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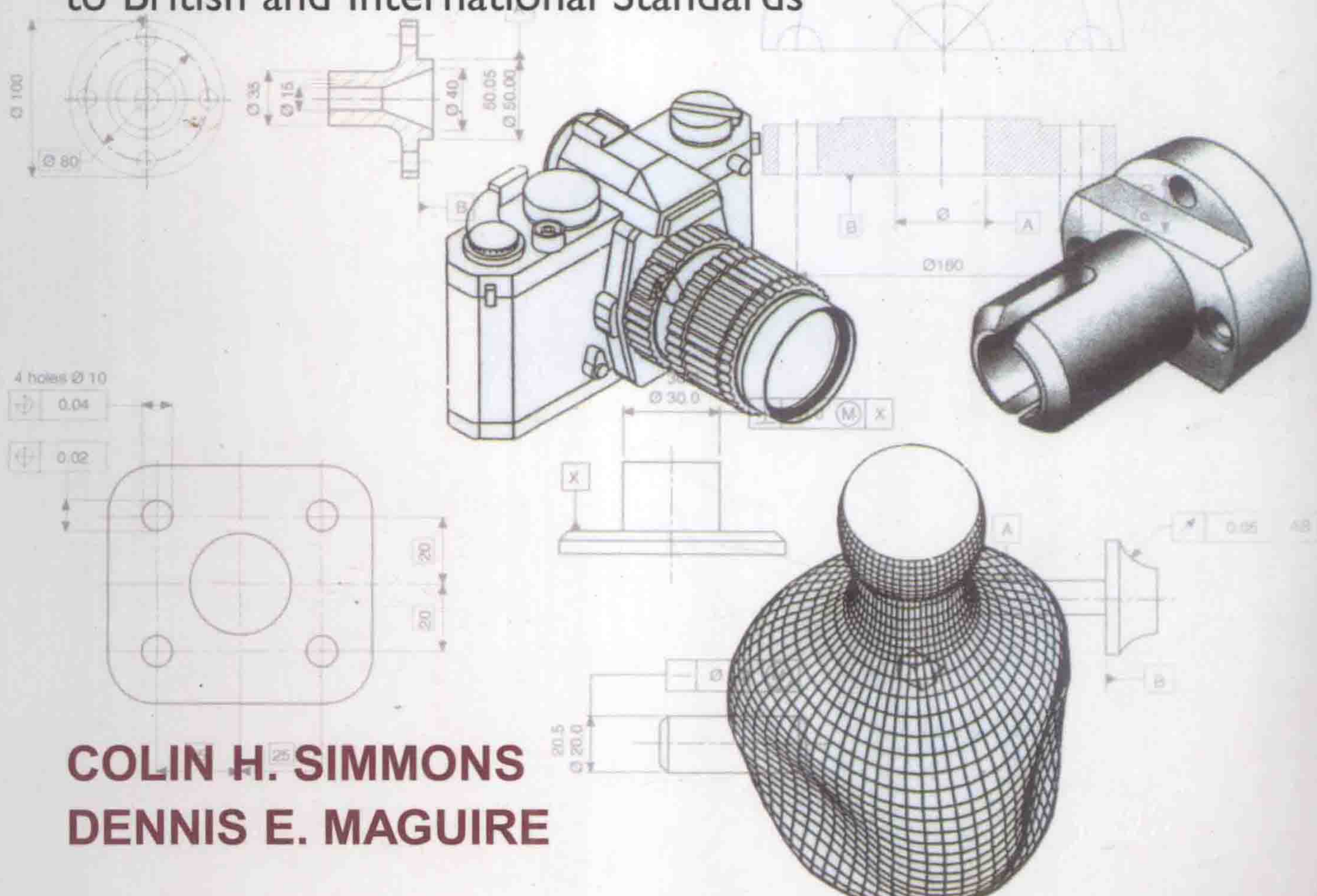
MANUAL OF ENGINEERING DRAWING

to British and International Standards



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Newnes

Manual of Engineering Drawing

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*.

Contents

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;

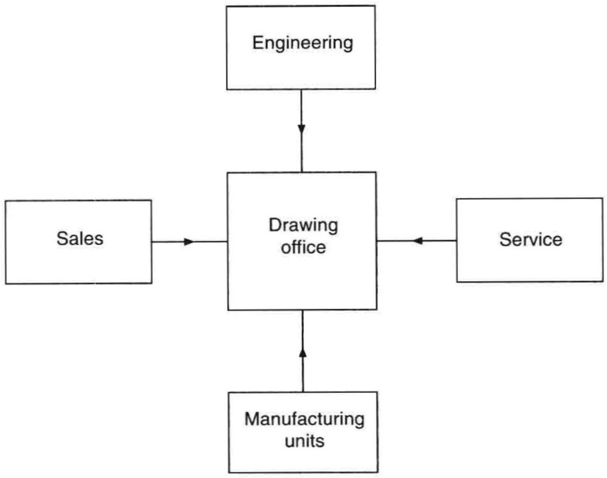

Fig. 1.1

(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

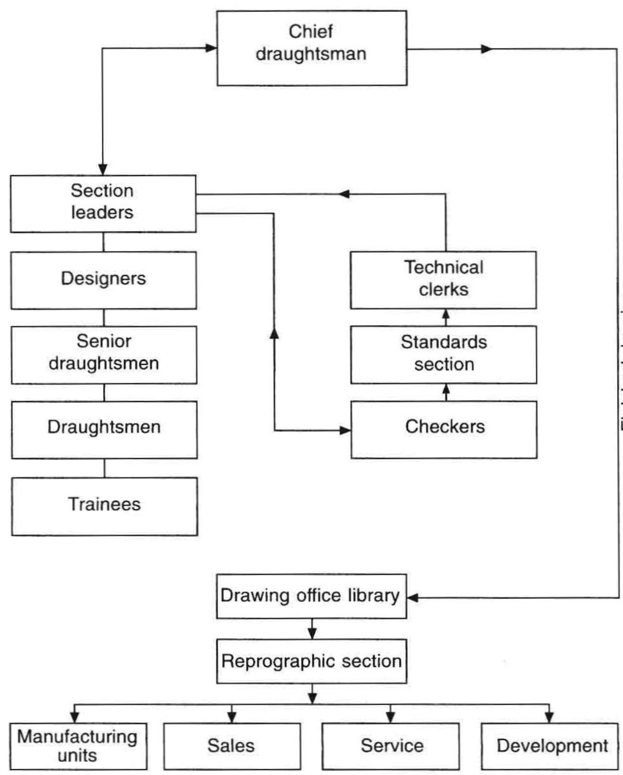

Fig. 1.2

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.

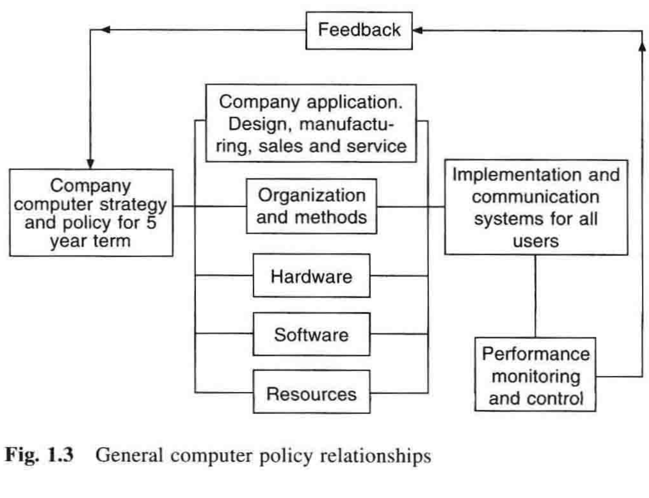

Fig. 1.3 General computer policy relationships

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.

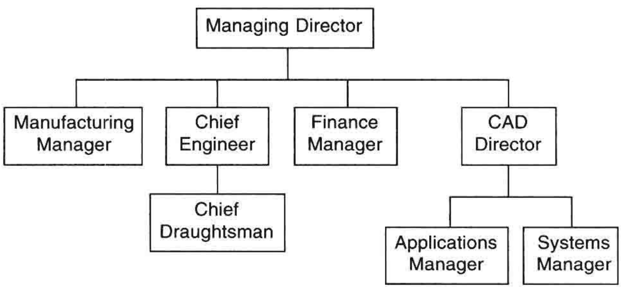

Fig. 1.4

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 similar terms but often with slightly different interpretations despite their apparent commonality.

An urgent need to harmonize the meaning of these terms was recognized by ISO. An international meeting in 1989 formed a Joint Harmonization Group.

The Danish Standards Association funded a project to bring all design, measurement, and metrology standards together using definitions common to all, but with appendices for each discipline.

A full ISO committee (ISO/TC 213) was formed, with the Danish being responsible for the secretariat. The task allocated to this very vibrant committee progressed considerably, with many new international standards being published.

A major happening that would affect the future of BS 308 was the UK's agreement in 1993 with the European Standards Authority (CEN), whereby BSI would withdraw standards relating to technical drawing in favour of the implemented ISO standards covering the same subject. Initially, BSI systematically withdrew various clauses of BS 308 as the relevant ISO Standards were introduced.

PD 308 was introduced in June 1996 as a guidance document to assist the transition from BS 308 to the implementation of ISO drawing standards. In 1999, as was the case in 1927, major decisions were deemed necessary, and the following were made:

- To transfer the United Kingdom totally to the ISO Standards base.
- To prepare an applications standard to serve as both a specification for specifying and graphically representing products, and as a route map to the ISO Standards.
- To withdraw BS 308.

From this positive commitment, BS 8888 was created and published on 15 August 2000.

The complete comprehensive title of BS 8888 is:

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

Basic differences

The fundamental differences between BS 308 and BS 8888 are:

- The title: Technical product documentation (TPD) Specification for defining, specifying and graphically representing products.
- Confirmation of the conventional use of the comma as the decimal marker.
- BS 308 was a Code of Practice, a guidance document. BS 8888 is essentially an applications specification, providing a route map to 106 ISO standards. The operative word is 'specification'. BS 8888 carried forward and contains a significant number of valuable clauses contained in BS 308, which, at present, is not in any ISO documentation.
- BS 8888 is capable of accommodating significant technical changes, known to be in development, plus the facility to accommodate future additions and changes.
- With 106 related ISO standards, BS 8888 has a much broader field of application than its predecessor and its 30 related ISO standards.
- BS 8888 provides common understanding, and acceptance between the designer and the metrologist of 'uncertainty'. These are caused by differences between the Design Intent Measurand (Characteristics Specification) and the Measured Value (Characteristics Evaluation) of the actual manufactured part.
- BS 8888 is a uniform source of reference and will be regularly updated to keep abreast of developments as new international standards are finalized and implemented.
- It will capture any fundamental changes and will reflect moves towards an integrated system for definition, manufacture and verification.
- BS 8888 links each standard to the appropriate stage of the design process and lays the foundations for future development.

BS 8888 will be revised every two years.

Chapter 2

Product development and computer aided design

Work undertaken by a drawing office will vary considerably with different branches of industry. Generally, work of a 'design and make' nature will follow a plan which sets out stages in development from the time a potential client makes an enquiry until the completed product is delivered. The function of the product will dictate many of the associated activities.

A vehicle manufacturer will not design and make all of the parts used but subcontract components from specialists. The engine incorporates electrical and mechanical components and these need to conform to agreed specifications. They must also be designed for installation in specified areas and be suitable for operation in well defined conditions. Component manufacturers strive to improve quality and performance in conjunction with end user.

The stages in design and development for components in this category are shown typically, step by step, in Fig. 2.1.

1 A client requiring a certain product is often not completely familiar with specific details and needs the experience and advice from a specialist producer to clarify initial ideas. When a range of viable alternatives is presented, opinions can be focused and firm decisions made.
2 The Chief Engineer in a company has the responsibility of producing the company specification for a product. He will no doubt seek advice where aspects of the total design are outside his range of experience, and where design is involved on the fringes of Technology. However a top executive plan needs to be carefully prepared because at the outset the company must know whether or not it wishes to entertain, or get involved with, design proposals to satisfy the client. For example, while rewards may well be great the firm may not be able to cope with the scale of financial and labour demands and delivery requirements in view of current work. They simply may not wish to take the risk and, in view of available production capacity, the firm may prefer not to tender for a possible order.

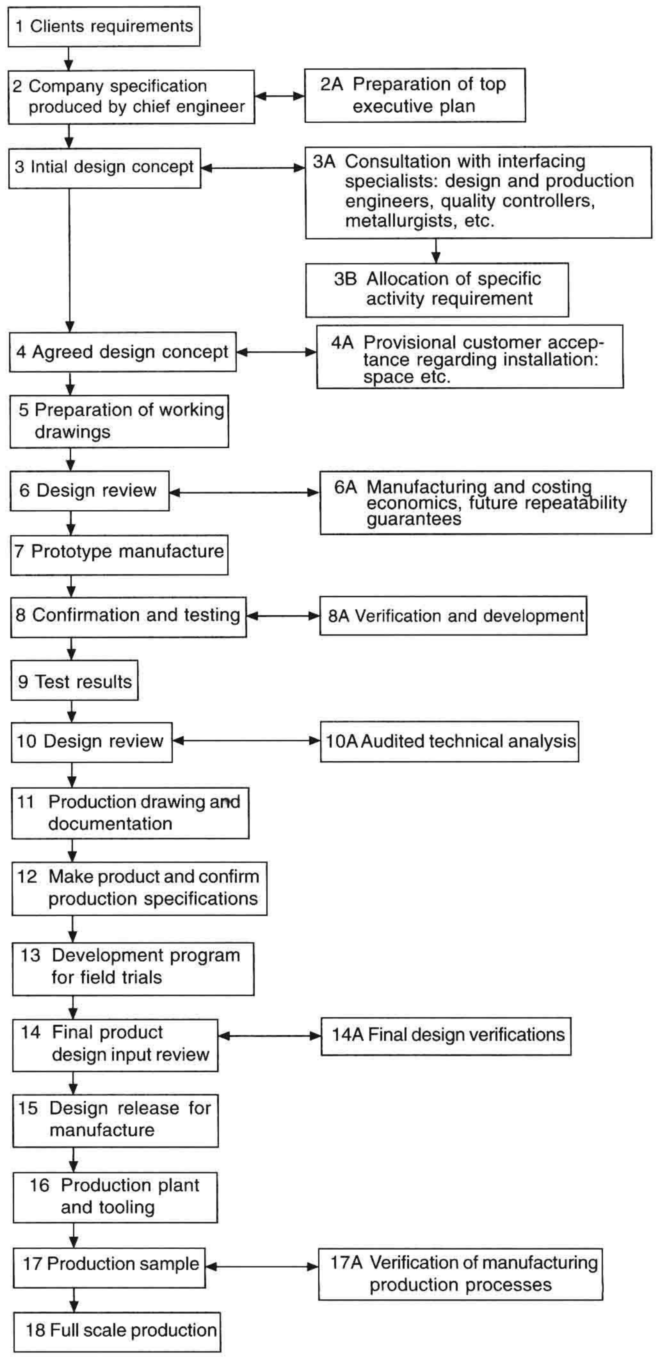

Fig. 2.1

3 Drawings at this stage should be regarded only as provisional. The exercise is needed as an aid to thinking around the problem, with contributions being made by specialists within the firm to ensure feasibility.

CAD has many virtues at this stage of primary design. All information, defined in mathematical terms, can be stored in the system and manipulated on the display. After the basic geometry is established, design variations can be kept and in redrawing alternatives, sections of the previous proposals which were found to be acceptable can be used repeatedly. At any point in development the designer can take a printout, so that suggestions and comments can be made by other technical staff.

It is essential that the Company should appreciate the extent of their commitment if a firm order is accepted at a later date. This commitment includes not only the technical ability to complete the design and manufacture a satisfactory product but also the financial issues relating to its introduction on the factory production line.

4 With the completion of preliminary design work an agreed design concept will have been established, but it is necessary to obtain customer approval before work continues. If our product is to be used in conjunction with others in a large assembly, then, for example, expected overall dimensions and operational parameters need to be confirmed with the client before money is spent on further development.

5 If all is well, working drawings will be prepared. These are not production drawings—at this stage, we as a company have only ensured that our proposals are in line with requirements and that hopefully we shall be able to deliver. The object now is to prepare working drawings to formulate construction methods.

6 A design review is necessary to check the feasibility of manufacturing, to ensure that all aspects of design requirements have been incorporated in an economic manner and to guarantee future supplies.

7 A prototype or a small batch may now be manufactured. The ultimate production methods of manufacture will not be employed here. For example, components which may be moulded could be machined from solid to eliminate casting costs.

8 Prototypes are used for testing to make certain that operational requirements of the specification can be achieved. As a result design changes may be necessary. Product tests cover all areas where the component will be expected to function without failure, and these could include use in extremes of temperature and humidity, also when subject to shock, vibration and fatigue.

9 Proven test results are vital to confirm the validity of these tests.

10 A design review and analysis ensure that progress at this point will be acceptable in every technical aspect to each responsible member of the team.

11 Production drawing can commence now that the performance targets from the prototype have been confirmed. Drawings of the prototype will be reviewed and modifications made to use full scale production processes during manufacture. For plant to be used efficiently plans need to be prepared for loading and progressing work through the factory. The necessary documentation now commences.

12 Manufacture of the final product following production of the prototype has involved modifications and different manufacturing processes. It is therefore prudent to check that the specifications can still be kept.

13 Following trials where the equipment is used in its operational environment and its performance exhaustively checked, the design details can be released for full scale production.

14 Production involves not only the use of machines, but many jigs, fixtures, tools, gauges, inspection procedures need to be planned, and auxiliary equipment designed to move materials on and off production lines.

15 Inevitably teething troubles occur and samples are taken to verify that all plant and equipment operates as planned. Economic production requires that downtime is eliminated before full-scale production commences.

Computer aided draughting and design

CAD is much more than drawing lines by electronic means. Similarly by the purchase of a CAD system, a design does not emerge at the push of a button. 'Buy a computer and you don't need a draughtsman' is also very different from reality. The engineering designer is very much responsible for decisions taken at all technical stages between conception and production. The computer is an aid and performs as it is directed with rapidity and accuracy. The following notes are included to indicate areas of useful activity to assist the draughtsman.

The preparation of two and three dimensional drawings and the projection of associated views is the 'bread and butter' work in the drawing office. Service manuals use exploded views so that people with no technical training can follow assembly sequences. Children stick together model kits with guidance using pictorial diagrams.

CAD programs are available where a three dimensional model can be produced automatically given two dimensional views. From the dimensions of the component, the computer will calculate surface areas, volumes, weights for different materials, centres of gravity, moments of inertia and radii of gyration it can also use the applicable values for stress and other calculations, which are a necessary part of design. Computer models permit a study of special relationships and applications are given in the chapter which follows. Models can be manipulated into pleasing forms for artistic approval before production work follows. Previous techniques included modelling with plasticine and plaster, and applications ranged from ornaments to boat hulls and car bodies. CAD has revolutionized modelling capabilities.

Sales departments utilize 3D illustrations in brochures and literature for promotional applications. Desk top publishing from within the company can very simply use illustrations generated as part of the manufacturing process. The scanning of photographs into a CAD system is also an asset especially as photographic work can be retouched, manipulated and animated. Multi-media applications with video and slide presentations form a large part of selling and advertising.

Structural design requires a thorough knowledge of engineering materials properties. Calculations of stress, strain and deflection are essential to determine proportions and dimensions in structural applications. Computers now have the ability to perform millions of calculations per second and with the availability of powerful desk top models, finite element analysis has developed as a principal method. One advantage of finite element analysis is that design engineers can produce better designs and eliminate dubious options during the conceptual design phase. CAD systems permit the rapid generation of models of proposed designs as wire frames. The component can be defined as a collection of small loaded elements. The computer memory stores details of all the geometric data to define each part of the frame. Numerical analysis will then verify whether or not the suggested design will be capable of supporting the expected loads. Formerly, stress calculations were time consuming and in the early days of computing, although the calculation time was considerably shorter, computer time was relatively expensive. This is now not the case and for this type of design work CAD is an essential tool in the drawing office.

CAD is very suitable for repetitive and fast documentation where a product is one in a range of sizes. Assume that we manufacture a range of motor driven pumps operating at different pressures. Many parts will be used in different combinations in the range and the computer database documentation is programmed accordingly. Company standard designs will be offered when enquiries are received. A computerized tender can be sent with the appropriate specification and technical details. On receipt of an order, all of the documentation relating to manufacture, testing, despatch and invoicing will be available. An obvious advantage is the speed of response to the customer's enquiry.

CAD will be linked to CAM (computer aided manufacture) whenever possible. Documentation will include parts lists, materials details of parts to be manufactured or bought out, stock levels, computerized instructions for numerical controlled machine tools, instructions for automated assemblies, welding equipment, etc. Printed circuit boards can be designed on CAD and manufactured by CAM.

Production tooling requires the design of many jigs and fixtures. A *jig* is a device which holds the component or is held on to the component, locating the component securely and accurately. Its function is to guide the cutting tool into the component or for marking off or positioning. A *fixture* is similar to a jig but it does not guide the tool. Generally a fixture will be of heavier construction and clamped to the machine tool table where the operation will be performed. Jigs are used frequently in drilling and boring operations. Fixtures are a necessary part of tooling for milling, shaping, grinding, planing and broaching operations. The use of jigs and fixtures enables production to proceed with accuracy, and hence interchangeability due to the maintenance of tolerances (see Chapter 19) and especially by the use of unskilled or semiskilled labour and robotics.

The traditional method of jig and tool draughting was to draw the component in red on the drawing board. The jig or fixture would then be designed around the component. This process ensures that the part is located and clamped correctly, can be loaded and unloaded freely, and that the machining operation can be performed without hindrance.

With a CAD system, the component drawing can be shown in colour on one of the 'layers' (see Chapter 3) and design work undertaken on the other layers.

Machining operations need to be checked to ensure that tools and cutters do not foul any other equipment in the vicinity. The path taken by the tool into its cutting position should be the most direct and the shortest in time. The actual cutting operation will take a different time and the tool may traverse the component several times, cutting away more material on each occasion. Machining sequences can be simulated on the screen and when the optimum method has been obtained, the numerical program prepared. All relevant data for the machining operation is converted into coded instructions for continuous production.

Programs are available for the economic use of metallic and non-metallic materials. Many engineering components are manufactured by flame cutting intricate shapes from plate or sheet and these need to be positioned to minimize scrap. The cutting head is guided by computer using the X and Y coordinates at each point along the curve. Other applications use a variety of cutters and saws to shape materials singly or heaped into a pile, such as foams in upholstery or dress fabrics.

The tool draughtsman, for example, will use many standardized components in tooling and designing associated handling equipment for production. If a range of parts is similar it is common practice to produce a single drawing with dimensions in a table of the separate features. A typical example is given in Fig. 7.2 and is the normal manual draughting procedure. CAD can however use a parametric technique where the component drawing is dimensioned by algebraic expressions understood by the computer. Each separate size of component will be given its own part number. When a particular part is required and called up, the computer calculates sizes, draws the part to the correct scale for the draughtsman to position where required on the assembly drawing. This is a very useful facility and only available through the introduction of CAD.

CAD always produces drawings finished to the same high standard, and of a uniform quality and style. All tracing costs are saved.

It will be seen from the above notes that CAD fits in with many of the separate procedures necessary for design and production, but it is vital that, before its introduction, software must be available with proven ability. Likewise, staff must receive training to extract the maximum advantages and benefits.

Draughting in an organization which uses CAD equipment does involve the question of security.

Technical product documentation

Individual companies generally develop their own systems largely depending on the type of work involved and the size of the undertaking, e.g. original designs, drawing revisions, modifications, repairs, new contracts, enquiries and proposals.

These notes provide guidelines for new business routines where both manual and computer based systems are used. They refer to internal communication within companies and between other organizations.

There are five short Standards dealing with the handling of computer-based technical information during the design process.

Part 1: BS EN ISO 11442–1. Security requirements.

This document details advice and precautions regarding the system installation, power supply, ventilation and cooling, magnetism and electrostatic environment, also computer access.

Notes regarding service and maintenance, stand-by equipment and back-up copies are given. Useful comments relate to document authorization and copyright.

Part 2: BS EN ISO 11442–2. Original documentation.

Definitions are provided for various types of document used by industry in the Drawing Office.

Part 3: BS EN ISO 11442–3. Phases in the product design process. Distribution of documents during each phase is detailed.

Part 4: BS EN ISO 11442–4. Document management and retrieval systems. This section deals with activities in the design process and the handling of associated documents, e.g. identification and classification of administrative and technical documents. Provides helpful advice in the management of documentation in parallel with the phases of product development. Assistance also given for drawing revisions, document handling, classification and retrieval of data.

Ready-made 'Turnkey' data-processing systems are available and can be adapted by specialist suppliers.

Part 5: BS EN ISO 11442–5. Documentation in the conceptual design stage of the development phase.

Part 5 deals with documentation in the preparation of a design specification, design proposals and solutions.

Problems can arise from power cuts of short and extended time periods, and from spikes, or fluctuations of power, due to other electrical equipment being switched on. Stormy weather can cause surges and static build ups. A reliable power source with a stable supply is essential. Consideration should be given to the provision of a backup supply, if in doubt. Service and maintenance arrangements may require the issue of external contracts, as computer downtime resulting in lost production can prove expensive.

Computers generate heat, and wide variations in environmental temperatures should be avoided. Air conditioning in the complex may be necessary if cooling is required and clean air cannot otherwise be guaranteed. Part of the computer complex may need to be out of bounds except to authorized personnel, to maintain an acceptable environment. Care should be exercised in the selection of floor coverings and furniture to protect equipment from static electricity. Similarly tapes and discs need to be shielded from stray magnetic fields. Ensure that the CAD complex is kept locked and secure when not in use at night and weekends.

An organization must develop a routine for storing data on which company fortunes may depend. In the even of power failure, work in progress may be lost. It could also be lost due to operator error or computer malfunction, fire, flood, vandalism, etc. Backup routines must cover personal responsibility aspects, together with frequency of copying, storage medium and designated places of safety. Backup copies should not be stored in the same buildings as the originals.

Programs used for operating and applying CAD systems need to be checked at regular intervals to ensure that intended methods are being kept in practice. Computer aided designs and production information could easily be copied and some countries do not have legislation prohibiting unauthorized use. Documents should therefore include a clause relating to copyright where design information is transmitted, it is recommended that the clause should appear before the text and again at the end.

Many grades of staff are involved in the design process; senior designers, detailers, checkers and technical clerks all make a positive contribution. Each member's duties must be carefully defined with rules applied, an authority given, so that each can only operate within his or her agreed sphere of activity. By means of passwords it is possible to access design information at appropriate levels. Revision procedures will ensure that modifications are only made at the correct point by authorized designated staff. Quality assurance systems require strict application of these methods.

Access into the computer network

Every CAD installation requires access responsibilities to be defined for the operating staff and the following example relates to an educational establishment.

A typical College of Technology may consist of three separate departments, each requiring to use a common computer facility where a central processing unit is installed. Each department is serviced using a tree and branch system leading to the desks of staff holding different levels of responsibility, and to student outlets in classrooms, drawing offices and laboratories. All members of staff and students need to gain access to the computer freely, and in their own time, and be able to store their work safely.

A Head of Department, however, may need to gain access to the students' work to monitor progress.

All members of the college staff would wish to have a personal file and keep confidential records. A lecturer must be free to allocate space to students in several classes, so he or she will open subdirectories as necessary and possibly delete work at the completion of a course.

Figure 2.2 shows a directory structure where access can only be made into the system provided the keyboard operator logs in a personal identity number. Each member of staff will be assigned two directories:

(a) a top level directory (TLD);
(b) a personal directory (PD).

The TLD is the attach point for the user into the system. The lecturer is free to 'open subdirectories for students' work and each student's file will be protected from the rest of the class. The Head of Department has access to a lecturer's TLD and through to a student's file.

The above system can be adapted for any graded organization where controlled access and protection for records is desirable.

Quality assurance

BS EN ISO 9000 series relates to quality systems and is produced in several sections. The principles of quality assurance embrace all activities and functions concerned with the attainment of quality. *BSI Quality Management Handbook QMH 100* is essential reading.

Having purchased quality CAD equipment, the products which the company propose to manufacture need to be designed and developed from conception following an agreed *quality assurance* working procedure practised by all employees throughout the organization. QA systems are usually accredited and certified by a third party such as a professional institution or association.

An organization should be able to show that all drawings, documentation and necessary calculations

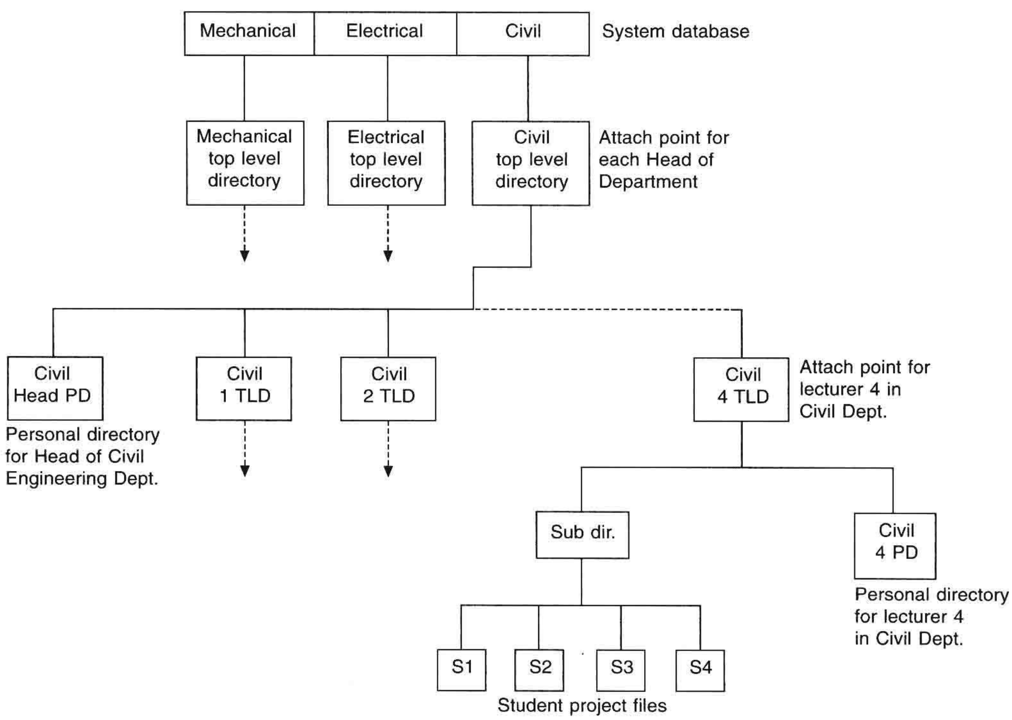

Fig. 2.2 Directory tree for controlled access to database