish suitable dimensions for a range of sizes of metal bars, sheets, nuts, bolts, flanges, etc. following the Industrial Revolution and used by the Engineering Industry. The first British Standard for Engineering Drawing Office Practice published in September 1927 only contained 14 clauses as follows:

1 Sizes of drawings and tracings, and widths of tracing cloth and paper
2 Position of drawing number, date and name
3 Indication of scale
4 Method of projection
5 Types of line and writing
6 Colour of lines
7 Dimension figures
8 Relative importance of dimensions
9 Indication of materials on drawings
10 Various degrees of finish
11 Screw threads
12 Flats and squares
13 Tapers
14 Abbreviations for drawings.

There were also five figures illustrating:

1 Method of projection
2 Types of line
3 Views and sections
4 Screw threads
5 Tapers.

First angle projection was used for the illustrations and the publication was printed on A5 sheets of paper.

During the early days of the industrial revolution manufacturers simply compared and copied component dimensions to match those used on the prototype. However, with the introduction of quantity production where components were required to be made at different factory sites, measurement by more precise means was essential. Individual manufacturers developed their own standard methods. Clearly, for the benefit of industry in general a National Standard was vital. Later the more comprehensive British Standard of Limits and Fits was introduced. There are two clear aspects, which are necessary to be considered in the specification of component drawings:

1 The drawing shows the dimensions for the component in three planes. Dimensions of the manufactured component need to be verified because some variation of size in each of the three planes (length, breadth and thickness) will be unavoidable. The Designers contribution is to provide a Characteristics Specification, which in current jargon is defined as the ‘Design Intent Measurand’.
2 The metrologist produces a ‘Characteristics Evaluation’ which is simply the Measured Value.

The drawing office is generally regarded as the heart of any manufacturing organization. Products, components, ideas, layouts, or schemes which may be

presented by a designer in the form of rough freehand sketches, may be developed stage by stage into working drawings by the draughtsman. There is generally very little constructive work which can be done by other departments within the firm without an approved drawing of some form being available. The drawing is the universal means of communication.

Drawings are made to an accepted standard, and in this country, is BS 8888, containing normative and informative references to international standards. These standards are acknowledged and accepted throughout the world.

The contents of the drawing are themselves, where applicable, in agreement with separate standards relating to materials, dimensions, processes, etc. Larger organizations employ standards engineers who ensure that products conform to British and also international standards where necessary. Good design is often the product of teamwork where detailed consideration is given to the aesthetic, economic, ergonomic and technical aspects of a given problem. It is therefore necessary to impose the appropriate standards at the design stage, since all manufacturing instructions originate from this point.

A perfect drawing communicates an exact requirement, or specification, which cannot be misinterpreted and which may form part of a legal contract between supplier and user.

Engineering drawings can be produced to a good professional standard if the following points are observed:

(a) the types of lines used must be of uniform thickness and density;
(b) eliminate fancy printing, shading and associated artistry;
(c) include on the drawing only the information which is required to ensure accurate clear communication;
(d) use only standard symbols and abbreviations;
(e) ensure that the drawing is correctly dimensioned (adequately but not over-dimensioned) with no unnecessary details.

Remember that care and consideration given to small details make a big contribution towards perfection, but that perfection itself is no small thing. An accurate, well delineated engineering drawing can give the draughtsman responsible considerable pride and job satisfaction.

The field of activity of the draughtsman may involve the use, or an appreciation, of the following topics.

1 *Company communications* Most companies have their own systems which have been developed over a period of time for the following:
   (a) internal paperwork,
   (b) numbering of drawings and contracts,
   (c) coding of parts and assemblies,
   (d) production planning for component manufacture,
   (e) quality control and inspection,
   (f) updating, modification, and reissuing of drawings.
2 *Company standards* Many drawing offices use their own standard methods which arise from satisfactory past experience of a particular product or process. Also, particular styles may be retained for easy identification, e.g. certain prestige cars can be recognized easily since some individual details, in principle, are common to all models.
3 *Standards for dimensioning* Interchangeability and quality are controlled by the application of practical limits, fits and geometrical tolerances.
4 *Material standards* Physical and chemical properties and non-destructive testing methods must be borne in mind. Note must also be taken of preferred sizes, stock sizes, and availability of rod, bar, tube, plate, sheet, nuts, bolts, rivets, etc. and other bought-out items.
5 *Draughting standards and codes of practice* Drawings must conform to accepted standards, but components are sometimes required which in addition must conform to certain local requirements or specific regulations, for example relating to safety when operating in certain environments or conditions. Assemblies may be required to be flameproof, gastight, waterproof, or resistant to corrosive attack, and detailed specifications from the user may be applicable.
6 *Standard parts* are sometimes manufactured in quantity by a company, and are used in several different assemblies. The use of standard parts reduces an unnecessary variety of materials and basically similar components.
7 *Standards for costs* The draughtsman is often required to compare costs where different methods of manufacture are available. A component could possible be made by forging, by casting, or by fabricating and welding, and a decision as to which method to use must be made. The draughtsman must obviously be well aware of the manufacturing facilities and capacity offered by his own company, the costs involved when different techniques of production are employed, and also an idea of the likely costs when work is sub-contracted to specialist manufacturers, since this alternative often proves an economic proposition.
8 *Data sheets* Tables of sizes, performance graphs, and conversion charts are of considerable assistance to the design draughtsman.

Figure 1.1 shows the main sources of work flowing into a typical industrial drawing office. The drawing office provides a service to each of these sources of supply, and the work involved can be classified as follows.

1 *Engineering* The engineering departments are engaged on
   (a) current production;

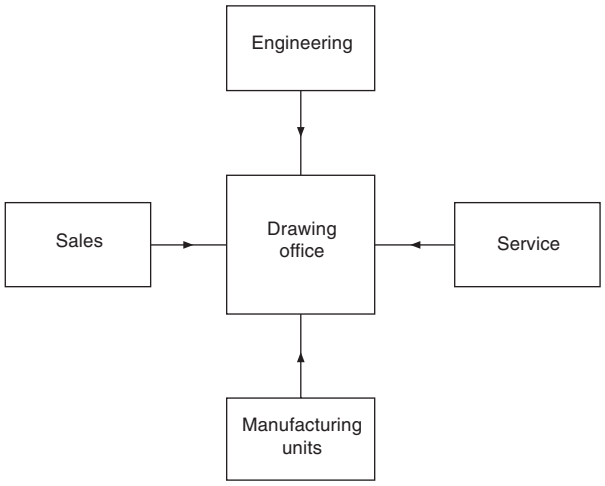

Fig. 1.1

(b) development;
(c) research;
(d) manufacturing techniques, which may include a study of metallurgy, heat-treatment, strength of materials and manufacturing processes:
(e) advanced project planning;
(f) field testing of products.

2 *Sales* This department covers all aspects of marketing existing products and market research for future products. The drawing office may receive work in connection with
(a) general arrangement and outline drawings for prospective customers;
(b) illustrations, charts and graphs for technical publications;
(c) modifications to production units to suit customers' particular requirements;
(d) application and installation diagrams;
(e) feasibility investigations.

3 *Service* The service department provides a reliable, prompt and efficient after-sales service to the customer. The drawing office receives work associated with
(a) maintenance tools and equipment;
(b) service kits for overhauls;
(c) modifications to production parts resulting from field experience;
(d) service manuals.

4 *Manufacturing units* Briefly, these cover all departments involved in producing the finished end-product. The drawing office must supply charts, drawings, schedules, etc. as follows:
(a) working drawings of all the company's products;
(b) drawings of jigs and fixtures associated with manufacture;
(c) plant-layout and maintenance drawings;
(d) modification drawings required to aid production;
(e) reissued drawings for updated equipment;
(f) drawings resulting from value analysis and works' suggestions.

Figure 1.2 shows the organization in a typical drawing office. The function of the chief draughtsman is to take overall control of the services provided by the office. The chief draughtsman receives all work coming into the drawing office, which he examines and distributes to the appropriate section leader. The section leader is responsible for a team of draughtsmen of various grades. When work is completed, the section leader then passes the drawings to the checking section. The standards section scrutinizes the drawings to ensure that the appropriate standards have been incorporated. All schedules, equipment lists and routine clerical work is normally performed by technical clerks. Completed work for approval by the chief draughtsman is returned via the section leader.

Since drawings may be produced manually, or by electronic methods, suitable storage, retrieval and duplication arrangements are necessary. Systems in common use include:

(a) filing by hand into cabinets the original master drawings, in numerical order, for individual components or contracts;
(b) microfilming and the production of microfiche;
(c) computer storage.

The preservation and security of original documents is of paramount importance in industry. It is not normal

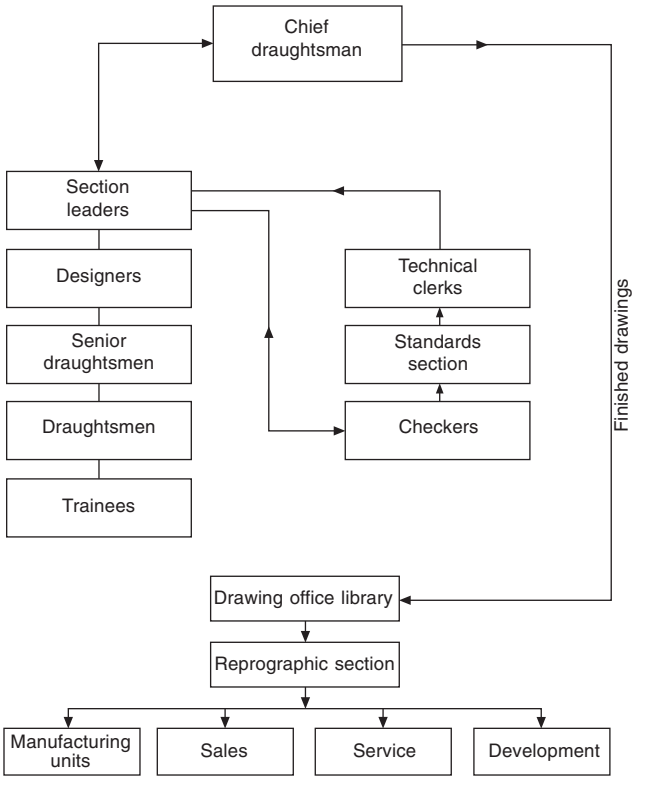

Fig. 1.2

practice to permit originals to leave the drawing office. A drawing may take a draughtsman several weeks to develop and complete and therefore has considerable value. The reprographic staff will distribute copies which are relatively inexpensive for further planning, production and other uses. A library section will maintain and operate whatever archive arrangements are in operation. A large amount of drawing office work comes from continuous product development and modification so easy access to past designs and rapid information retrieval is essential.

Engineering drawing practices

The comments so far refer to drawing offices in general and typical organizational arrangements which are likely to be found within the engineering industry. Good communication by the use of drawings of quality relies on ensuring that they conform to established standards.

BS 5070, Parts 1, 3 and 4 dealing with engineering diagram drawing practice, is a companion standard to BS 8888 and caters for the same industries; it provides recommendations on a wide variety of engineering diagrams. Commonly, as a diagram can be called a 'drawing' and a drawing can be called a 'diagram', it is useful to summarize the difference in the scopes of these standards. BS 8888 covers what are commonly accepted to be drawings that define shape, size and form. BS 5070 Parts 1, 3 and 4 covers diagrams that are normally associated with flow of some sort, and which relate components (usually indicated by symbols) functionally one to another by the use of lines, but do not depict their shape, size or form; neither may they in general indicate actual connections or locations.

Therefore, any drawing or diagram, whether produced manually or on computer aided draughting equipment, must conform to established standards and will then be of a satisfactory quality for commercial understanding, use and transmission by electronic and microfilming techniques. All of the examples which follow conform to the appropriate standards.

Drawing practice and the computer (CAD: Computer aided draughting and design)

The computer has made a far bigger impact on drawing office practices than just being able to mimic the traditional manual drawing board and tee square technique. However, it depends on drawing office requirements and if only single, small, two dimensional drawings and sketches are occasionally required, then there may be no need for change. CAD can however perform a much more effective role in the design process and many examples of its ability follow—but it will not do the work on its own. The input by the draughtsman needs to follow the same standards applied in the manual method and this fact is often not understood by managers hoping to purchase CAD and obtain immediate answers to design enquiries. The draughtsman needs the same technical appreciation as before plus additional computing skills to use the varied software programs which can be purchased.

To introduce CAD an organization must set out clear objectives which are appropriate to their present and future requirements and Fig. 1.3 includes aspects of policy which could appear in such plans. The following need consideration:

(a) CAD management roles;
(b) creation, training and maintenance of capable CAD operators;
(c) CAD awareness of design project team members in addition to their leaders;
(d) the flow of work through the system and the selecting of suitable types of project;
(e) associated documentation;
(f) possible changes to production methods;
(g) needs involving the customer;
(h) system needs relating to planning, security and upgrading;
(i) CAD library and database (Storage of drawings, symbols, etc.) and archive procedures.

Many similar aspects will be appropriate in particular applications but good intentions are not sufficient. It is necessary to quantify objectives and provide dates, deadlines, numbers, individual responsibilities and budgets which are achievable if people are to be stretched and given incentive after full consultation. Present lines of communication will probably need to be modified to accommodate CAD, and planning integration is vital. A possible approach here is the appointment of a CAD Director with the ultimate responsibility for CAD technology assisted by a Systems Manager and an Applications Manager.

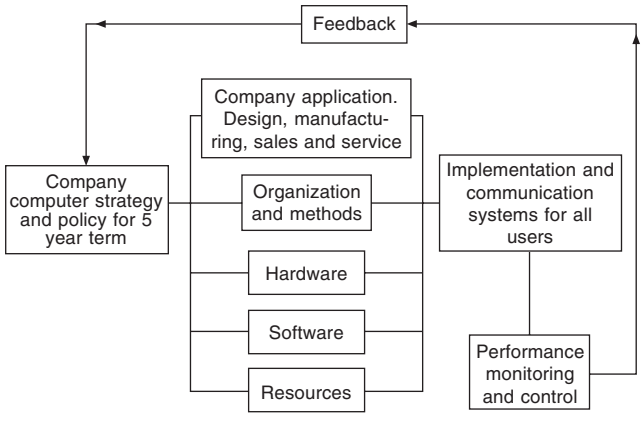

Fig. 1.3 General computer policy relationships

A CAD Director has the task of setting and implementing objectives and needs to be in a position to define binding policy and direct financial resources. He will monitor progress. A Systems Manager has the role of managing the computer hardware, the software and the associated data. Company records and designs are its most valuable asset. All aspects of security are the responsibility of the Systems Manager. Security details are dealt with in the next chapter. The Applications Manager is responsible for day to day operations on the CAD system and the steady flow of work through the equipment. He will probably organize training for operators in the necessary computer skills. Both of these managers need to liaise with the design project leaders to provide and maintain a draughting facility which is capable of increasing productivity to a considerable degree.

Figure 1.4 shows the probable position of the CAD Director in the management structure. His department will be providers of computer services to all other computer users within the company.

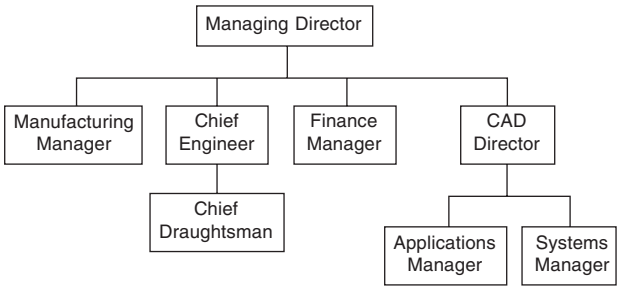

Fig. 1.4

Why introduce BS 8888 and withdraw BS 308?

For 73 years, BS 308 was a highly regarded drawing office practice document. Why the change and what was behind the decision to withdraw BS 308 and replace it with BS 8888?

A drawing standard

From time immemorial, drawings have been the medium used to convey ideas and intentions. Hence the adage that 'a picture is worth a thousand words'. No need for language, the picture tells it all. In recent years there has, unfortunately, developed another opinion since CAD appeared on the scene, that there is no need for a draughtsman now as the computer does it all. The truth of the matter is that the computer is able to extend the range of work undertaken by the draughtsman and is really a very willing slave. The evolution of the Industrial Revolution required the 'pictures' to be more detailed. In the pre-mass-production era, manufacture was based on 'matched fits', with the assistance of verbal communication. The advent of mass production however, demanded more specific and precise specifications.

A national form of draughting presentation was needed to promote a common understanding of the objectives and in September 1927, BS 308 came to fruition, as the recognized National Code of Practice for Engineering Drawing.

The initial issue was A5-size and contained only 14 clauses. Dimensioning was covered in four paragraphs and tolerancing in only one. The recommendations were based on just two example drawings. The recommended projection was first angle.

Revisions

The life span of BS 308 was 73 years and five revisions were made. The first in December 1943, followed by others in 1953, 1964, 1972 and 1985. The 1972 revision was a major one, with the introduction of three separate parts replacing the single document:

> The fifth (1985) revision replaced the Imperial standard with a Metric edition.
> BS 308 was finally withdrawn and replaced by BS 8888 in 2000. The revisions were necessary to keep abreast of technological innovations.

As manufactured products became more sophisticated and complex, the progress and development of manufacturing and verification techniques accelerated. Advances in the electronics industry ensured more applications in manufacturing with a very high degree of sophistication. Much progress was also made since that single paragraph in the original 1927 version relating to tolerancing, together with the four paragraphs and the two examples covering dimensioning. Geometrical tolerancing was not referred to at all in early versions. The subject gained prominence during the 1960s, especially when it was realized that a symbolic characterization would assist in the understanding of the subject by users and replace the use of lengthy notes relating to geometric controls.

This activity was addressed by the major revision in 1972 with the publication of Part 3, devoted entirely to the dimensioning of geometric tolerancing.

The replacement of BS 308

Formerly, the Chief Designer and the drawing office set, and were responsible for, company manufacturing standards and procedures, for other disciples to follow. This practice gradually eroded away because of the advancement of progressive and sophisticated techniques in the manufacturing and verification fields.

Increasing commercial pressure for Design for Manufacture and Design for Inspection, created the demand for equal status. During the period separate standards were gradually developed for design, manufacture and measurement. Each discipline utilized