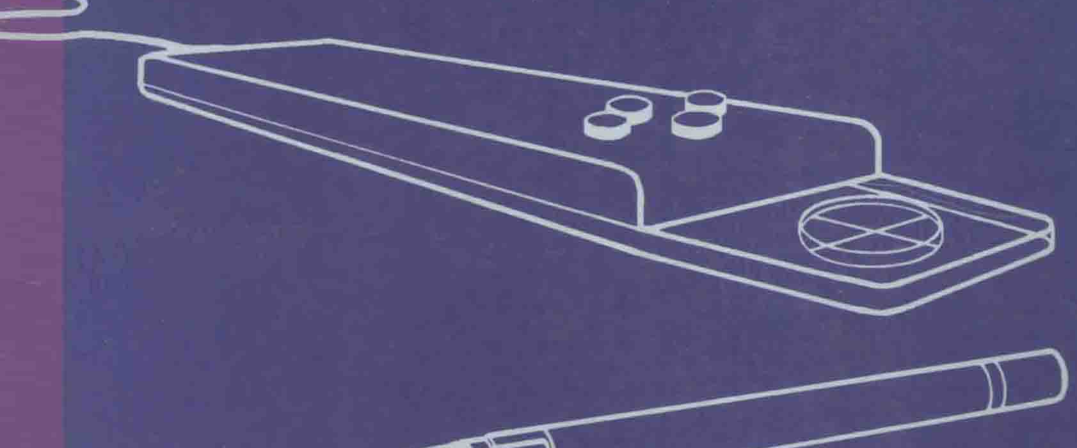
MANUAL *of* ENGINEERING DRAWING

to British and International Standards



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Manual of Engineering Drawing

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Edward Arnold
A member of the Hodder Headline Group
LONDON MELBOURNE AUCKLAND

First published in Great Britain 1995 by Edward Arnold,
a division of Hodder Headline Plc, 338 Euston Road, London
NW1 3BH

Distributed in the USA by Routledge, Chapman and Hall, Inc.
29 West 35th Street, New York, NY 10001

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British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 0 340 58484X

Typeset in 10/11 Linotron Times by Wearset, Boldon, Tyne & Wear
Printed and bound in Great Britain by The Bath Press, Avon

Preface

This completely revised edition of *A Manual of Engineering Drawing Practice* has been rewritten to include all of the important BS and ISO revisions which are relevant in current draughting practice. During the last twenty years advances in computer technology have gradually made an increasing impact in engineering activities. Methods and procedures in the drawing office, which is the heart of product conception, design and development, have undergone considerable changes with the application of computer power. Drawing office practices involve a vast amount of data manipulation, storage, retrieval and transmission. Stages in the design process require computer models of alternative solutions with associated drawings, calculations and documentation. The ability to speedily incorporate necessary and desirable alterations—to improve solutions as design develops—is vital in competitive industry.

In parallel with computerisation of company draughting facilities has been a firm commitment towards improving product quality. Inferior design can occur from poor company standards or practices, resulting in reduced profits—especially where the product is mass produced, then widely distributed. Typical examples being the recall of cars and electrical equipment for inspections and safety modifications. A growing area of awareness and concern relates to the subject of Product Liability. Litigation resulting from product malfunction often attracts considerable publicity by the media. No company would welcome a loss in stature or reputation due to avoidable design errors or production faults.

A quality product is the result of a sound design followed by adequate checks at each stage in its life, from raw material input to satisfactory operation in service.

Quality requires clearly defined company policies, carefully controlled company procedures and a close adherance to national and, where applicable, appropriate international standards. Quality control aspects of engineering are defined in BS 5750 and start with a clear unambiguous drawing. Although notes on drawings may well be translated into foreign languages, the drawing itself is accepted as a graphical language of communication and its function is to provide an efficient transfer of information between the draughtsman and the end user. This demands that we all speak the same graphic language.

In Great Britain the general intention is to unify in BS 308 one set of standards with recommendations for drawings embracing all areas of mechanical, electrical and electronic engineering associated with the manufacturing industries. However, British Standards in engineering do not operate in isolation but participate actively in International Standards Organization Committees (ISO) assisting in the creation of worldwide agreed standards.

For the benefit of our readers we have included a list of associated engineering standards which will be of assistance to drawing office personnel.

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 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 *Teach Yourself Technical Drawing* from TEACH YOURSELF BOOKS.

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 in 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.

Acknowledgements

The authors express their special thanks to the British Standards Institution, 2, Park Street, London, W1A 2BS for kind permission to reprint extracts from their publications.

We are also grateful to the International Organization for Standardization, Genève 20, Switzerland, for granting us permission to use extracts from their publications.

We very much appreciate the encouragement and friendly assistance given to us by:

H C Calton, Ford Motor Company Ltd
Geoff Croysdale, SKF (UK) Ltd
Susan Goddard, KGB Micros Ltd
John Hyde, Norgren Martonair Ltd
Bob Orme, Loctite Holdings Ltd
Tony Warren, Staefa Control System Ltd
Autodesk Ltd
Barber and Colman Ltd
Bauer Springs Ltd
GKN Screws and Fasteners Ltd
Glacier Vandervell Ltd
Lucas Diesel Systems
Lucas Electronic Unit Injector Systems
F S Ratcliffe Ltd
Salterfix Ltd

Dr Russell W H Parry, Senior Editor, and staff of Edward Arnold

Brian and Ray for sheet metal and machine shop examples and models

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 *A Manual of Engineering Drawing*.

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Contents

Chapter 1

Drawing office management and organization

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 308. BS 308 is aligned to the International Organization for Standardization (ISO). 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 recognised 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 possibly 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.

Fig. 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;
   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) feasability 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,

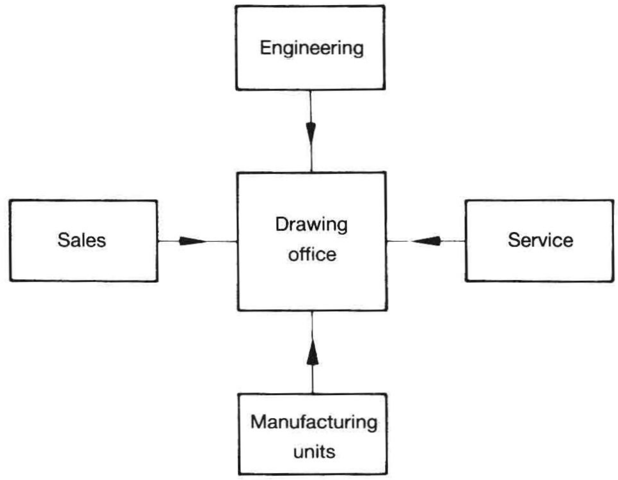

Fig. 1.1

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.

Fig. 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 practice to permit originals to leave the drawing office. A drawing may take a draughtsman several weeks to

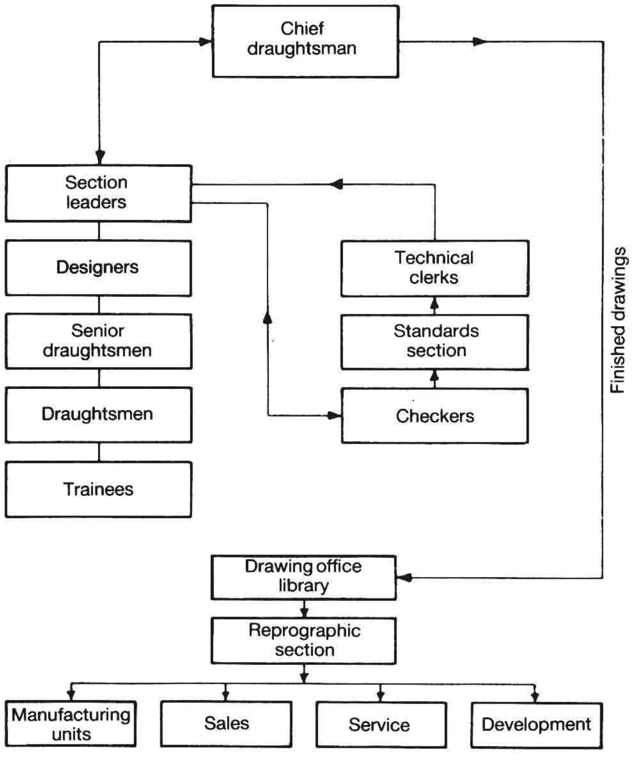

Fig. 1.2

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 308 is written in three sections:

Part 1—*Recommendations for general principles*
Part 2—*Dimensioning and tolerancing of size*
Part 3—*Geometrical tolerancing.*

It is perhaps appropriate to clarify the scope of these standards and in the Foreword of Part 1 is the comment

('The recommendations of this standard have been established having regard to the requirements of microfilming. Drawings prepared in accordance with this standard should be suitable for microfilming and reduced-size reproduction techniques.

During the course of this revision particular attention has been paid to developments in computer aided machine draughting and it has been established that such machines are currently capable of complying with this standard. Any minor exceptions due to the limitations of a particular draughting system would not be expected to prejudice the understanding of a drawing otherwise claimed to comply with this standard.')

BS 5070, dealing with engineering diagram drawing practice, is a companion standard to BS 308 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 308 covers what are commonly accepted to be drawings that define shape, size and form. BS 5070 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

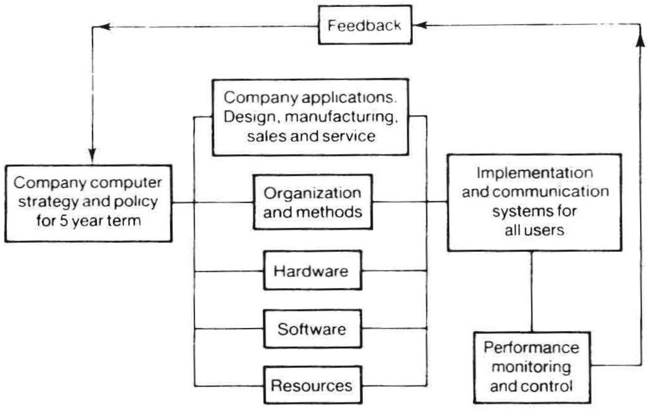

Fig. 1.3 General computer policy relationships

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;
j) 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.

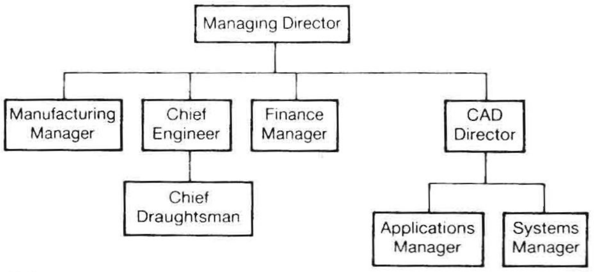

Fig. 1.4

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.

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 the 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.

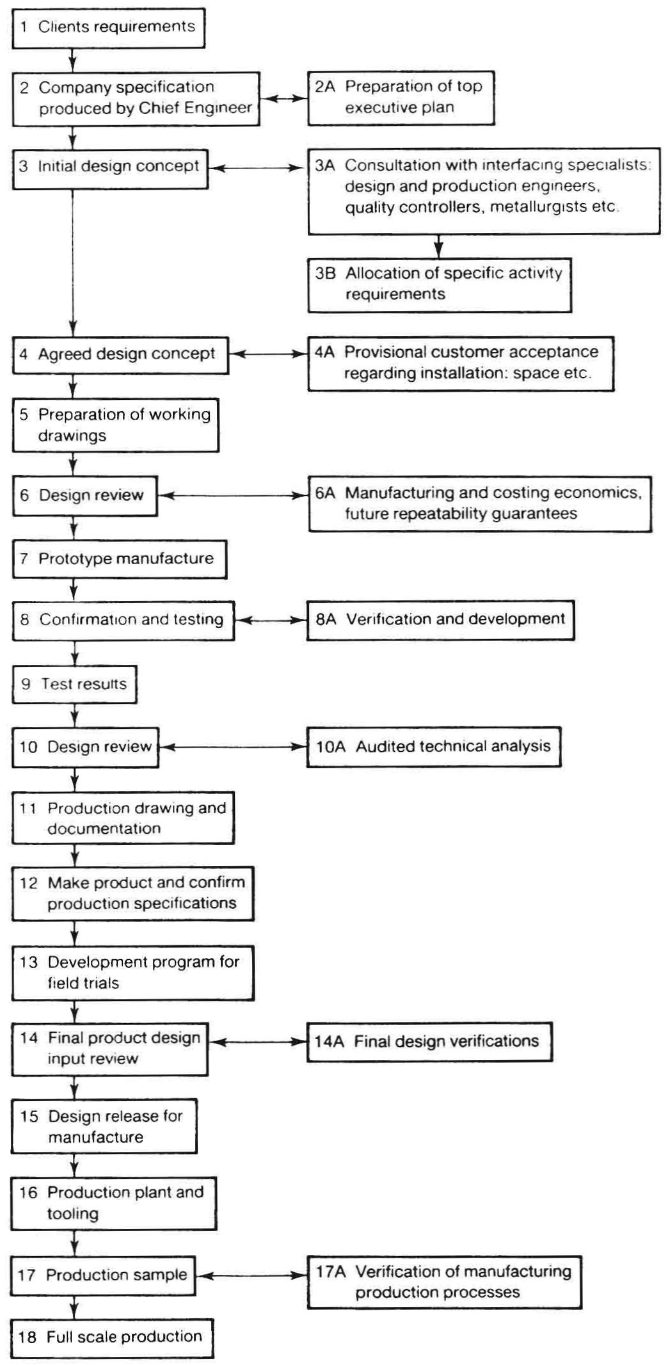

Fig. 2.1

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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.

14 Following trials [13] where the equipment is used in its operational environment and its performance exhaustively checked, the design details can be released [15] for full scale production.

16 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.

17 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 [18].

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 dimensional drawings and the projection of associated views is the 'bread and butter' work in the drawing office. However, draughting three dimensional illustrations is by comparison more time consuming. They are of course used in countless applications since this is how we see the world around us. 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. Multimedia 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 principle 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 computerised 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, computerised 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 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.

Security aspects of CAD

There are four distinct areas to be addressed:

a) installation and operation;
b) system security;
c) document content;
d) communication.

Installation and operation

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 up. 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.

Backup copying

An organization must develop a routine for storing the data on which company fortunes may depend. In the event 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.

System security

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.

Document content

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, and 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.

Communication

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.

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

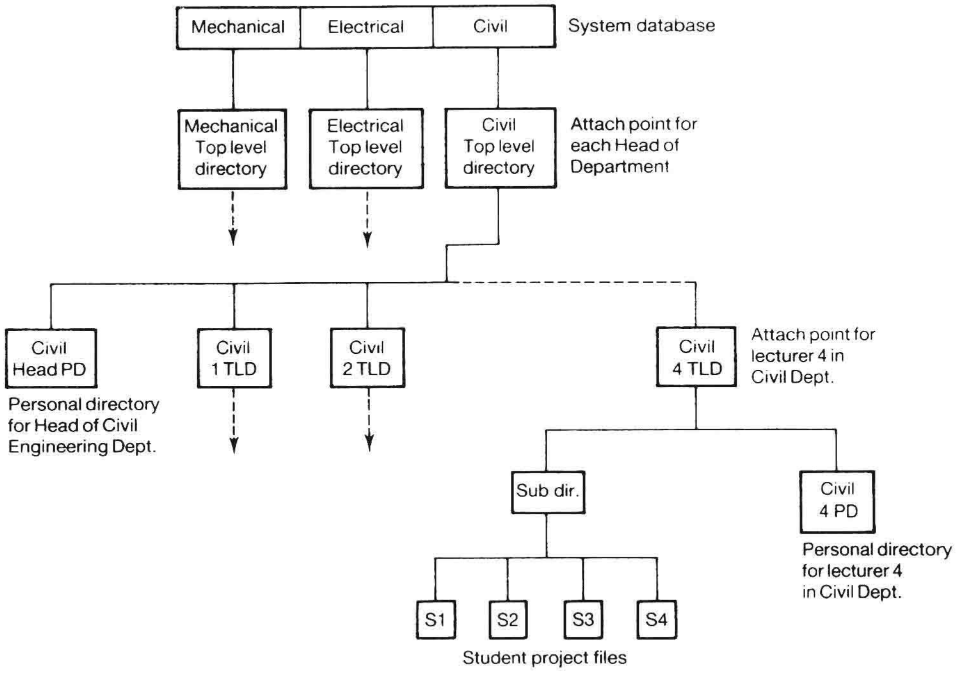

Fig. 2.2 Directory tree for controlled access to database

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 5750 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 Handbook 22* 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 relating to the design, are vigorously checked and approved by management. The stage by stage development of the product will follow an agreed work plan with checks, inspections and correction procedures. Similar plans will cover the manufacturing stages from raw material checks to the tested product. Good communication between all of the participants is essential to ensure that the product meets its specification and the customer's exact requirements.

A company which can demonstrate superior technical skill and expertise has a considerable asset which can be used to advantage in marketing. Proven excellence invariably increases pride and well-being in company employees.

Chapter 3
CAD applications

Rapid development has taken place since the early 1970s when 2D drawing packages were introduced with the ability to draw lines, circles and text. The industry has expanded and progressed and now produces very powerful design and modelling programs. Drawings and notes on the computer screen can be modified and edited with changes displayed in an instant.

A wide range of screen sizes are available in monochrome or colour. Any shade of colour is obtainable by the graphic artist. Drawings are reproduced in many sizes and small items present little difficulty with zoom facilities. Views drawn to different scales can be arranged on the same drawing print.

Flexible drawing systems provide a drawing area and a menu on the screen. 'Help' advice is freely available at the press of a button. Selecting and drawing from the menu is done by using a device such as a mouse or digitiser. Choosing from the options listed on the screen is performed by pointing and clicking the device.

The provision of multi layers provides a very useful method of working on CAD. Imagine transparent sheets placed on top of each other which may be shuffled and rearranged so that you can draw on the top. Each of the layers underneath in the pile can be turned on or off, they may be given identification colours and selected parts of drawings moved from layer to layer if required.

Assume that we want to draw plans for a house. Layer 1 could be used to draw a plan view of the building plot. Layout work is often easier if graph paper is used. On layer 2 we make our own construction grid which is transparent graph paper with squares to any convenient scale of our choice. Using this grid under layer 3 we design a suitable ground floor layout. Layer 4 showing the first floor layout could be started by tracing the position of the outside walls from layer 3. When all of the required plans and elevations are constructed, they can be repositioned on a drawing arrangement; and, if necessary, the site layout reduced to a smaller scale. When completed, the construction grid may be deleted. Tracing facilities and the ability to print layers together or apart are a valuable draughting asset.

The physical equipment components of a computer system are known as the *hardware*. The programs and data used on the computer are defined as the *software*.

Another advantage of CAD is its ability to store line systems and other entities which are frequently used on drawings. For example, software containing symbols to British, European and other International Standards is freely available for most engineering applications. Libraries of regularly used parts can be created by the draughtsman. For repetitive use on a drawing, a typical item may be retrieved and positioned in seconds, also oriented at any angle to suit particular circumstances.

As a drawing aid, every CAD program must provide geometric features, permitting the operator to blend lines and arcs. It is necessary in engineering drawing to be able to determine points of tangency between straight lines and curves and between curves of different radii. Productivity is much improved by a program enabling you to easily draw polygons, ellipses, multiple parallel lines and multiple parallel curves. The speed of machine drawing is increased by the use of automatic fillets and chamfers. Layout work benefits when use is made of construction grids; and the computer's ability to 'snap' automatically to particular geometric points and features, will speed the accurate positioning of linework. Copy, rotate and mirror facilities are also very handy when drawing symmetrical parts.

Automatic cross hatching within closed boundaries is useful in the construction of sectional views and when indicating adjacent parts and different materials. Many changes of hatch patterns are supplied with CAD programs. Filling areas in various colours is a requirement in artwork.

The ability to zoom in and out is an asset when drawing to scale. It is possible to work on fine detail in an assembly and then zoom out to observe the result in context.

CAD information is stored in digital form and hence, irrespective of the size of the final printed drawing, it is possible to accurately dimension components automatically.

Different 'type-set' and alternative style fonts are always supplied with CAD programs. If a special font is required to match an existing style then specialist vendors can supply. Alphabets in different languages present no problem.

Quite clearly the physically largest affordable screen has many advantages. If the draughtsman is involved with desk top publishing, it is ideal to be able to work on a screen which displays two A4 paper sheets side by side so that 'what you see is what you get'. The screen should give high resolution (1024×768 pixels minimum); this is necessary to give an image which is flicker free. The quality of the display will have a big contribution to make in the avoidance of fatigue and eye strain. On some installations the graphics are drawn on one high resolution screen with documentation and calculations directed to a smaller display. First hand practical experience is important here for an ideal solution.

Plotting and printing equipment will vary according to drawing office requirements. It is true however that many CAD installations are judged by the quality of their plotted drawing. It is necessary to have a demonstration and this will ensure that an excellent CAD system will have an output to do it justice.

A wide variety of plotters are available for reproductions from A4 to A0 in size, in colour or monochrome, and in a quality suitable for production work or the most prestigious presentations.

Autodesk Ltd (Cross Lanes, Guildford, Surrey GU1 1UJ) is the world's leading producer of CAD visualisation and animation software for personal computers and workstations. AutoCAD programs have been adopted in educational establishments, and since 1987 certified national courses of study by the City and Guilds of London Institute have been conducted throughout the country. Authorised training centres cater for the needs of local industry and of those who wish to develop their CAD skills further.

Autodesk has been at the forefront of applying standards within the computer aided design environment.

The main professional program AutoCAD is very much a non-specific or generic CAD tool and many applications are available to the basic graphics package which enhance its suitability for a particular discipline. The *AutoCAD Applications Handbook* which is a CAD User Publication lists more than 500 software packages which can be used to maximize productivity in association with AutoCAD.

AutoSketch

A typical starter CAD program is AutoSketch which is easy both to learn and to use. It is a low cost package, ideal for anyone who wants to use a computer to sketch or draw without investing in a full-scale system.

Drawings are created by choosing drawing and editing commands from pull down menus. Drawings, patterns and fonts are represented by simple symbols, or icons. You can draw on multiple layers and look at them in any combination. Repetitive drawing is eliminated; you can use previously created drawings to build libraries of frequently used symbols, saving time.

Having drawn an object you can move, copy, rotate, mirror, stretch and erase it until it matches your needs. You can group components together and treat them as one, and break them apart for editing. The UNDO command permits drawing changes, or to change back again, use REDO. Expanded memory support allows you to work with large drawings. Part clipping allows you to select items from existing drawing files and use them in others. Text and notes can easily be added or edited on the drawing using a variety of fonts. The drawing features include line options, arcs, ellipses, circles, points, pattern fill areas, spline curves and polylines with variable line width. Automatic fillets and chamfers are possible, and the program also offers zoom and pan facilities.

The program uses the industry standard DXF format, which allows you to export drawings directly into AutoCAD, and a wide selection of desktop publishing packages.

Computer requirements: IBM PC/XT/AT or PS/2 or 100% compatible. 640K RAM. A hard disk and floppy drive.

AutoCAD AEC

A comprehensive 2D and 3D draughting and design software package is available for architectural, engineering and construction work. From a 2D site survey, as an Ordnance Survey DXF file for example, you are able to start original design schemes. Speed and ease of revision permit different ideas to be considered without the need to redraw the entire plan. If the site survey is in 3D, you can also create 3D models and incorporate them into the site. An automatic perspective facility will allow you to view the design from any viewpoint, and to check on the look and feasibility of the project. Animated perspective walkthroughs can be produced with ease. BS 1192 Part 5, specifies a layered format and the scheme design could assemble 2D general arrangement drawings and layouts.

A vast library of architectural symbols is at your disposal. To insert a door into a wall, for example, you select one from a large range of door types, point to where you want to place it, the program will break the wall, insert the door and form the relevant detail. If you change your mind, repositioning is easy: just move it and the previous wall opening will automatically readjust itself. Bearing in mind that the library can contain all the standard types of doors, windows and furnishing items etc. that you regularly use or supply, then a proposal drawing is easy and quick to produce. At this stage initial costings and specifications can also be prepared. Facilities are also available for the design and modelling of the roof and staircases.

At the production stage a 3D model can be assembled from the approved detail available from 2D floor layouts, elevations and sectional details. The management facility in the program allows you to specify and attach production information to the drawings, and to extract it for estimating purposes and for the preparation of bills of material quantities. All members of a project team can share accurate and detailed information. Adapted drawings can be used by facilities managers to plan or change the function of a building for the benefit of occupants.

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