COMPUTER INTEGRATED MONITORING

VOL 1

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Computer Integrated Monitoring
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SUMMARY

Computer integrated monitoring is a very large area in engineering where on-line, real time data acquisition with the aid of sensors is the solution to many problems in the manufacturing industry as opposed to the old data logging method by graphics analysis. The raw data which is collected this way however is useless in the absence of a proper computerized management system. The transfer of data between the management and the shop floor processes has been impossible in the past unless all the computers in the system were totally compatible with each other. This limits the efficiency of the systems because they get governed by the limitations of the computers.

General Motors of U.S.A. have recently started research on a new standard called the Manufacturing Automation Protocol (MAP) which is expected to allow data transfer between different types of computers. This is still in early development stages and also is currently very expensive.

This research programme shows how such a shop floor data acquisition system and a complete management system on entirely different computers can be integrated together to form a single system by achieving data transfer communications using a cheaper but a superior alternative to MAP. Standard communication character sets and hardware such as ASCII and UARTs have been used in this method but the technique is so powerful that totally incompatible computers are shown to run different programs (in different languages) simultaneously and yet receive data from each other and process in their own CPUs with no human intervention.

KEYWORDS: Data acquisition, MAP, ASCII, CPU, UART

To my parents and yesterday's dreams.

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Chapter 1

Introduction

Monitoring is an essential part of engineering manufacture which has been in existence for a number of years. It is the single most important process which allows to increase the efficiency of any manufacturing operation. It is also the vital link between design and manufacture which some people imagine as missing. Many engineering companies spend millions of pounds on computer aided design or computer aided manufacture but never look further to see whether the design or the manufacture is successful.

The manufacturing process must be monitored to obtain such information as to whether it is progressing to the desired level. There can be two reasons for performance being not optimum. The first is that the physical process of manufacturing is faulty while the second is more serious and that the design of the components is faulty. Monitoring therefore not only allows corrective action to be taken on the manufacturing process but also to redesign a faulty or an inadequate design.

Monitoring was carried out in the early days by the graphics analysis method where an ink pen was attached to the process. This pen used to draw curves on a plotter and the management could analyse data at the end of an operation. This method does not allow the data to be analysed on the shop floor itself and as a result prompt corrective action can not be taken in the case of an error in any operation. On the other hand, Computer Integrated Monitoring on a real time on line basis allows the management to observe every operation while it is taking place. However, the monitored variables will not be much of a use in the absence of a proper management system which can process the data and present them in a proper format. Such a management system can establish the essential link between computer aided design and computer aided manufacture.

To monitor the shop floor processes one must first of all build some suitable sensors on to the equipment and these sensors should feed the appropriate data or control signals to computers. More than one level of computers is needed to couple the design and management work with the shop floor monitoring and data acquisition. Unfortunately this is where most of the companies halt their computerization due to the very complicated nature of monitoring.

Selecting compatible computers[1] for all the different levels or buying a complete system from a single vendor is a nightmare for the companies because of the complexity of requirements and the huge capital outlay which is involved. A further problem is that a company who has a computer aided design system and wants to extend it to manufacturing has no other alternative but to buy further equipment from the same vendor who supplied the computer aided design equipment, so that all the equipment is compatible. The vendor at this juncture may or may not be in business which gives rise to many more problems.

All the above problems led the industry to a search for a standard system which enables totally different peripherals to communicate with each other regardless of their sizes, capabilities or the formats in which the data is stored or handled. Therefore in the mid 1970s; the International Standards Organization (ISO), National Bureau of Standards (NBS), Computer Business Manufacturers Association (CBMA) and the American National Standards Institute

(ANSI) started work on a project called the Open System Interconnection (OSI) standard. Meanwhile the International Electrotechnical Commission (IEC) and the Instrument Society of America (ISA) began work on the PROWAY standard for the industrial and process data highways. The Institute of Electrical and Electronic Engineers(IEEE) of USA then formed the project 802 committee in 1980 for the purpose of Local Area Network (LAN) standards.(2)

In early 1980s General Motors (GM) realized that they require multivendor automation systems in order to compete with the Japanese and win back a portion of the market which originally belonged to them. They were also aware that the OSI standards were already accepted by a majority of manufacturers.(3) This gave way to their much publicized Manufacturing Automation Protocol or MAP for which OSI was chosen as the basis. GM has spent millions of dollars to date on research on this model.(4)

These standards however are not only in their early development stages but also are very expensive for a small or a medium range manufacturing company to implement. One of the main objectives of this research is to use a cheaper alternative to MAP in order to design and implement a complete computerized management and a shop floor monitoring system for a West Midlands based manufacturing company, which will be referred to as 'the client' from hereon.

The company has an annual turnover of in excess of £12 million in the business of sheet metal work and the raw material arrive in form of coils to be fabricated by cold rolling. The company has a string of subsidiary companies; each of which is headed by it's own General Manager and is responsible for its own operations, expenditure and profits.

Each subsidiary company also has four rolling mills (production lines) and all the operations are manual. The future policy of the group is that all the subsidiary companies should adopt same methods of manufacture so that it is feasible for the top management to have access to all the information throughout the group of companies although the personnel of one company should not have access to the data of another company.

The main objectives of this research programme can be summarized as follows.

(1) Create a large data base using a suitable host computer for all manufacturing processes including job creation, historical product and performance information, overall production reports and management activities.

(2) Design and develop application software and a set of rules for easy extraction and the usage of above information in the manufacturing process.

(3) Design and develop software for real time automatic scheduling of jobs for all production lines to optimize performance.

(4) Design a microprocessor based on-line real time monitoring system (software and hardware) which will acquire data from the shop floor and feed automatic control signals to a monitoring computer.

(5) Design software and hardware to allow operators to input manual signals to a computer which relate to categories of downtime.

(6) Design and develop suitable protocols for the total integration of the sections 4 and 5 above.

(7) Investigation in to a suitable cheaper alternative to Manufacturing Automation Protocol and usage of this in automatic data transfer communication between the host and the monitoring computer.

(8) Design hardware and software protocols for the above communication.

(9) Design and develop suitable methods of security so that the system is completely fool proof and that different users have different levels of access.

(10) Investigation in to different alternatives of hardware for cost effective, stage by stage design, development and

implementation of the system ensuring that the progress is made in the correct direction by constant liaison with the company personnel.

Chapter 2

Cold Roll Forming

2.1 Introduction

Cold roll forming which is also known as contour roll forming is one of the important metallurgical methods for fabrication of materials. The objective of this chapter is to describe the cold roll forming process briefly because it is the business of the company which is involved in this research. It is however not the intention of the author to look in to this aspect deeply because a substantial amount of research has already been carried out[5,6,7] in this area.

2.2 Definition of cold roll forming

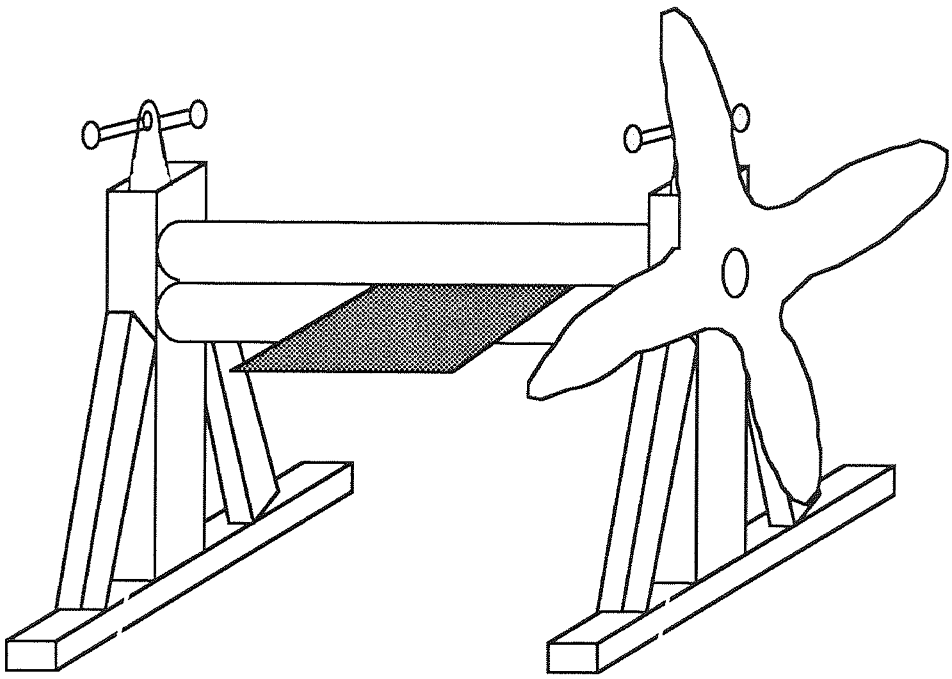
Cold roll forming is a process of forming metal from sheet, strip or coiled stock, in to shapes of essentially uniform cross section, generally by feeding the stock longitudinally through successive pairs of rolls, each pair progressively forming the stock until the finished cross section is produced.[8]

2.3 History of rolling

The history of cold rolling goes as far back as the fourteenth century where hand driven rolls were used to flatten precious metal and coinage metal. These rolls were small and were about 1.25cm of diameter.

Proper documentation on cold rolling exists only from the later part of the 15th century and the first known rolling machine was designed by Leonardo da Vinci in 1480. This was known to consist of two mills which were driven by worm gears. This machine was known not only to roll lead sheets but also to produce tapered lead bars by means of a die and a spiral roll.[9]

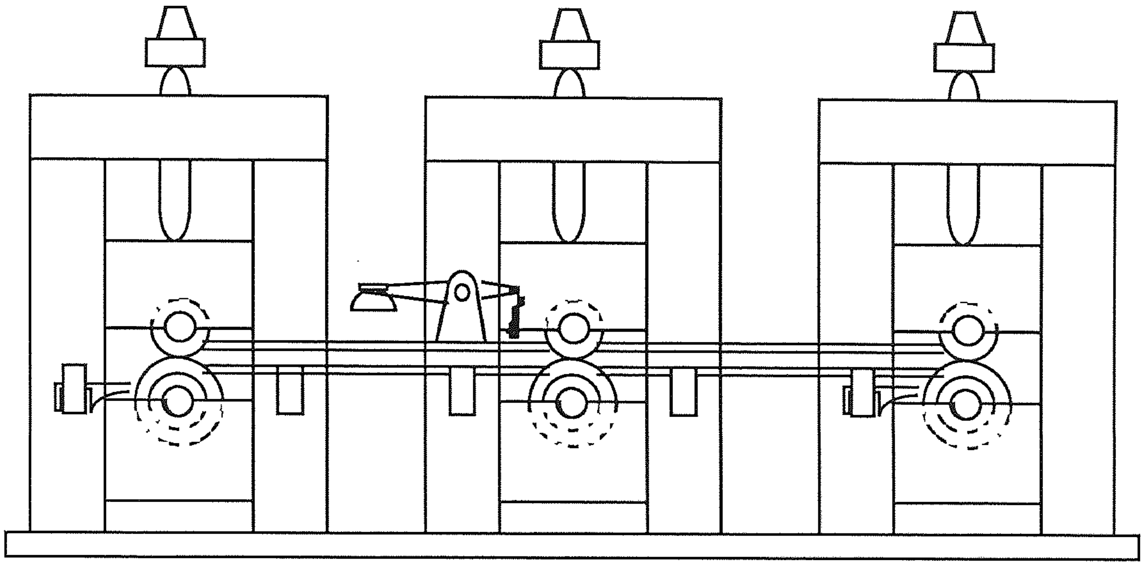
Lead sheets became popular for roofing in the early 17th century and Solomon de Caus built a hand operated mill in 1615. A sheet of lead or tin was fed between two rather long rolls (almost like bars) in this mill and these rolls had to be rotated by turning a large cross shaped part of the mill which is pivoted from the centre to the lower roll. The cross has to be large (figure 2.1) since the human who is turning it can do so by applying the minimum necessary force at a maximum distance from the pivot so that the maximum moment is obtained.



Solomon de Caus's hand operated mill

Figure 2.1

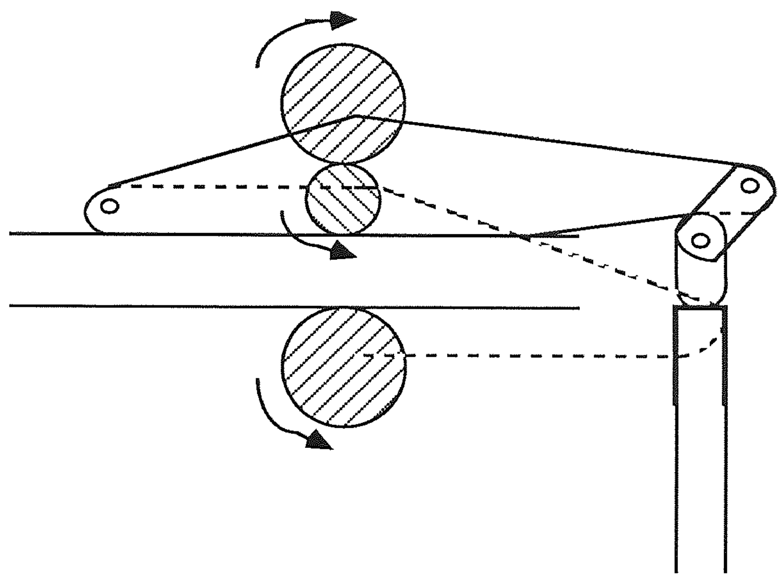
These early developments of rolling mills obviously were able to roll only softer metal alloys and presumably at elevated temperatures which made the process hot rolling rather than cold rolling. More efficient rolling mills were available towards the turn of the seventeenth century for both hot and cold rolling of many harder materials. Rolls were grooved in the mid eighteenth century with coupling boxes and nut pinions for turning them in unison. This saw the advent of the tandem mill (figure 2.2) in which the metal is rolled in successive stands. These tandem mills were modified in the nineteenth century by adding mechanical guides.



Tandem mill

Figure 2.2

It was in the nineteenth century that the demand for cold rolled products began to grow rapidly because of the industrial revolution in Britain. Therefore the sizes of mills also increased almost in hand in hand with this demand. It was also in this period that the three high mills (figure 2.3) were introduced. The middle roll in this mill which is driven is fixed but the other two are adjustable. Derived from the three high mill a number of other types of mills, with varying number of rolls began to be in use since then and many of these are still in use today.

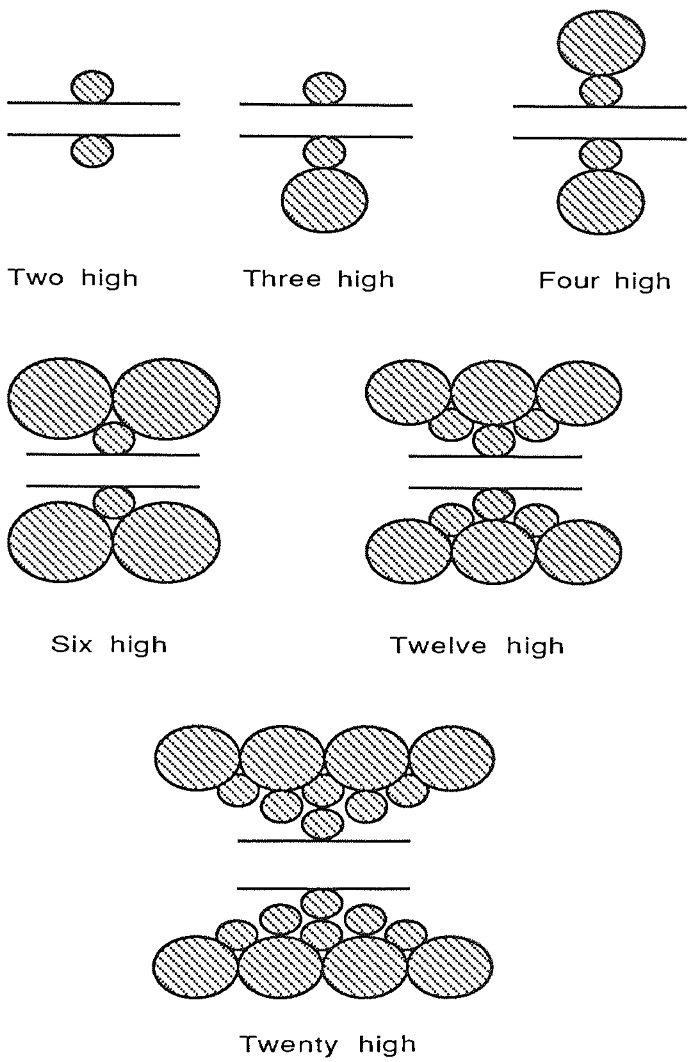


Three high mill

Figure 2.3

2.4 Rolling mills

The rolling mills are normally classified on the basis of their roll arrangements. Two high, three high, four high and cluster type of mills (figure 2.4) are some of these.



Different types of mills

Figure 2.4

Most of these mills are known as sheet mills while tin mills roll the same material to tinplate stock. Some of the mills which are known as foil mills reduce the metal to a thickness of about 0.04 of a milimetre.

2.5 Materials used in cold roll forming

Steel is the most popular material which is fabricated by rolling although any ductile material[10] can be roll formed. Stainless steels which have a wide range of chemical compositions and physical properties are rather difficult to cold roll than carbon steels but it is not uncommon for such steels to be cold rolled.

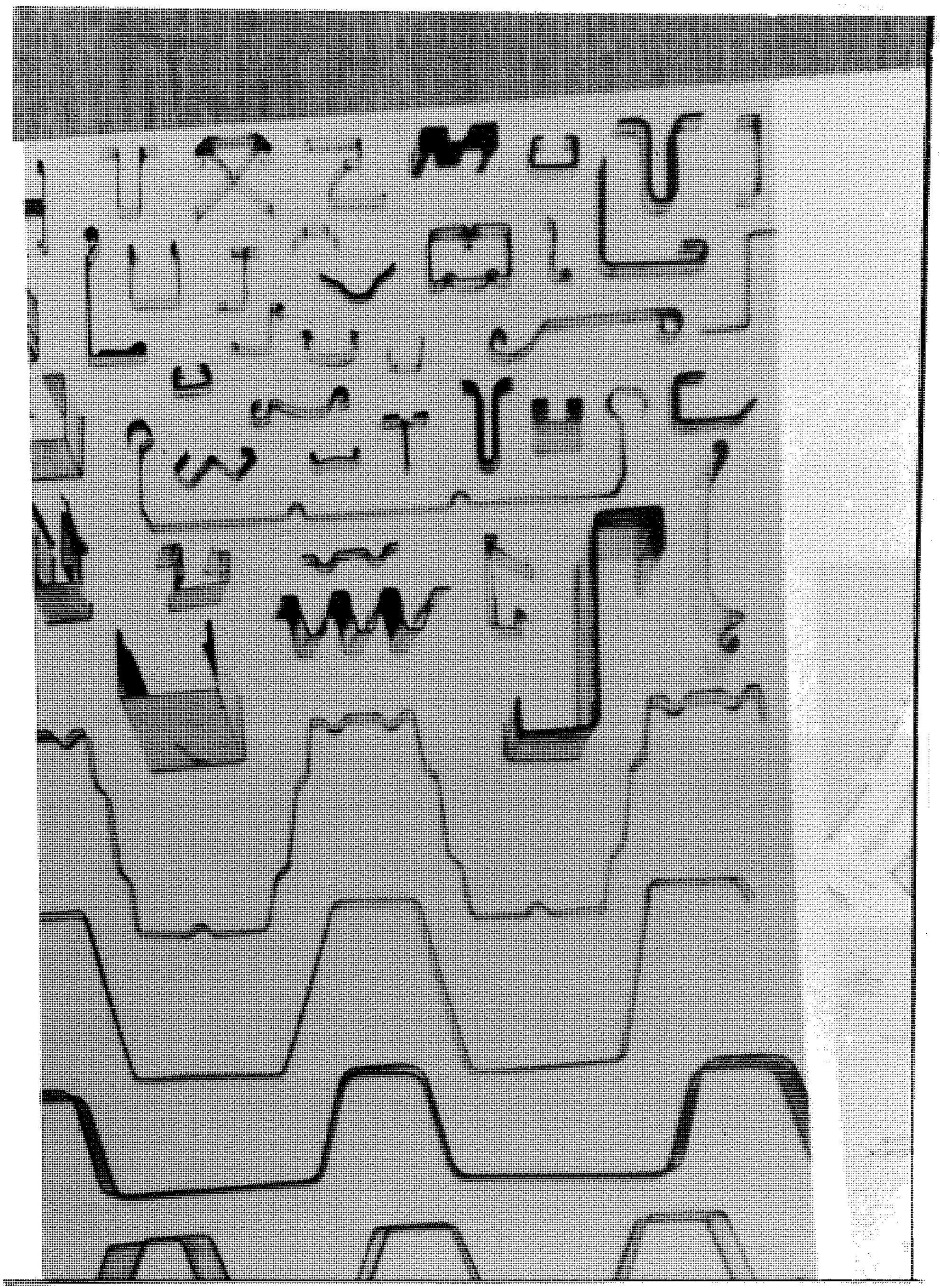
Ductile non ferrous metals are also fabricated by cold rolling while brittle alloys like Magnesium and Titanium have to be rolled at elevated temperatures like 200 to 300 ^{0}C to achieve the required ductility, thus making the process hot rolling. Cold rolling of perforated steels are also common and some of these are galvanized sheet, terne and sheets with metallic painting. Even the sheets with paint or non metallic coating can be successfully fabricated by cold roll forming.

2.6 Cold roll formed products

Cold roll formed products range from various sections (plate 2.1) which form household ceilings, water drain pipes, wall panels and drawer assemblies to flanges, steel joints, and channels. In addition, cold rolled products are used in parts of railway freight cars, ship bodies and automotive panelling. Even heavy building construction components such as individual structural members or floor, roof and wall panelings use these products. One booming industry which uses cold rolled products today is the double glazing industry where aluminum door and window frames are very popular.

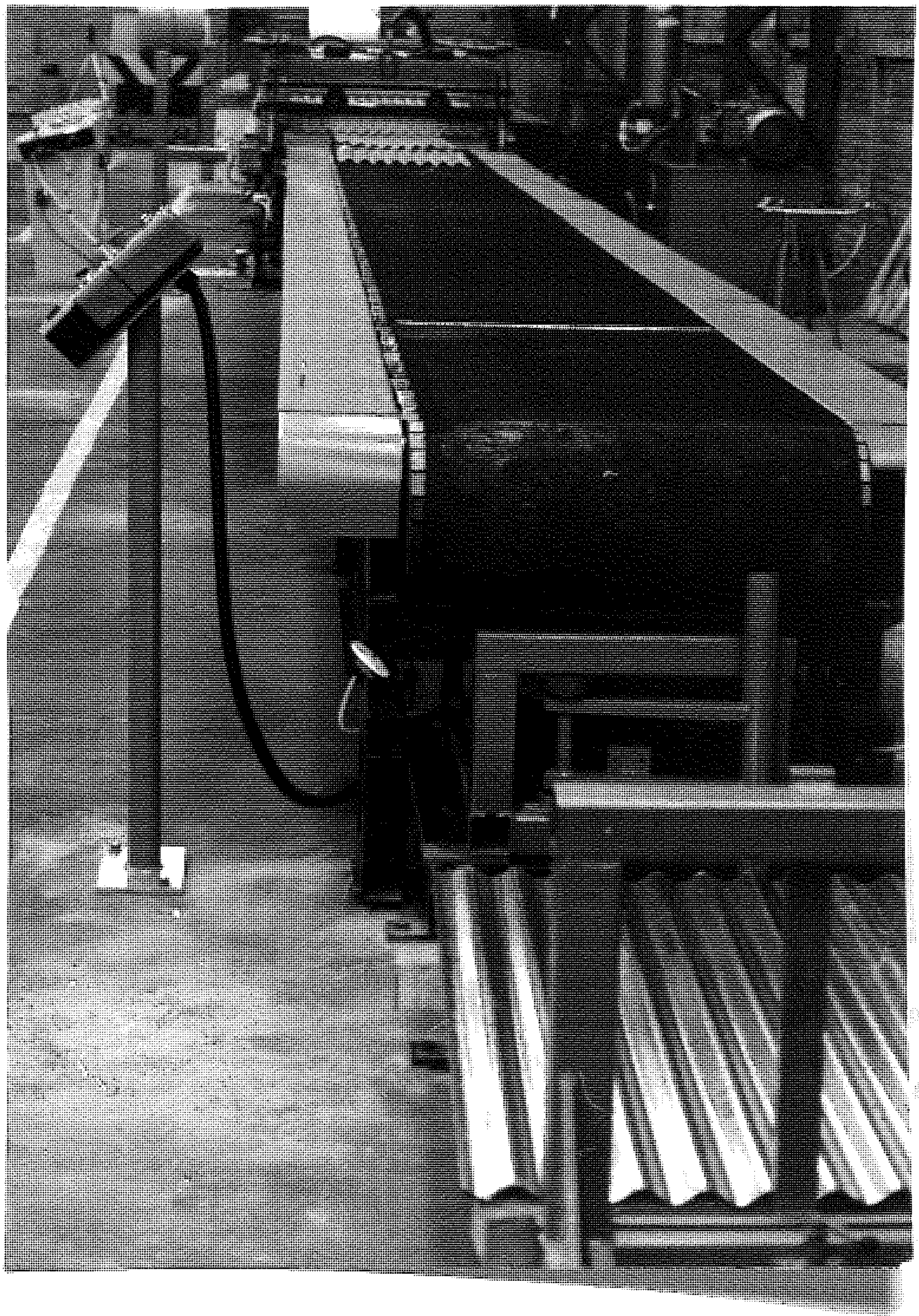
2.7 Forming operation

A typical rolling mill (plate 2.2) consists of a welded steel base on which are mounted a series of roll stands, each of which can hold a pair of horizontal rolls. These positions are called forming stations. The raw material which consists of sheet, strip or coiled stock is generally fed longitudinally through these pairs of rolls to form the required shape gradually at the stations.



Some cold roll formed sections

Plate 2.1



A typical cold rolling mill

Plate 2.2

The number of roll forming stations, the shape of rolls or the width of the base can vary depending on the complexity of the operations to form the required shape of the final product. It is quite normal to have an ironing operation at the end where the rolls have the mirror image of the contours of the finished section. It may also be possible to have one or two vertical rolls which are known as side rolls, at some stations in order to form more complex shapes. The distances between stations and also the heights of the rolls are adjustable. The whole process is usually manual while the rolls are electrically operated.

The raw material which is relevant to this research always consist of coiled stock; and the lengths, widths or gauges of these vary just as in the finished products. The production is done in the batch basis and each batch of finished products has to comprise of the same width, gauge, length and shape. The rolling mills have to be set up each time a new batch is required.

Cutting off operation (plate 2.3) is done at the end of the mill by a press or a guillotine. The position of the press can be set up by setting up a movable plate (plate 2.4) which is attached to the mill base. An electro-mechanical switch is attached to this plate which in turn is connected to a relay which operates the press. The position of the plate is fixed for a whole batch of products and they can be cut to a fixed length as accurate as $^{1}/_{100}{}^{th}$ of a milimetre. The final product has to be collected and stored by an operator at the end of the press operation. This has to be done before the next unit is arrived but the operator can switch the rolls off and hence stop flowing of the work in progress at any time if he requires.

Lubrication performs a major part of roll forming as in many other manufacturing operations by reducing friction and cooling both the material and the tools so as to maintain a high standard of surface finish. It is also necessary to use strip guides (plate 2.5) to prevent the material from moving away from the base.

2.8 Additional operations

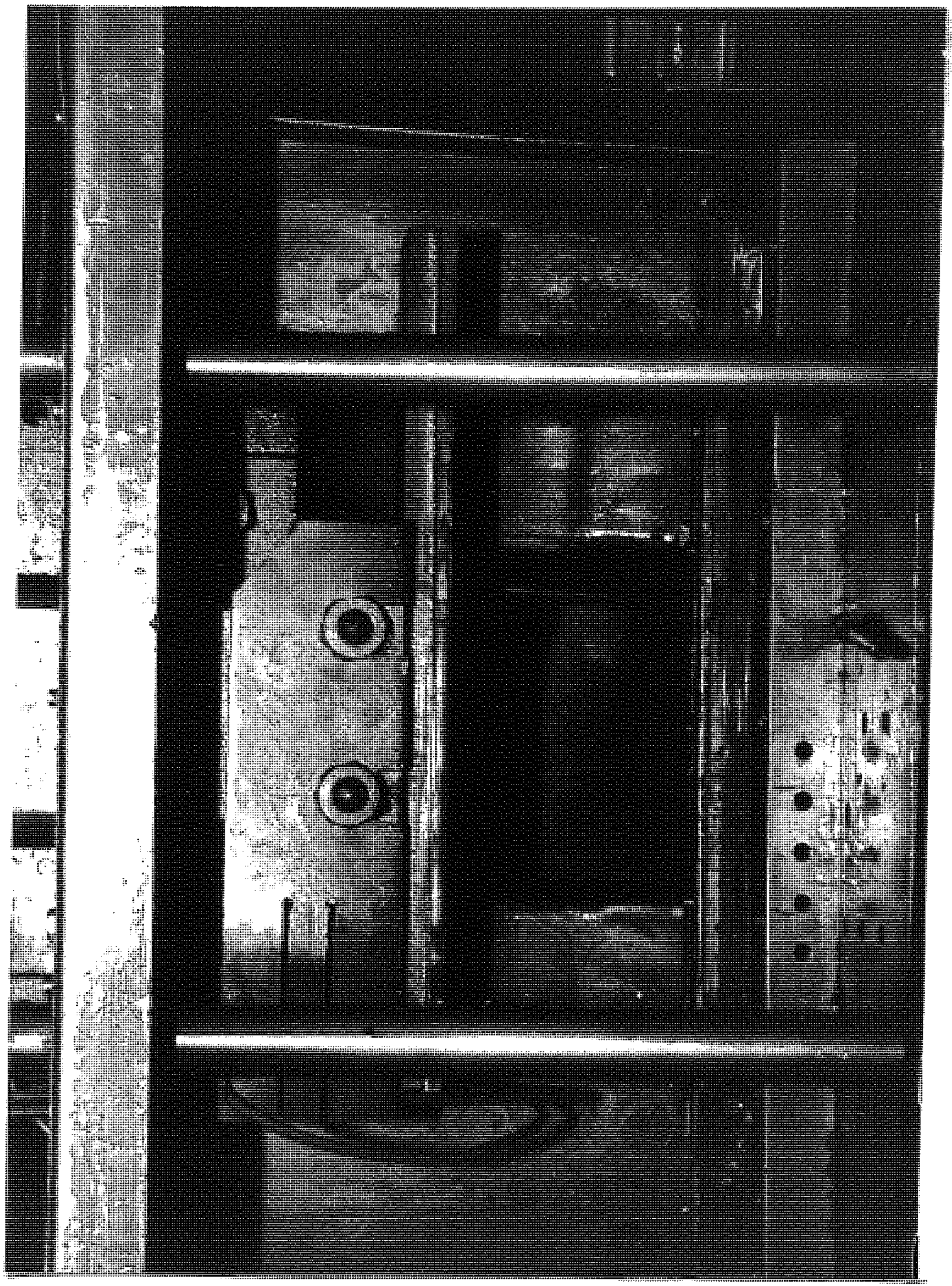
The additional operations which are of special interest to this research are piercing and notching. While it is not the intention of the author to go in to details of cold roll forming it must be emphasized the importance of these additional operations because the earlier mentioned relay is used for these operations, thus energizing it more than once for each unit. The effects of this will be discussed later.

While press work is the most important, painting and packing[11,12] can be the other two frequently associated additional operations.

2.9 Microstructural changes during rolling

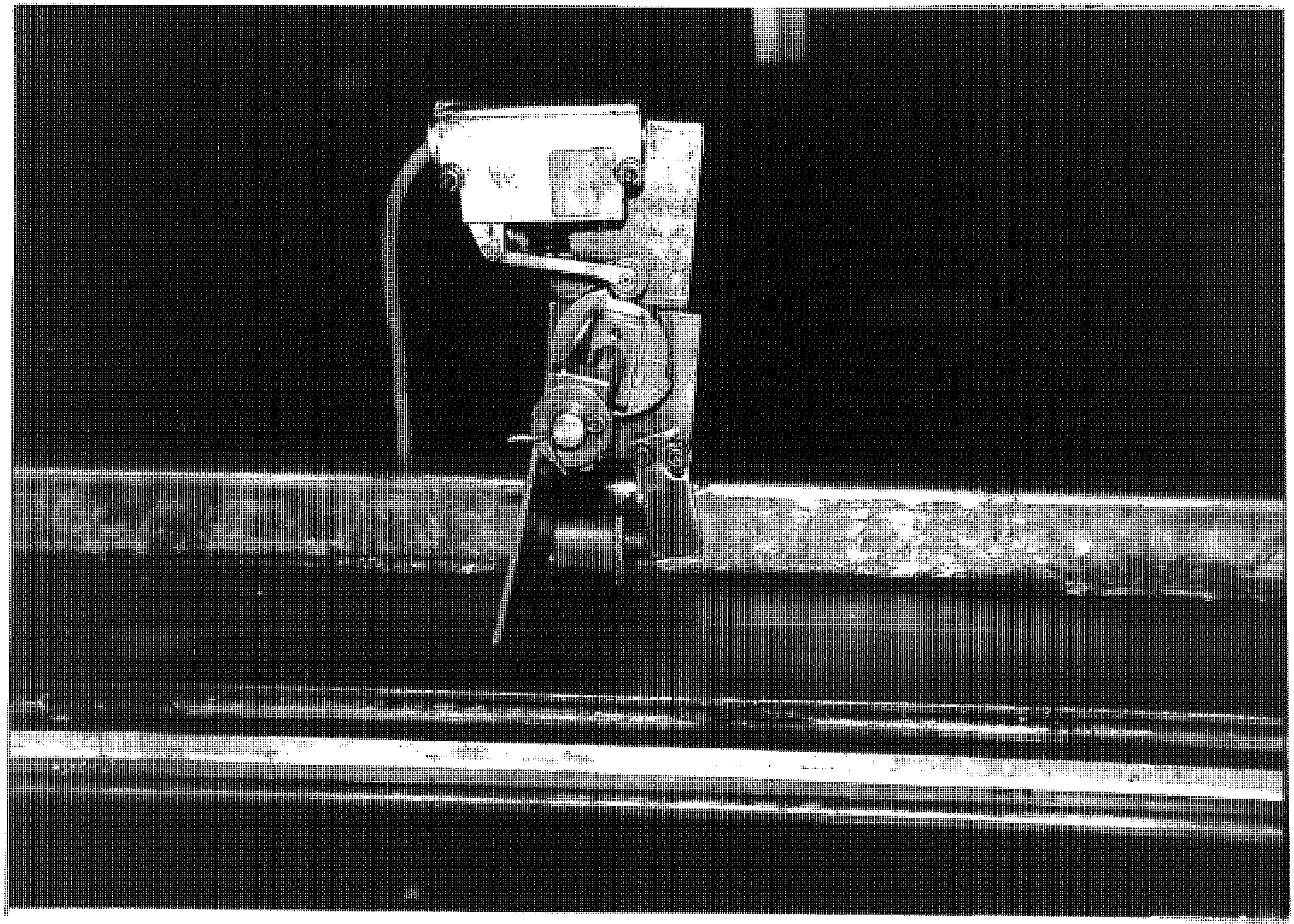
The impurities are re-distributed during rolling rather than being eliminated, and the effects of segregation which was present in the original material are reduced. The mechanical mixing action of rolls also produces a more homogeneous product but with a reduced grain size.

The crystals are first distorted in rolling and then mechanical slip takes place and as a result they become work hardened. The degree of cold work when a material is rolled, not only gives the required surface finish but also is sufficient to give the required combination of work hardening, ductility and strength.



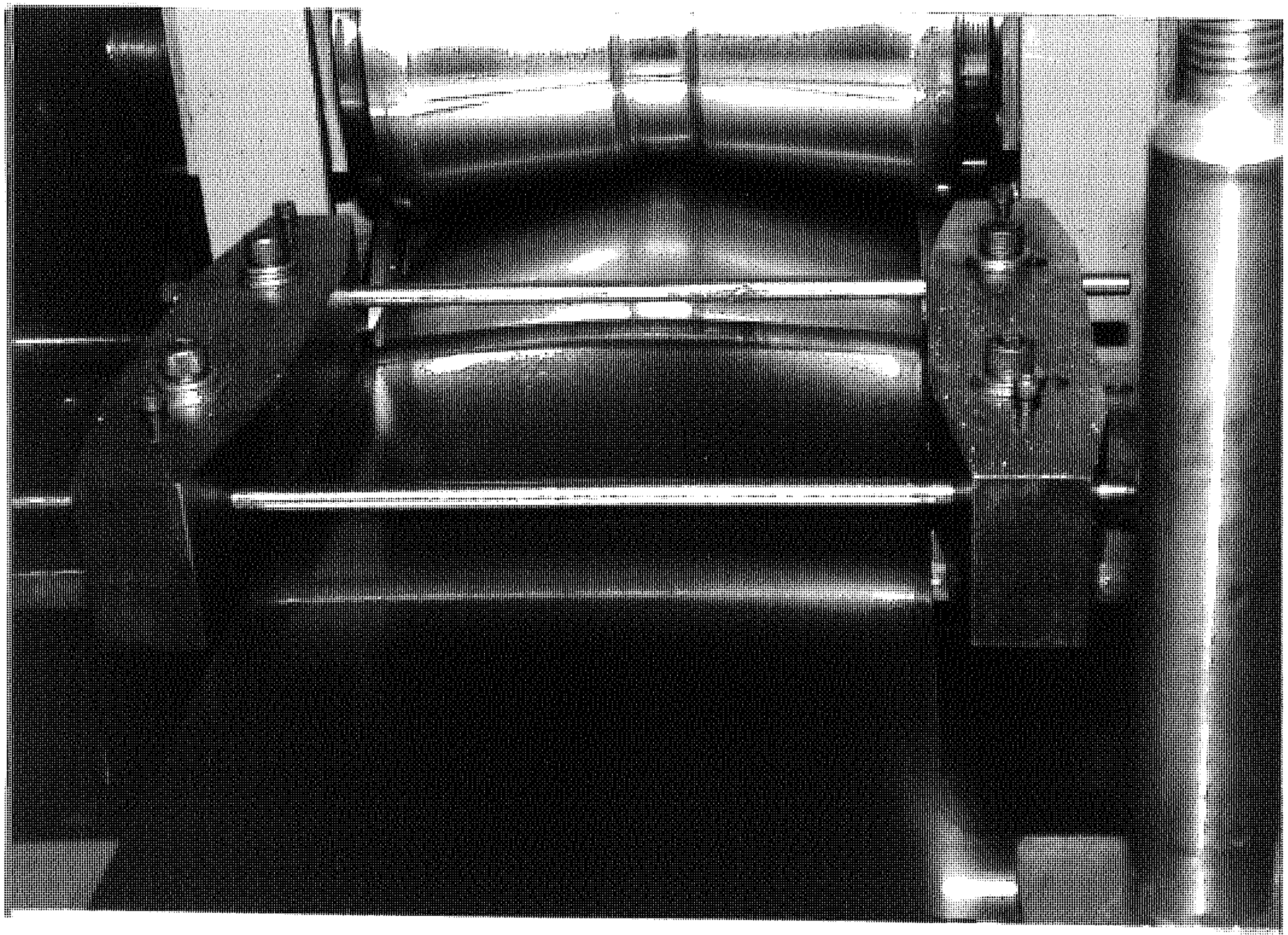
Press operation

Plate 2.3



Movable plate in press operation

Plate 2.4



Strip guides

Plate 2.5

2.10 Advantages of cold roll forming

The biggest advantage of cold roll forming is the capacity for high production. Generally speeds of 25 to 50 metres per minute can be achieved while speeds as high as 100 metres per minute are reported to have been achieved.[9] A production rate of 900 to 1500 metres per working day is not uncommon in the industry.

Another advantage is that the sections which are produced by cold roll forming have a uniform cross section and can be held within the required tolerances. It is possible to be within tolerances as small as 0.025 of a milimetre.

Furthermore, cold rolling can be performed without any destruction of the surface finish or coating. Even those material which are painted, electroplated or pre coated can be successfully rolled without harming their surface finish.

Another interesting and an important advantage of cold roll forming is that, more than one different material can be fed in to the same machine simultaneously to be combined in to a single product. Not only metal but also wood, felt, fabric, cord or wire can be incorporated to a roll formed channel or a box shape. An example of this is the weather stripping metal strip around vehicle windows while another is the flexible sound insulating coupling for an air conditioning duct which is made by combining galvanized steel strip and fabric.

Finally it must be mentioned that the cost of manufacturing is greatly reduced in cold roll forming because of the possibility of manufacturing a large number of components at a high speed once a machine is set up.

2.11 Alternative methods of fabrication

There are many other methods for fabrication of metals, each of which is suitable for a different type of a metal or an alloy depending on it's properties. Since most metals are found as Oxides, Sulphides, Chlorides or Carbonates;(13) the ores must first be converted to metals by chemical reduction which is known as Extraction metallurgy or Chemical metallurgy.

As opposed to Chemical metallurgy; fabrication by Physical metallurgy allows atoms to re-arrange themselves[14,15] in a different order by changing the temperature. This can be done suddenly by quenching, and plastic deformations occur as a result, making the crystal harder. This is known as work hardening and recrystallisation occurs when the metal is annealed thus eliminating all plastic defects. Completely different atomic patterns are developed by this method and some alloys like aluminum when left at room temperature after quenching, form atoms in small clusters[16] and the process is known as precipitation hardening.

A number of intermediate compounds like Ferrite, Cementite, Pearlike, Martensite and Baynite are obtained when the iron ores are reduced by heat treatment methods. Some of these are stable while some others are meta-stable.

Casting is another section of Physical metallurgy where the required shape is obtained by pouring molten metal in to a mould. Methods of casting are numerous and some of them are Sand casting, Die casting, Ingot casting, Chill casting, Centrifugal casting, Shell moulded casting and Continuous casting.[13,15,16,17]

Cold rolling comes under Mechanical metallurgy and this section of Metallurgy is equally popular as the other sections. Some of the methods under Mechanical Metallurgy which are comparable to cold rolling are described briefly below.

2.11.1 Forging

Forging is suitable for billet or bar stock and is worked progressively in to the required shape by the use of dies with cavities and contours[18] which are previously cut. The work piece which has been heated up to the forging temperature by hot Coke is inserted in the die and is hammered until the die is completely filled.

More complicated shapes can be produced by forging because the necessary contours can be built in to the dies. Closed die forging where two die blocks are used to form a hollow pattern in the middle is a good example of this. Usage of two dies makes it easier to fill the cavity completely.

2.11.2 Extrusion

Extrusion is a method which is used to produce solid and tubular stock[18,19] in relatively complex sections. An example of a finished product is the tooth paste tube.

These products are made by forcing a heated cast billet through a die by applying pressure using a hydraulic ram. Extrusion is a very popular method of fabrication since the final shape can be obtained in a single process from a billet.

2.11.3 Drawing

Cold drawing process[18,19,20] is used for the production of rods, wire, high quality tubing and hollow sections. The rod or the tubing is reduced gradually by drawing it between successive pairs of dies or grips and therefore can be directly compared with cold rolling.

Any ductile material can be drawn down to very small diameters and to exact sizes. The surface finish also is much better than that of forged or extruded products. Cold drawing however, is rather a slow process and therefore is more expensive. Some of the allied processes of drawing are Redrawing and Deep drawing.

2.11.4 Powder Metallurgy

Powder metallurgy is the only method which can be used to produce some very complicated shapes and certain properties. The metal powders are mixed, blended and compacted[15,16,17] before being sintered to a temperature below the melting points of any of the constituents to give the appropriate shape. Therefore nearly all machine operations are eliminated, thus reducing scrap.

Chapter 3

An overview of Computer aided design, manufacture and monitoring

3.1 Introduction

The purpose of the engineering practice is to provide 'ingenious' systems to fulfil human needs. For this purpose the engineer must make a selection from all the available resources, of what seems to be the most suitable at a glance.[21] The engineer must then check, improve and optimize this to achieve this target. This process is known as the design.

Manufacturing on the other hand is the physical process which fulfils the human need while it must essentially come after the design and sometimes it is only at this stage that certain design faults are identified. Monitoring is a vital part of this manufacturing which helps to identify such problems and it also allows to achieve a more efficient manufacturing process.

3.2 Design

Design which is defined below is a very ancient art and it can be called a science when used in conjunction with engineering.

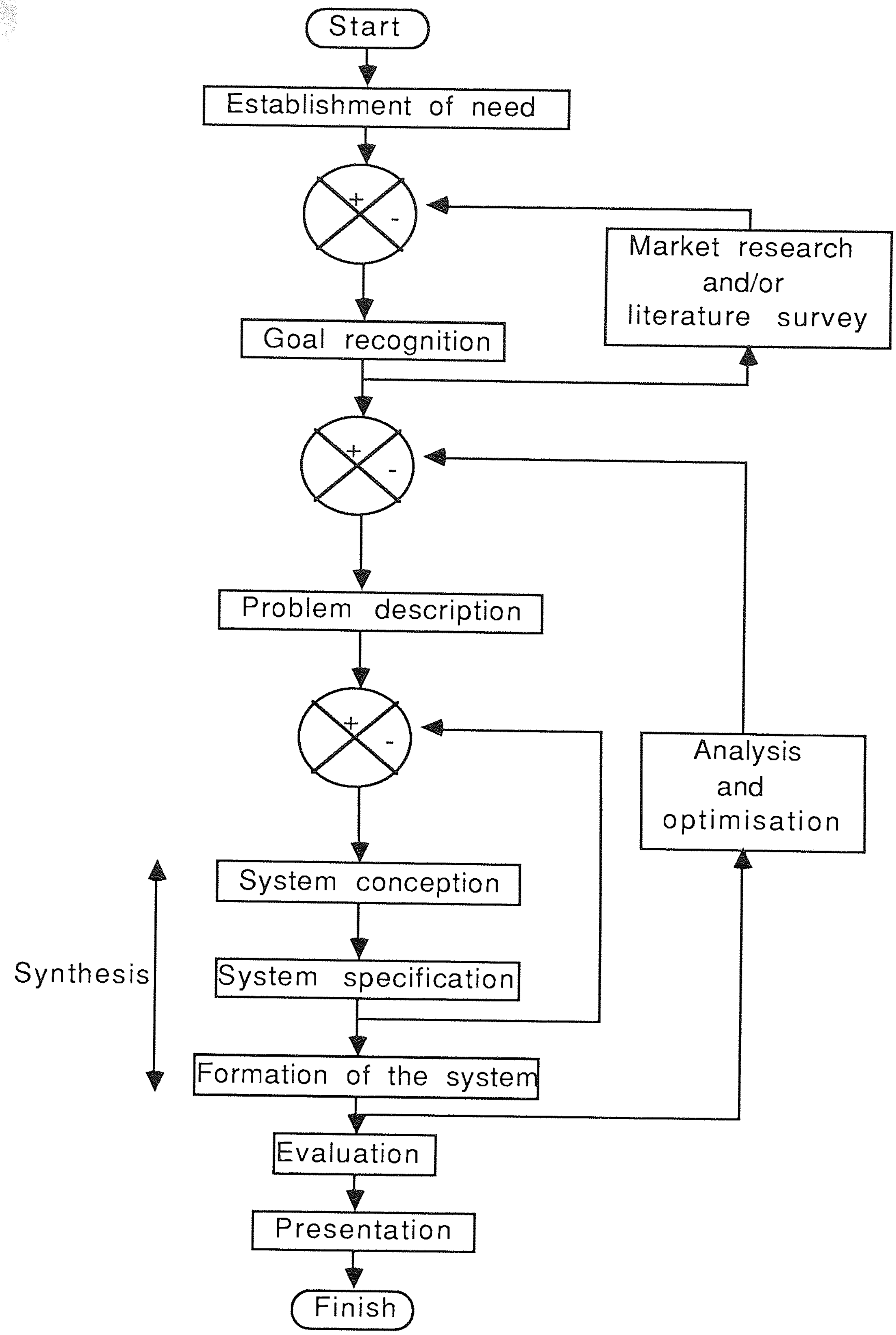
(1) A goal directed problem solving activity.[22]

(2) The conditioning factor for those parts of the product which come in to contact with people.[23]

(3) It involves bringing in to being something new and useful that has not existed previously.[24]

The author of this thesis defines design as a process in which an expert forms ideas and presents them in such a way so as to create a new product or to change an existing product to satisfy the needs of an individual or a group of people.

The actual design process can be expressed in the following six stages[25,26] and chart 3.1 shows how these are connected.



The design process

Chart 3.1

(i) Establishment of need.

(ii) Definition of the problem (Goal recognition)

(iii) Synthesis (engineering design)

(iv) Analysis and optimization (engineering analysis)

(v) Evaluation

(vi) Presentation (engineering drawings)

Hence it is obvious that the design is a very long and a complicated process and the designer must not only have a creative mind but also should be very methodical and has to work in a structured manner. There are a number of techniques to aid the design process and design is sometimes called 'the problem' while the design techniques as follows are known as problem solving techniques.

(1) Brainstorming

(2) Synectics

(3) Delphi technique

(4) Morphological analysis

(5) Attribute listing

(6) Marple's design trees

(7) Inversion

(8) Fantasy

(9) Empathy

(10) Analogy

(11) Visualization

3.2.1 Brainstorming

Brainstorming is one of the oldest yet most successful techniques in design. It is a technique where a small group of people gather in an informal environment to contribute ideas freely. In Webster's dictionary[27] brainstorming is described as 'to practice a conference technique by which a group attempts to find a solution for a specific problem by amassing all the ideas spontaneously contributed by it's members.' Creative thinking is the key subject in this technique[28] and humor is encouraged to such an extent that Von Fange[29] calls it 'a bull session in a relaxed atmosphere'. Criticism however is not allowed as this may discourage people from expressing their ideas for the fear of being ridiculed in public.

The designer should write down all the ideas at the session without discrimination, to be analysed later. It has been known that the best results are achieved when the members know nothing about the problem prior to the discussion and this type of creative thinking is known as divergent thinking.(30)

3.2.2 Synectics

Sinectics is a more structured process than brainstorming and is also more formal. The group in this case consists of a leader, an expert and 6 or 7 other members who are experts in their own areas. Ideally they should have had a number of jobs,(31) which would have given them a broader knowledge and an understanding about varied processes while there is no need to have a prior knowledge about the problem in discussion.

The meeting starts by the leader introducing the problem to the members and the technical term for this is 'problem as given'. The expert then explains all he knows about the technique and this is known as 'making the strange familiar'. Each member is then asked for suggestions and the expert comments on them. Any potential solutions are written down at this stage and are called 'view points'. The process of narrowing down all the suggestions to the potential solutions is called 'purge'.[32] This type of thinking is called convergent thinking.

Each member of the group can and will see the problem in a slightly different manner ('problem wishful') and they will contribute to re-pattern the original conflicting ideas until a pattern which is capable of resolving the conflict emerges.[33]

The human brain sometimes tends to reject certain ideas simply because they seem irrelevant at first. Synectics takes this behaviour in to account by introducing strangeness deliberately in to certain topics in design. For example in a case where a paratroopers' equipment has to be designed, the title can be given as 'an organized mess'. This technique is known as 'Book titles'.[34]

The synectics technique has been so successful in the past that even a company has been formed[35] in the United States of America for the business of solving design problems for other companies. The representative of Synectics Inc. will become the leader of a synectics group who will get only an introduction about the problem from the company which has the design problem while the expert is their designer. It can be seen from here that the employees of Synectics Inc. are not expert designers but are experts in guiding the designer to solve the problem.

3.2.3 Delphi technique

Delphi technique is also a group technique but a group does not gather as in the cases of brainstorming or synectics. The designer describes the problem and sends a questionnaire to the group and the group can answer it in leisure.

The replies are then collected before the standard deviations and the average of the answers are calculated. Once these calculations are done, the members are contacted again for then to re-consider their original replies. If the original reply of a certain member is outside the standard deviation then he would be asked to give reasons for his reply while the others need not justify their original answers.

This technique is useful after the designer forms his original ideas about the design because he himself gets a chance to re-consider the original ideas before proceeding. Personalities do not clash in Delphi technique as the people do not meet each other and therefore it is also a good market research technique.

3.2.4 Morphological analysis

This technique forces the designer to look at a methodical procedure of analysing all possible combinations.[36] In morphological analysis all different dimensions of a problem have to be looked at and all concerned parameters are listed vertically and horizontally[37] in a table or a matrix. Finally each square where there is the slightest possible combination (table 3.1) is marked. The marked values are then further analysed.

3.2.5 Attribute listing

This technique is based upon describing the characteristics of an equipment which are essentially the following.

(1) the materials from which the item is made

(2) possible methods of manufacture

(3) the specific ways in which the item is used

Listing these attributes is somewhat similar to morphological analysis but the possible alternatives are searched in this case instead of trying to find the possible combinations. Then all ideas which have arisen as a result of this 'alternatives search' are listed and analysed.

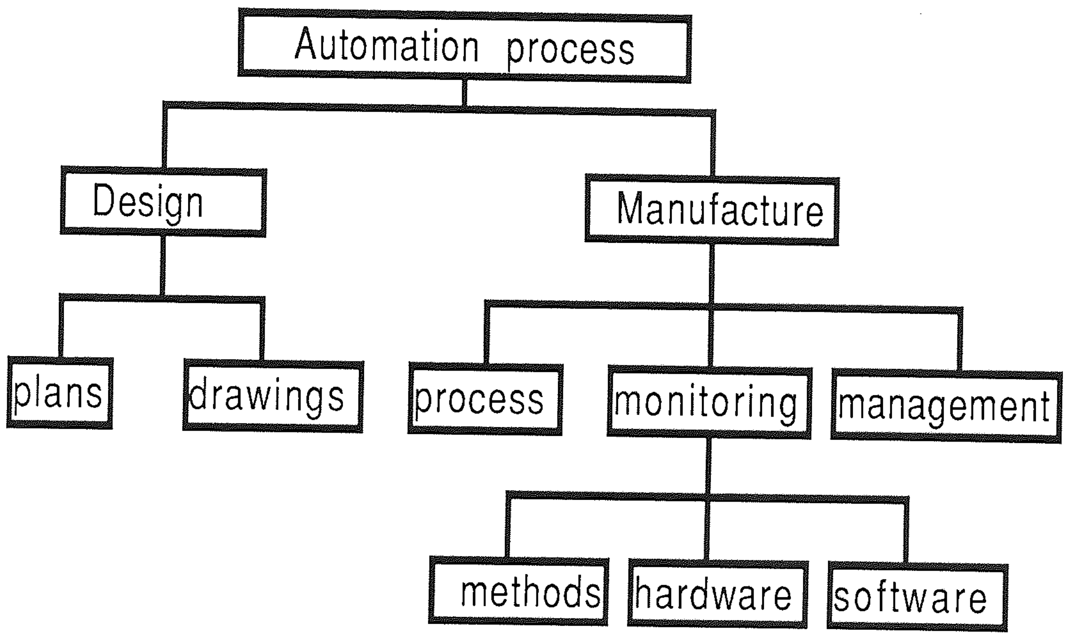
	plastic	aluminium	steel	bronze	magnesium
casting		✓	✓	✓	
forging	✓				✓
drawing			✓		
extrusion		✓			
rolling			✓		

Morphological analysis for the manufacture of a ceiling component

Table 3.1

3.2.6 Marples decision trees

Any design can be regarded as the outcome of a sequence of problems and their solutions. Therefore the complete problem is broken down to several smaller problems[38] in a tree structure (figure 3.2). Solving each of these smaller problems will solve the main problem.



Marples decision tree for an automation process

Figure 3.1

3.2.7 Inversion

As the name of suggests this technique looks at an alternative which is an inversion of the original problem. For example in trying to design a revolutionary chair, the designer under normal circumstances would think along the terms of a chair which can be kept on the ground. In inversion the designer looks at the feasibility of a chair which hangs from the ceiling.

3.2.8 Fantasy

The designer who uses this technique tries to develop new ideas without initially limiting himself by thinking about the practicability of them. In certain cases designers have been known to use science fiction to design revolutionary products.

3.2.9 Empathy

Empathy is the technique of projecting one's personality in to the object of contemplation. For example the designer who is contemplating to design a new product would imagine himself as either the product itself or as it's end user. This would enable the designer to be able to recognize what is required by the product.

3.2.10 Analogy

The designer in this case looks for another system whose inputs and outputs are analogous[39] to the required one. An electrical or an electronic analogy for a mechanical system can be analysed.

3.2.11 Visualization

Visualization can be the most important design technique of all types. However it is difficult for an expert or a designer to visualize certain shapes and sizes in his mind, especially when they are complicated engineering shapes. Therefore the concept of using pencil and paper in order to clarify ideas led the designer to the drawing board which has been the most important tool for designing in the engineering industry for a long time.

3.3 Computer aided design

Digital computer has taken over the design activity to replace the conventional manual systems, and it performs a major role in the industry today. This can be used in a wide variety of operations ranging from the design of a product right down to the manufacture and delivery to the end user.

CAD/CAM is one of the latest acronyms in the manufacturing industry as a result of this take over, and it stands for Computer Aided Design/Computer Aided Manufacture. CAD/CAM can be defined in many ways and one is 'Any design activity for the manufacture which involves the effective use of the computer to create or modify an engineering design'(40) while another is 'CAD/CAM is a working tool and communication methodology which today represents the fastest, most accurate and consistent way to progress to tested, inspected and assembled components.(41)

There are two basic reasons for using the computer in the design of a product as follows.

(1) To increase the productivity of the engineer, i.e., to help the designer to visualize the product, its components, sub assemblies and parts by reducing the time required.

(2) To create a data base for manufacture. (All information on products, stock balances, tool life, tool and cutter paths can be effectively stored in a computer data base to be extracted instantly. This will increase the productivity and also will help to understand the causes of problems.)

The computer can quite easily replace the drawing board as it can be used for visualization of models by using various 2 or 3 dimensional draughting techniques. The added advantage is that it is also possible to rotate most of the diagrams on the visual display unit of a computer by using the above techniques rather than re-drawing the same diagrams at a different angle. Therefore the computer can be used for developing, analysing or modifying an engineering design to a very great extent.

Computer integrated design (CAD) packages are widely available in the market and they range from about £100 to thousands of pounds. The cheapest packages are normally only software while some more expensive packages provide the necessary hardware too. Such a system (plate 3.1 and figure 3.2) would normally comprise of a number of items[42,43] as follows.

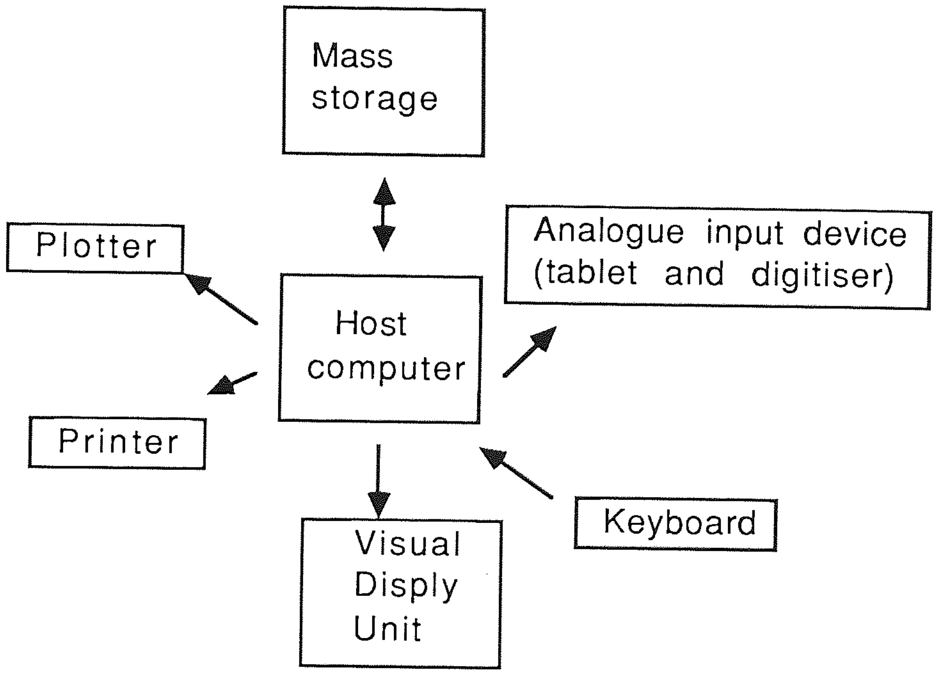
(1) a processor unit

(2) a keyboard and a visual display unit

(3) a storage device

(4) analogue devices

(5) a plotter and/or a printer



CAD system configuration

Figure 3.2

CAD workstation

Plate 3.1

3.3.1 Processor unit

This is the most important device of the whole package and it interprets the user commands and sends the appropriate signals to the screen for the user display. The unit can also deal with several users at one time while attending to some background jobs as well, but the operation is transparent to the users. This unit is usually located away from the users in a multi user environment, and is referred to as 'the computer'. It handles data in binary digits which are commonly known as 'bits' (eight bits are known as a byte). A computer has a large on-board memory in comparison to a human and this can vary from a few kilobytes to a number of Megabytes. This memory consists of two major parts which are known as RAM and ROM.

3.3.1.1 RAM

RAM is the abbreviation for Random Access Memory and this memory is available to the user for his work. This memory is volatile and is lost when the power is switched off.

3.3.1.2 ROM

ROM or the Read Only Memory is a non volatile memory and the user can only read the contents of it. It usually contains the applications software, computer languages and utilities.

3.3.2 Keyboard and the visual display unit

The keyboard, visual display unit and the processor are housed in the same unit in a smaller computer and are collectively known as 'the computer' while the former two are referred to as 'the terminal' in a larger computer. There can be many terminals in multi user systems and these are usually located remotely from the processor unit where many users can share the processor simultaneously. For this reason, the term 'computer' in such a system refers to only the processor.

The users interact with the system via the keys which send their appropriate codes to the processor to decode them to carry out the requested commands. The processor sends the requested items of information to the visual display unit by means of numbers, menus, text, diagrams, symbols and windows. There are three main accepted coding systems as follows[44,45,46,47] for communication between computers and peripherals.

(1) Bardot code

(2) ASCII code

(3) EBCDIC code

3.2.2.1 Bardot code

Bardot code is mainly used for international telegraph systems and there is a unique code for every character on a type writer/computer style keyboard including the lower case letters. This code is a five bit code and is extremely fast. Some of the characters have special meanings and therefore it is not very suitable for this code to be used on computers.

3.2.2.2 ASCII code

ASCII which is pronounced as 'as-key' is the abbreviation for American Standard Code for Information Interchange and is by far the most popular means of coding today. It uses the first seven bits out of eight to represent a character and the most significant bit is used for special purposes such as to do error checks and is called the 'parity bit'. The code also has control characters for special operations like, carriage return, line feed, bell, back space and enquiry. (Appendix 1)

3.2.2.3 EBCDIC code

This is the Extended Binary Coded Decimal Interchange Code and is used in some large computers. This uses eights bits as opposed to the seven in ASCII which gives it room for a larger number of codes. It however can not do the error checking by parity since it uses all eight bits for coding.

The display units also vary in the principle in which they display information and the following[48] are some of them.

(1) Raster scan

(2) Direct view storage tube (DVST)

(3) Direct beam refresh tube (DBRT) or vector scan

3.2.2.4 Raster scan

Raster scan display devices have been derived from televisions. The display consists of a number of dots which are called pixels and they can be lit up to make a picture. Light is emitted from the phosphor coating of the screen when these are lit up, and has to be refreshed about 25 times per second to keep a constant display. An acceptable display for engineering applications is about 2 pixels per milimetre and therefore a small display of 200 by 250mm requires 500,00 pixels. The computer's memory must store and maintain these and therefore a considerable amount of the user RAM is used for screen management. At higher resolutions the amount of user RAM used is greater.[49,50] The biggest disadvantage of the raster scan display is the staircase effect in the diagonal lines.

3.3.2.5 Direct view storage tube (DVST)

The DVST is used to eliminate the task of refreshing the display. It is similar to a conventional Cathode Ray Tube (CRT) but the picture is stored on a grid. There is an instrument called 'a flood gun' which deposits electrons continuously on the phosphor layer on the screen. As a result a steady picture with a very high resolution is obtained.

It was not possible to alter a detail once the picture was drawn on the screen on the earlier developments. The only way to do this was to delete the complete picture and re-draw it which was a very big draw back. This problem was eliminated in the more recent developments by introducing some degree of refreshment. Initially when the picture is drawn, it is refreshed in the usual way but the user is prompted to acknowledge when the picture is complete. It goes to the permanent mode when this acknowledgement is received, and the refreshing is no longer done.

3.2.3.6 Direct beam refresh tube (DBRT) or vector scan

This also continuously refreshes a phosphor coated screen but the picture is not drawn as in the raster scan and the generated image must be re-traced at a very high speed to avoid flickering. Therefore the flickering actually depends on the number of lines which it has to re trace.

3.3.3 Storage unit

Since the random access memory is volatile there must be some other means to store the data when the user finishes his session. The read only memory can not be used for this because it can not be written in to. Therefore the computers have to have an external memory for long term storage of data. These external devices when applied to large computers are known as mass storage units as these are much larger than the on-board memory of a computer. These devices are shared by many users in medium to large computers but each user however has his unique storage area to prevent his work being spoilt by other users. The data is usually recorded and retrieved in two different methods as follows.[51,52]

(1) Sequential access

(2) Direct or random access

3.3.3.1 Sequential access

The data in this method is stored as normal characters in a normal file and can be listed directly (figure 3.3) on a screen or a printer but has to be retrieved via application software in the same order in which it is saved originally. Therefore if a particular piece of information is required, then all the preceding information has to be read before it can be accessed. Any new information is only possible to be appended to the end of a file and this too has to be done by reading all preceding data from the beginning and writing it back. This is obviously a very slow method of data storage and retrieval; and yet many people(5,6,7) in the past have preferred this method.

140.0	84.0	5	120.0	80.0
170.0	84.0	5	160.0	80.0
20.0	74.0	8	20.0	68.0
60.0	74.0	9	60.0	68.0
120.0	74.0	9	120.0	68.0
160.0	74.0	6	160.0	68.0
20.0	84.0	6	20.0	80.0
60.0	84.0	6	60.0	80.0
120.0	84.0	9	120.0	80.0
160.0	84.0	9	160.0	80.0
20.0	60.0	9	20.0	58.0
130.0	84.0	2	110.0	80.0
180.0	84.0	2	110.0	80.0
20.0	60.0	2	20.0	58.0

An example of a sequential access file

Figure 3.3

3.3.3.2 <u>Direct or random access</u>

Storage variables in different records can be located immediately in direct access for both reading and writing by referring only to the location of the file. This type of storage is very quick and efficient and also is good for confidential files. The reason is that the actual storage is done in a very sophisticated manner and that unlike sequential access files, direct access files are not listable on a visual display unit or a printer. To be precise they do not look like readable information but simply look like a jargon of meaningless characters (figure 3.4) when listed. The only way to access the information is via an application software module and if this is designed to let access only to the authorized users, then the valuable data will be protected from the prying eyes of the unauthorized personnel.

```
    29-APR-8712:39:452222         CHICKEN TROUGH        STOCK
                     ZIN  BLACK ANODIZED
                      @Ha
@ML}@$peDEDn0 AOD`@HD@DyCAGANEh@HD@1 B BeDeD

C3   B(@ % OF MAT COST)
                                    h:CbBML3333         CH
```

An example of a direct access file

Figure 3.4

The physical devices which store information (whether in direct access format or sequential access format) are as follows.

(1) Magnetic tape

(2) Magnetic disk

(3) Floppy disk

(4) Micro floppy disk

(5) Magnetic drum

3.3.3.3 Magnetic tape

Magnetic tape storage devices are very similar to those which are used for sound recording. Most of the home computers are even built to record data on household cassette recorders. However a superior quality can be obtained from professional storage tapes.

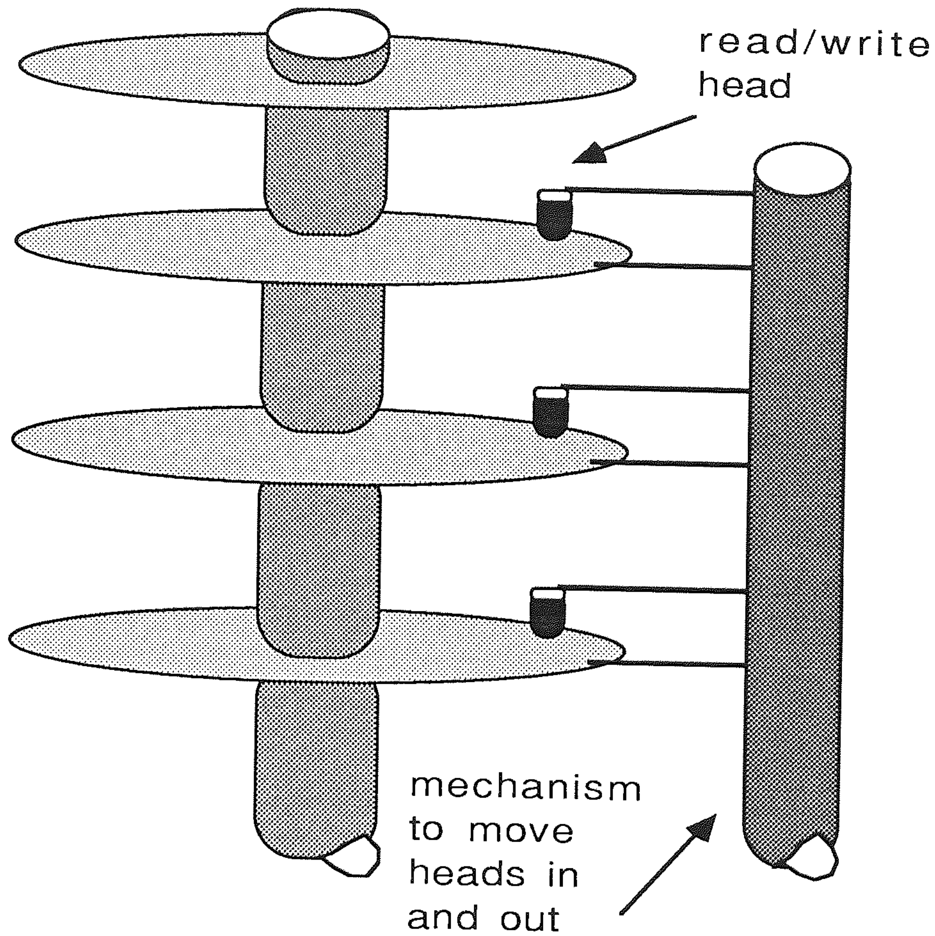
The magnetic tape is a continuous plastic material with a ferrous oxide coating and the data is stored as magnetized and non magnetized spots.[51] The magnetic tapes usually consist of either 7 or 9 tracks while the household cassette tapes consist of 2 tracks; one on either side. Data can be recorded at densities as high as 2.5kBytes per cm. The speed too can vary from about 100cm per second to 500cm per second while the typical width can be 1.25cm and the typical length about 725m with a diameter of 20 to 30cm when re-wound.

The magnetic tape is cheaper than the other devices but it can provide only sequential access. Therefore it is only suitable for a purpose like loading a program to the main memory while it is not suitable for access of data while a program is running.

3.3.3.4 Magnetic disk

These devices can be used to store data in the direct access format. They consist of metallic platter as in sound records. The tracks are concentric and not spiral. The platters are mounted about $1\ ^1/_4$ cm apart on a spindle (figure 3.5) which rotates at a speed of about 50 r.p.m and are coated with a metallic oxide like ferrous oxide on both sides. The data is stored just as in a magnetic tape but the tracks are divided in to sectors.

There can be about 256 tracks and about 32 sectors per surface on a typical platter of about 36cm diameter. Number of tracks vary from 3,500 to 15,000 per track depending on the density. Therefore the disk can store 20Mbytes to 1 Gbyte of data.



Magnetic disc

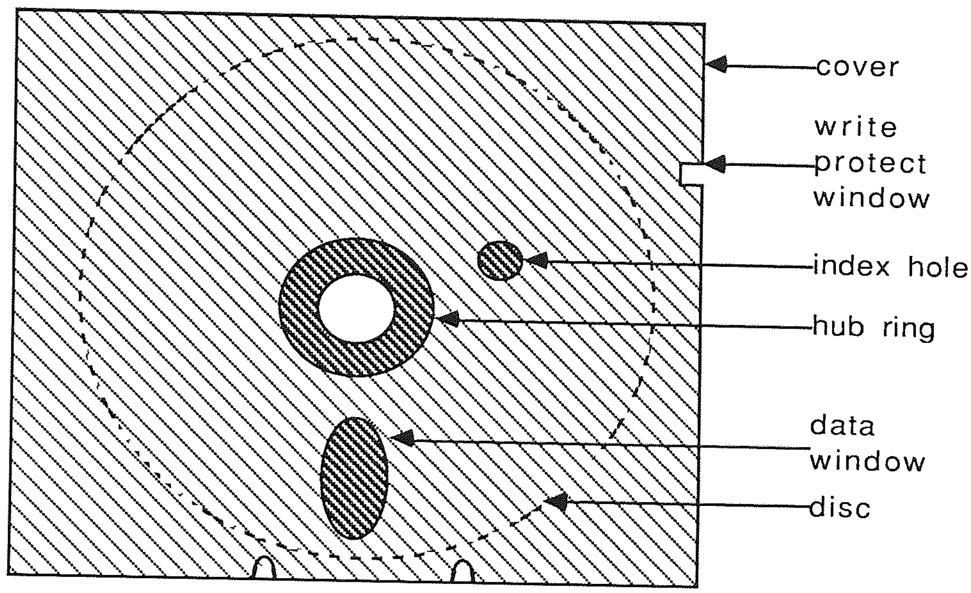
Figure 3.5

There are two types of read/write heads for magnetic disks and they are the moving head and the fixed head. There is a head for each track in the fixed head units while an arm like lever moves the head to the appropriate track in the movable head units. The information can be stored on the top and the bottom surfaces and in this case heads are required for both surfaces.

3.3.3.5 Floppy disk

Floppy disks are a low cost alternative to both the above systems and they come in two sizes, 8 inches (20cm) or $5^1/_4$ inches (14cm) in diameter. They consist of a flexible plastic platter in a thin cardboard sleeve. The platter is not taken out of the sleeve to read or write but is inserted in an external device which is called a disk drive. There is a motor which rotates at 300 r.p.m inside this drive and the platter inside the sleeve rotates at this speed when inserted.

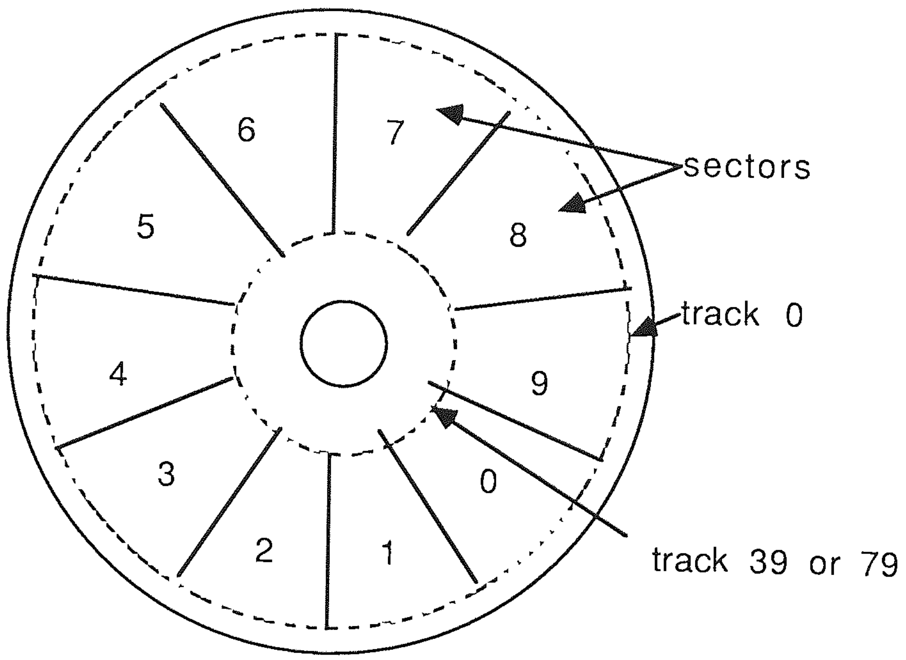
There is a large circular hole in the sleeve to fit the disk in to the drive motor and there is also a small window for the head. Additionally a notch is provided (figure 3.6) and when covered with a sticky tape, acts like a write protection shield. The data storage is exactly like in magnetic disks and the number of tracks can be either 40 or 80. The head is stationary and the total distance which the disk travels by rotating is the same for either number of tracks and the head inside an 80 track drive must step twice as many times as in a 40 track drive.[53] There has been another development in the recent years to produce a 40/80 switchable drive in which the head can move away and towards the centre of the disk.



Floppy disc

Figure 3.6

The 40 track disk has a pitch of 48 tpi (19 t.p.cm) while the 80 track disk has 96 tpi (38 t.p.cm)[54] and the density of storage can be single or double. There are 10 sectors (figure 3.7) in single density storage with 256 bytes for each sector. Therefore a 40 track disk stores approximately 100k bytes of data while in an 80 track disk this figure is 200k. These figures are doubled in double density or double sided storage and are four times as much for double density and double sided storage.



Sectors on a floppy disc

Figure 3.7

3.3.3.6 Micro floppy disk

Micro floppy disks are the latest in a generation of cheaper disks and they too must have a drive which contains a read/write head to rotate them.

These are very similar to floppy disks but are just 3 $^{1}/_{2}$ inches (9cm) or 3 inches (7.5cm) in diameter of which the former is universal. The sleeve of both types is made out of robust plastic while the window which is used for reading and writing data is covered with metal protection shutters in the universal type[55] and slide open when the disk is inserted in the drive. There is also a built in write protection tab in each disk. The storage capacity is about 390k on a single sided disk and the universal type is quite popular in the latest mini and micro computers like Acorn,[56] Apple[57] and Apricot[58] while the other type is used only in the latest versions of Amstrad computers. The micro floppy discs are currently very popular due to their size and the robustness.

3.3.3.7 <u>Winchester disk</u>

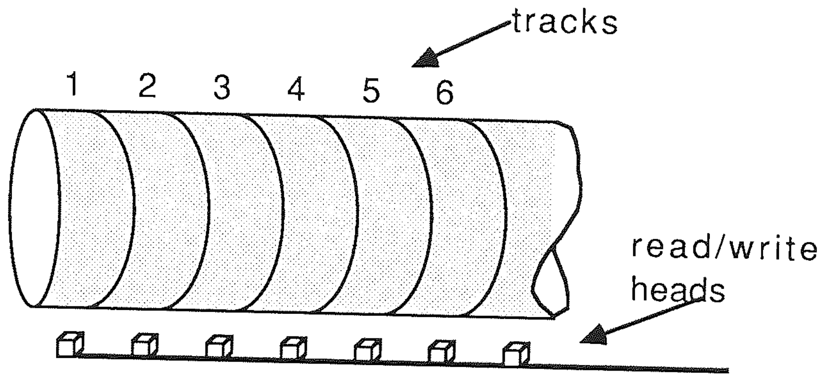
The winchester disk is a recent development and it too has a platter which is coated with ferrous oxide. The difference is that there is a special lubricant which reduces the friction between the surface and the read/write heads.

The platter is contained in a sealed chamber to prevent it being contaminated with dust. The advantage of the winchester disk is that greater precision can be achieved from it while a greater number of tracks and a higher density than floppy disks would allow more data to be stored.

Winchester disks also come in sizes of $5^1/_4$, 8 or 14 inches (14, 20 or 36 cm) while the typical storage capacities are 10, 20 or 40 Megabytes. They are more expensive than the floppy disks and hence are supplied with more expensive higher range computers while the cheaper ones have to be content with the floppy discs.

3.3.3.8 Magnetic drum

Magnetic drum is the oldest means of data storage and it too can provide direct access. It has a metal cylinder with a coating of magnetic oxide over it and the data is stored on this coating in the same way as the other devices but in circular tracks on the surface (figure 3.8) which are known as bands. The drum is kept in a cabinet and there is one read/write head for each band and hence the data access is faster than that of a disk; typically between $^1/_4$ to a massive $1\ ^1/_2$ million characters per second.



Magnetic drum

Figure 3.8

3.3.4 Analogue devices

One or more of the analogue devices as described below contains in a typical CAD package and they are very useful in draughting as they help to digitise or draw complicated shapes without the problem of having to supply the co-ordinates of all different curves to the computer via the keyboard.

(1) Light pen

(2) Digitiser and tablet

(3) Joystick

(4) Tracker ball

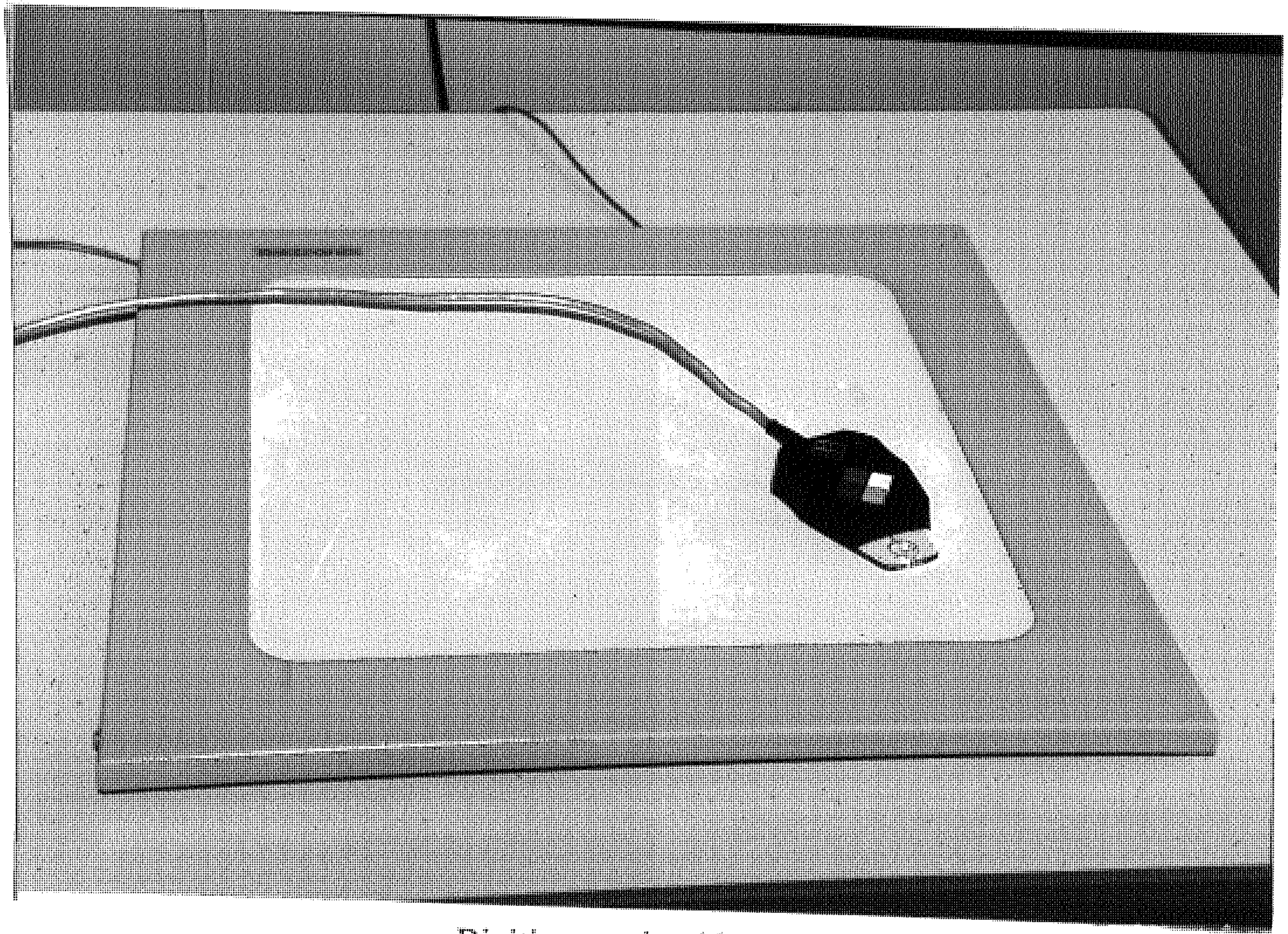
(5) Dial

3.3.4.1 Light pen

Light pen is similar to the fountain pen in shape and size, and it detects light on the screen by using a photo diode and an optical sensor. The co-ordinates of these positions can be passed in to the computer's memory by pointing the light pen at positions of display. The name 'light pen' is also sometimes used for a bar code reader but it is not used to digitise a picture on a visual display unit.

3.3.4.2 Digitiser and tablet

A digitiser is also used to determine the X and Y co-ordinates of a diagram by moving it on a tablet. These co-ordinates can be stored in the memory to draw the picture by placing it on the tablet and moving the digitiser along it's curves.



Digitiser and tablet

Plate 3.2

Joysticks

Plate 3.3

The tablet (plate 3.2) is physically made up of a grid of wires in X and Y directions. It can sense when the digitiser moves on it. It sends the position (co-ordinates) of the nearest junction from the digitiser, to the computer when a button is pressed.

3.3.4.3 Joysticks

Joysticks (plate 3.3) can be operated on a persons palm and there are two types of joysticks, namely the on/off type and the analogue type. The on/off type as the name suggests is not very useful because they can send only a digital pulse of either 0 or 1 while the analogue type can send a different voltage at each position of the joystick either in X or Y direction when moved. These voltages can be interpreted as co-ordinates when the total range is considered and can be very useful when digitising a picture.

3.3.4.4 Tracker ball

This performs a similar function as joysticks but is more accurate. It is a simple[59] device with a rotating sphere which is mounted on rollers inside a box so that about $^1/_3$ of the ball is exposed.

The cursor movement which is directly proportional to the number of revolutions of the ball is calculated by application software to build the appropriate diagram.

3.3.4.5 Mouse

The mouse is very similar to the digiser and can work with the same principle or with the principle of a tracker ball. The mouse can be used to point out objects on the screen by moving it on a flat surface and the movement is considered as directly proportional to the cursor movement on the screen. The user simply has to move the mouse until the cursor moves to the appropriate position on the screen such as either a co-ordinate of a picture or an icon and click a button to select the item which the cursor is on. This is very much easier than typing commands on a keyboard.

3.3.4.6 Dial

This is a small dial like instrument which is located on the side of the keyboard on some devices like Tektronix workstations[60] so that the user can twist it around either the X axis or the Y axis. The

X and Y axes on the screen are moved with the twisting movement. This is also useful for graphical applications.

3.3 Manufacture

Manufacture can be defined as 'all the processes which are carried out between the design of a product and the delivery of it.' It can have a number of complicated sub processes and the profitability of a company depends on the efficiency of manufacture to a very great extent.

The manufacture as related to sheet metal industry is the fabrication of the metal for the formation of the required shape.

3.4 Computer aided manufacture

Groover[25] defines computer aided manufacture as 'the effective utilization of computer technology in the management, control and operations of manufacturing through either direct or indirect computer interface with the physical and human resources of the company'.

The major deficiency in the industry however is the lack of sufficient computer aided manufacture. This is perhaps because it is not even understood what aspects of manufacture are needed to be computerized and why. This results in some companies paying vast sums of money to purchase computerized systems without realising that those are not flexible enough to fulfil their requirements.[1]

Computer can be used in manufacturing in many ways such as to prepare punch tapes for Numerical Control (NC) machines, to control conveyers on production lines, to link weighing machines to other peripheral equipment and in many other areas. Already there are highly automatic systems available in the industry; some of which are Computer Numerical Control (CNC) or Direct Numerical Control (DNC) machines,[61] robots,[62] and Automatically Programmed Tools (APT).[63] The computers can also be indirectly used in processing manufacturing information in Flexible Manufacturing systems (FMS),[64] Material Requirements Planning (MRP),[65,66] Manufacturing Resource Planning (MRP2),[67] Distribution Resource Planning (DRP),[68] Production control systems,[69] Stock Control,[70,71] Process Planning,[72] and Production management.[73]

3.5 Monitoring

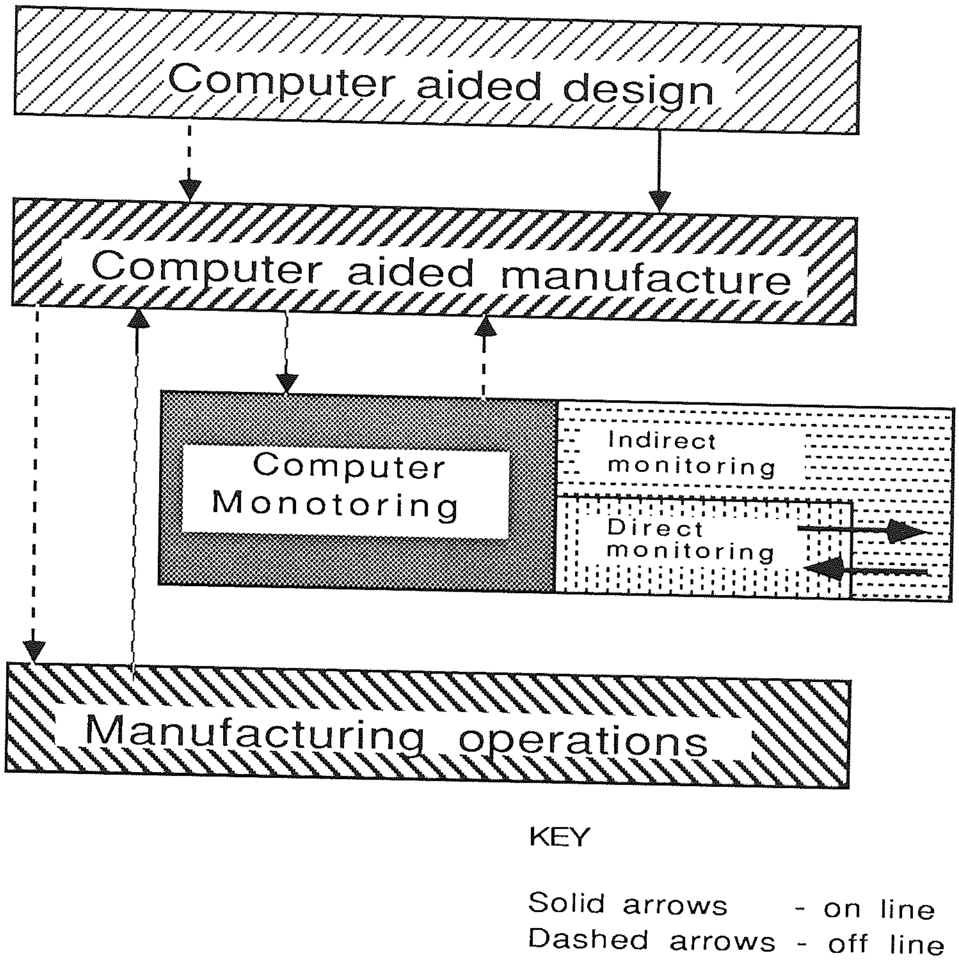
Monitoring which can be regarded as the link between design and manufacture is ignored by some of the companies because of their lack of knowledge. It must be regarded as a very important function for any successful manufacturing operation.

3.5.1 Indirect Monitoring

Indirect or analogue monitoring is carried out by the graphics analysis method as explained in chapter 1. It is often difficult and time consuming to analyse the results of this type of monitoring especially because of it's analogue nature. Therefore it is impossible to take prompt corrective action even in the case of a serious error.

3.5.2 Direct Monitoring

Direct Monitoring (figure 3.10) or Computer Integrated Monitoring uses a digital computer to observe the process and other related equipment to collect data. The computer can process the data and present them in a digital format very quickly and hence allow direct or indirect action to be taken promptly.



Monitoring in a manufacturing environment

Figure 3.10

The digital computer can monitor more than one variable simultaneously but it is not practical to use the computer only to monitor variables continuously because it can prevent the computer from attending to various other tasks such as calculating, displaying and printing. Therefore the process variables are sampled periodically, with the sampling frequency being sufficient to approximate the performance of the process.

The control of the process can be done by the computer using it's own feedback[74] in the cases where such precision is required. This is a separate branch of engineering which is known as Control Engineering or Automatic Control.

The computers are used only to measure the performance of a process in Computer Integrated Monitoring, while the control of it remains in the hands of humans although the feedback from the computers is used for this. The reason for this is the high flexibility which is required of some operations making it impossible to build a set of rigid rules for the computers to make decisions on.

3.6 Reasons for needing an monitoring system

There may be one or more reasons for a particular company to require a monitoring system and these reasons may vary from one company to another. One of the main reasons for needing a monitoring system is to increase the efficiency of operations by reducing the downtime and production errors and thereby increase productivity and profitability. Some other reasons are as follows.

(1) to correct a certain design fault.

(2) to preserve accurate data over a long period of time to help future planning.

(3) because of product warranty requirements.

(4) government regulations in the case of certain types of products.

(5) to collect data to be used as legal evidence in the case of liability suits.

3.7 Types of monitoring systems

There are four main types of monitoring systems as follows of which more than one can be present in some systems.

(1) Manual entry systems

(2) Data logging systems

(3) Data acquisition systems

(4) Multilevel scanning

3.7.1 Manual entry systems

This type of systems are the simplest and can range from a single push button device on the shop floor to a device with a full size keyboard.

They can sometimes communicate directly with a host being 'on-line' or alternatively, collect data in an external device for subsequent processing by the computer and be 'off line'. The manual entry systems can be classified in to two categories depending on their locations.

(1) Data entry stations

(2) Time entry stations

3.7.1.1 Data entry stations

Factory data such as down time, job status and piece counts are entered by the operators at these stations. The operators therefore have to be fully trained to use the special equipment in order to enter data accurately.

3.7.1.2 Time entry stations

These stations are quite common and are located at entrance doors of factories to monitor operators' in and out times. They usually consist of a clock and a set of time cards (one for each operator for a specific period such as a week, a fortnight or a month) where the time is stamped on the card each time it is inserted in the appropriate slot of the clock.

3.7.2 Data logging systems

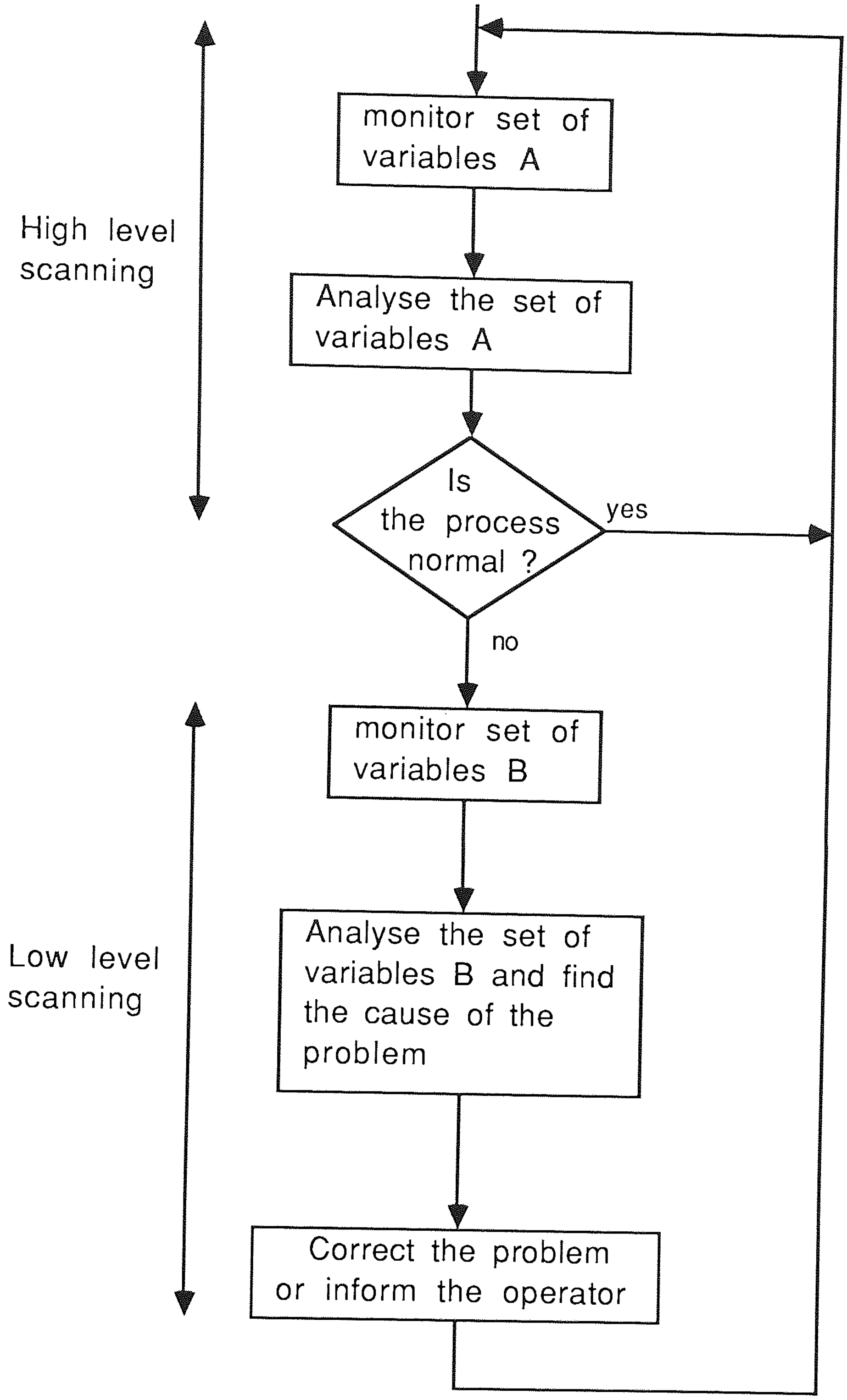
Data logging devices collect data automatically, allowing data to be analysed on an off line basis. Normally the collected data is analysed without the aid of a computer although a computer can be used for collecting data. This type of a system is not useful for taking immediate corrective action in the case of a fault. The input and output variables of such a system can be either analogue, digital or both.[75] The disadvantage of collecting analogue data is that they have to be converted to a digital format before doing the calculations or being displayed.

3.7.3 Data acquisition systems

Data acquisition systems are essentially on-line systems and therefore are linked to digital computers. The data is not only collected automatically but also is processed and analysed by computers immediately on a real time basis.

3.7.4 Multilevel scanning

It may be necessary to monitor more than one variable in a data acquisition system, but all the variables may not be needed to be motored at all times. The variables which have to be monitored under normal operating conditions are called the key variables and monitoring of these is referred to as high level scanning.



Multilevel scanning

Chart 3.2

If the key variables indicate that the process is not normal then the computer can switch itself (chart 3.2) to monitor more variables in order to perform a more detailed analysis to determine the source of the fault. This is known as low level scanning.

3.8 Problems in monitoring

The following problems can occur in many production monitoring systems and therefore greatest care must be taken in designing such a system.

(1) Can generate too much information so that the operators are unable to recognize important data and less important data.

(2) The users may not be allowed to request only the information which they require.

(3) It is possible to have too many abbreviations when all he required data can not fit in to one page of display.

(4) A part of the data might scroll off the screen to accommodate more data before it is seen by the operator.

(5) Data might be printed out as numbers without any identification.

(6) The formats of reports can not be changed.

(7) Will not let certain authorized personnel to have access to certain materials while it is possible to give other personnel access to unnecessary areas.

(8) Limited flexibility.

3.9 Data

Collection of data can be accomplished by many methods such as through operators and manual computer terminals, via automatic computer terminals and via a direct connection between the computer and the process interface. The first method is called a data logging method, and the last one is an on-line data acquisition method while the second one can be an average of the two extremes.

3.9.1 Types of data

The data which need to be monitored can be classified in to three broad categories.

(1) Process data

(2) Equipment data

(3) Product data

3.9.1.1 Process data

These are the input output variables of the process which can be monitored to determine the overall performance. Some of the process variables are temperatures, pressures, forces and speeds. The computer instructs the operator to take corrective action when the process variables deviate from a previously determined target.

3.9.1.2 Equipment data

This is the type of data which relates to the status of the production, machine tools and equipment. This type of data is helpful to avoid machine or tool breakdowns, to monitor the utilization of equipment and to determine optimum tool changes.

3.9.1.3 Product data

A company may be required by law to collect and preserve product data because of government regulations. These are mainly product qualities, audit data, production rates and sometimes even material data. This is quite common in the chemical industry where toxic products are manufactured.

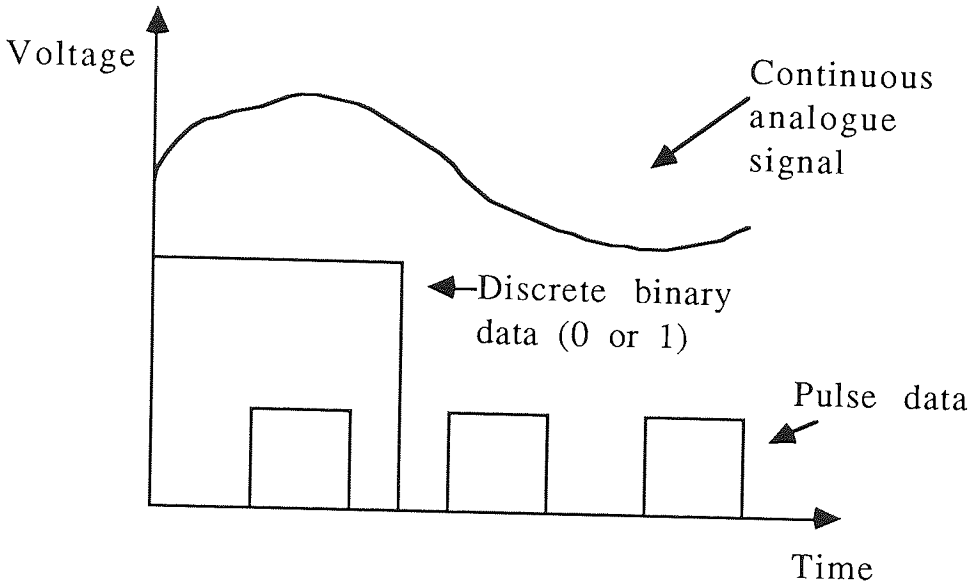
3.9.2 Structures of data

All three types of above mentioned data can not be collected in the same format by the computer. The data has first to be converted to some form of signals before they are fed in to the computer and these signals which flow back and forth between a computer (figure 3.11) and the particular process can be classified as follows.

(1) Continuous analogue signals

(2) Discrete binary data

(3) Pulse data



Different types of data

Figure 3.11

3.9.2.1 Continuous analogue signals

The simplest example is a current or a voltage which can be accepted by the computer. This however, is not very useful to the observer in this format. The analogue signal has to be converted to a digital value before being presented to be read, and the time for this depends on the ability of the computer.

3.9.2.2 Discrete binary data

The data in this case is a series of ones and zeros. This means that there can be only two possible states such as ON or OFF.

These are easier to be transferred to the decimal form than the analogue data since they are already digital. The data is first transferred to binary form during the communications of computers via serial or parallel ports, before being transmitted. The receiver receives the data in the same form and transfers back to the original form before displaying.

3.9.2.3 Pulse data

These are trains of pulses which relate to data and are discrete. They are similar to discrete binary data but the number of possible levels is not two.

Pulse data can be related to discrete data because the number of pulses in a train can be counted within a certain period of time.

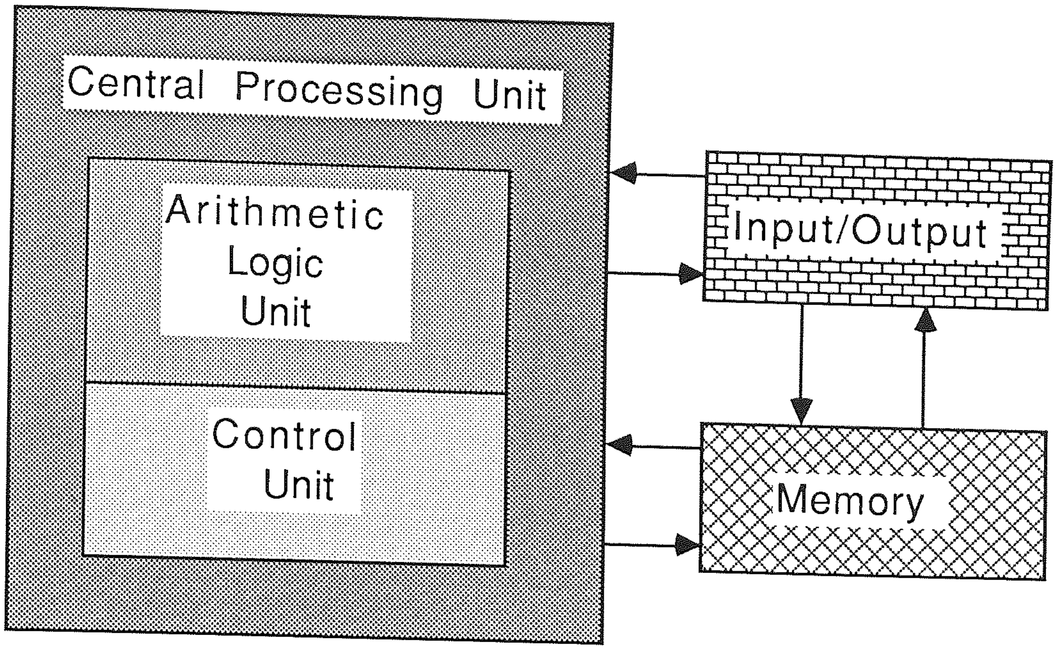
3.10 Computers in monitoring

A digital computer is an essential tool for computer integrated monitoring. It's most important component is the Central Processing Unit (figure 3.12) which performs the functions.

The Central processing unit or the C.P.U performs it's functions by means of registers. Each register consists of binary cells to hold bits of data. The number of bits in the register establishes the word length of the computer.

The following are some of the computers which are of different sizes.

BBC micro computer	- 8 bits
VAX II 750 mini computer	- 32 bits
ICL Perq mini computer	- 16 bits
Apple Macintosh	- 16 bits



Digital computer

Figure 3.12

3.10.1 Computer sizes

There are three general types of computers depending on their word lengths, capabilities and speeds. They can be categorized as follows.

(1) Micro computers

(2) Mini computers

(3) Large general purpose computers

3.10.1.1 Micro computers

These computers use a microprocessor as their basic C.P.U. They can have only one user at a time and the cheapest microcomputer is a pocket calculator.

3.10.1.2 Mini computers

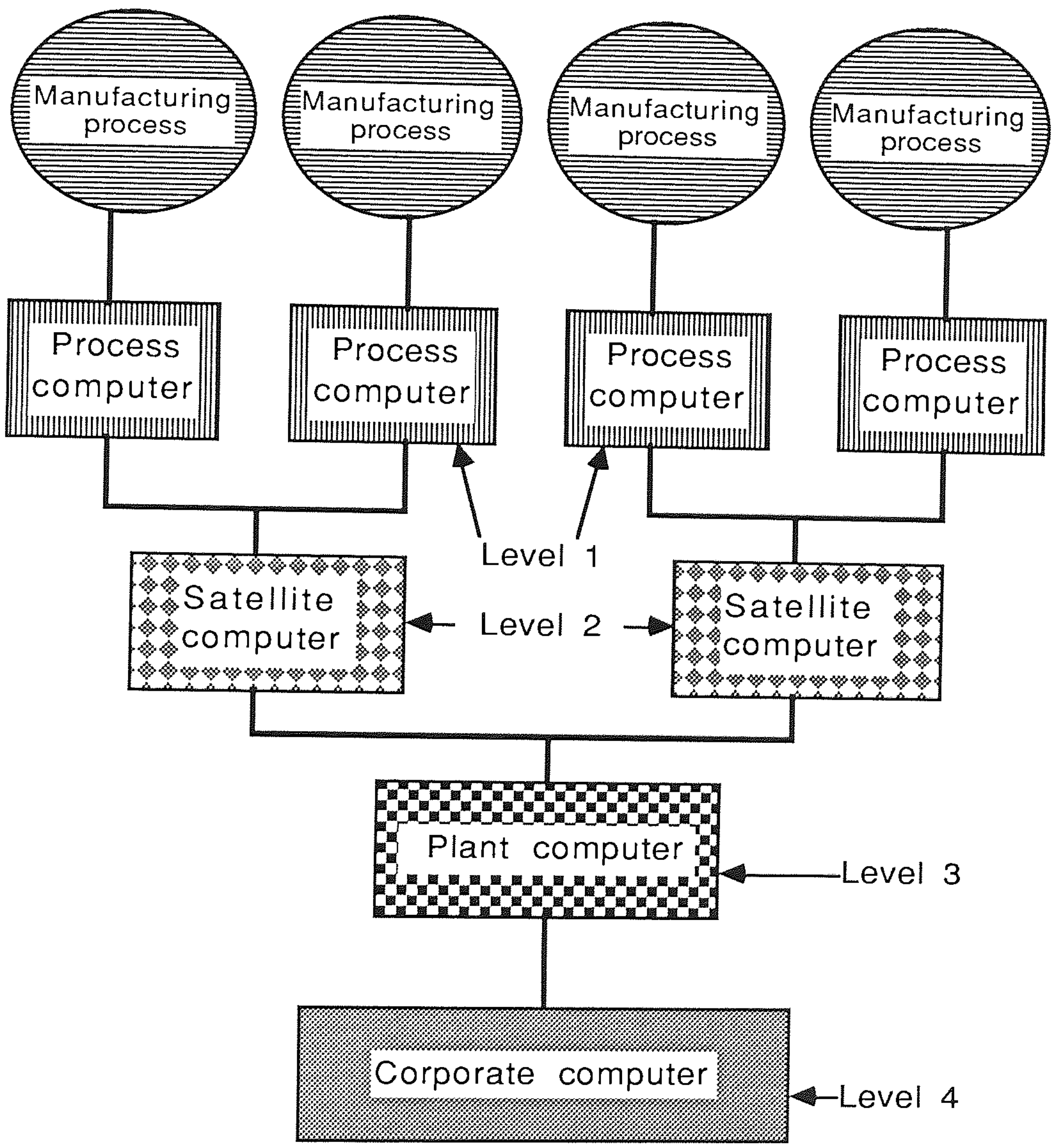
These were developed in the mid 1960s and could be bought for about £ 20,000 - £ 40,000 each. They have a fraction of a capacity of very large computers which were available before their time. The purpose of having these is to cut down the cost of buying a large computer which is not required sometimes to perform a relatively small amount of tasks. They are not so expensive today, and an example is an IBM computer which costs about £2,500.

3.10.1.3 Large general purpose computers

These are distinguished by their cost, capacity and the functions. The cost can be millions of pounds and the speed can be as high as ten times that of a mini or a micro computer.

3.11 Hierarchy of computers

The computers in a monitoring environment (figure 3.13) can be classified in to four different levels and such a hierarchical structure has proved to be most efficient.



Hierarchy of computers

Figure 3.13

3.11.1 First or the process level

This is the lowest level of the hierarchy. These computers are the ones which do the physical task of monitoring and are normally connected with the actual process and hence are located in close proximity of it. They are dedicated to a minimum number of tasks and the major tasks that they perform are, monitoring or control and communicating with the second level.

3.11.2 Second or the satellite level

These are normally micro computers. Several of these can be located throughout the plant and report to a larger plant computer. Their major task is to act as supervisory computers, and they co-ordinate the activities of the smaller computers.

3.11.3 Third or the plant level

The plant computers collect data from various plant operations and summarize them to make reports for the plant management.

3.11.4 Fourth or the corporate level

The data is collected from various plants and is compiled in the corporate computer. The communication with the individual plant computers can be achieved via telephone lines.

The purpose of this computer is to summarize information and perform tasks for the entire company. This computer must essentially be shared with the other departments like accounting, payroll, and sales to achieve maximum efficiency.

3.12 Advantages of a hierarchical structure of computers

The usage of such a hierarchical structure as described above can be very advantages to a company in many ways. Some of the advantages are as follows.

(1) The system will not crash due to the break down of one computer and the data will not be lost.

(2) The expense of implementing such a system can be gradual rather than having to spend a large capital for a direct system.

(3) The programming can be easy since it can be done in stages.

(4) The same language need not be used in programming all the computers.

(5) Programming of different computers can be done by different people in a team of experts.

(6) The installation of both the software and hardware can be done gradually, stage by stage.

(7) Debugging and testing of software is easier because each set of computers can be programmed separately.

(8) Independent parts of the system can be built and tested first, so as to build the confidence of the users.

(9) Failure of a part of the system would not result in re-building the system completely from the start.

(10) Future expansions of the system can be easy even if a part of the system has to be replaced as opposed to replacing the whole system.

Chapter 4

System plan and conception

4.1 Introduction

Having carried out a literature survey on the Computer aided design, manufacture and monitoring; the next stage is to understand the problem and hence establish the need for a new system. The end product or the goal (not the complete solution to the problem) can then be seen as applicable to the problem. It is only after that the conceptual model can be formed. The aim of this chapter is to approach the problem in this systematic manner using the design techniques which were described in chapter 3 as in a highly professional engineering environment.

4.2 The establishment of need

It was discovered that a number of problems exist after studying the system at the company concerned and having discussions with the personnel. These problems are as follows.

(1) Inaccuracy of production details

(2) Downtime reasons are not known early for corrective action

(3) Duplication of details which result in back and side tracking

(4) Backlog of paper work and the difficulty in finding records

(5) Customer delivery dates are not met

(6) Poor overall efficiency

(7) The need to increase profit

4.3 Goal recognition

Inaccuracy of production details gives rise to many industrial problems today and most of the manufacturers are aware of this. The simplest method to eliminate this is to use more manpower by employing more people. Even this will not give the expected levels of accuracy while the whole idea is not feasible due to the fact that the profits will be further reduced when the extra wages have to be paid. The alternative to this is to look for some type of a computerized solution. This type of a solution will be more difficult to implement and also will be costly in the initial stages, but will certainly have a higher degree of accuracy in the long term as it will be free of human error.

The downtime play a major role in reducing the profit of a manufacturing company and if the reasons for the downtime are not known early enough for the management to take corrective action, then the company may not even be able to survive for a long time. Therefore implementing some sort of a shop floor real time on-line monitoring system is vital. This system should have the highest priority and must go on functioning continuously throughout any shop floor operation.

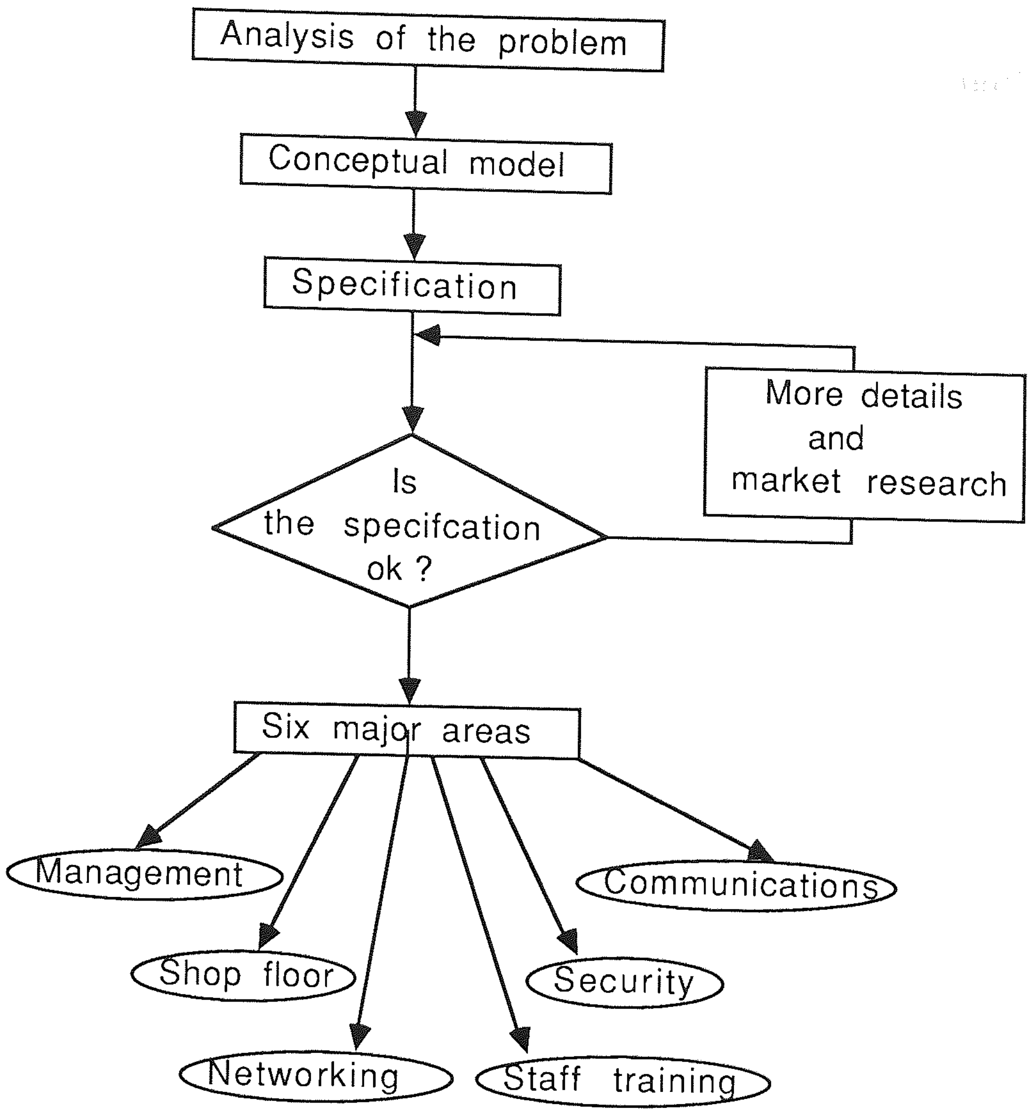
A large general data base must be maintained to eliminate the problem of duplication. A computerized solution is ideal in this case as any item of data can be recorded only once allowing fast retrieval when and where required.

There is no need to have a paperwork system running in parallel with a computerized solution unless in the early development stages. The ability of fast data access in a computerized solution would eliminate all paperwork problems.

The computerization must not halt at data bases and shop floor monitoring if there is a problem in meeting customer delivery dates. The stored data must be used for all different functions in manufacturing such as Production planning, Production management, Scheduling and control. It will be very easy for the computers to take over these functions when the data bases are ready although designing the application software is difficult.

Having one system for shop floor monitoring and another for all the management functions in the offices, however sophisticated they may be, will not increase the overall efficiency of a manufacturing environment to a very great extent if they function as two distinct systems. Both systems have to be integrated together to increase overall efficiency, although they may have their different and mutually exclusive features to some extent.

Increasing the overall efficiency will undoubtedly increase the profit margin. This can be further increased by computerizing all other functions which are linked to manufacturing. Even the control of stock by computers will contribute to a part of the efficiency and hence a higher profit as it will help to order the raw material and despatch the finished products in the most efficient way without tying up the valuable working capital.



The conceptual model

Chart 4.1

4.4 Conceptual model

The conceptual model has to be built by understanding the required goals further and having constant discussions with the end users. This process is somewhat similar to a market research and the designer can get valuable feed back for his initially generated ideas. Following this technique and the technique of Marple's decision trees, the research programme can be subdivided (chart 4.1) in to the 6 following major areas.

(1) Shop floor level

(2) Management level

(3) Communication

(4) Security

(5) Networking

(6) Staff training

4.4.1 Shop floor level

The aim of the work in this area is to recognize the actual problems on the shop floor and to eliminate them. The main task therefore should be to monitor the downtime. The shop floor operator should be able to inform the management each reason for downtime via a console which is located on the shop floor. This console should ideally consist of a number of buttons, each of which to be dedicated to a specific function. It must be noted that the shop floor operators are not trained to use a proper 'QWERTY' style keyboard, nor will they be amused of being burdened with the extra task of operating such a unit. This area therefore is an extremely sensitive one and any new design should comply with any industrial relations acts. However pressing a single key on a console is very much easier than either typing a string of characters on a keyboard or writing down the necessary details which relate to downtime on a piece of paper.

The computer can record the time when any button is pressed and the downtime for each reason can be calculated for each shift, each day and for each accounting period. Some of the reasons for downtime such as setting up of a machine or striping it down are essential for even an ideal job, but a specific time limit or a target can be set up for these by looking at the previous performances. To obtain the maximum use of monitoring, the computer must compare the actual times with the targets constantly and should inform the operator if these targets are exceeded.

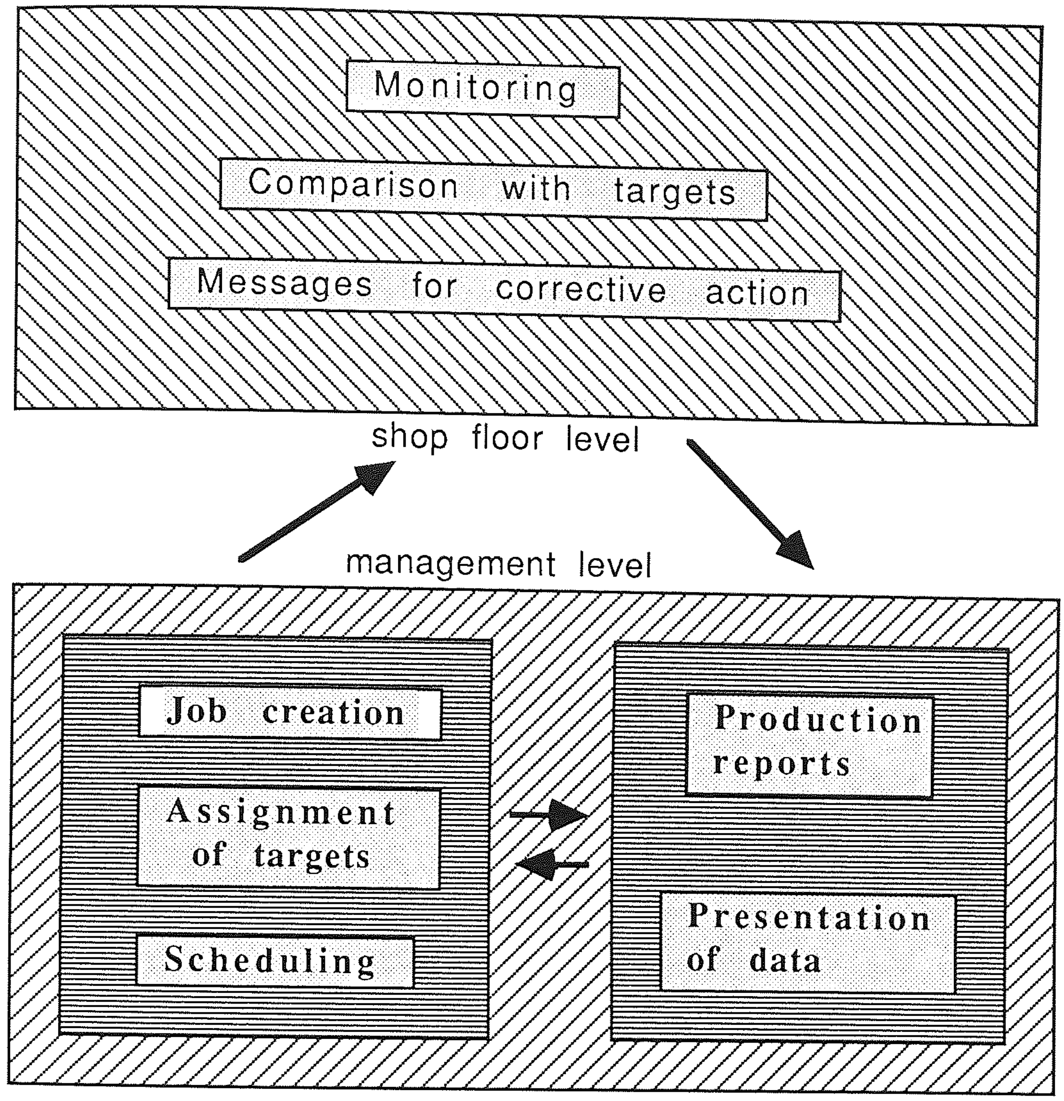
The downtime was found to be the major problem in establishing the need for a computerized system and one might be tempted to find a solution which would eliminate only this problem but all other aspects of manufacturing must also be covered in a good design. Downtime basically is a time when the rolling mill or the production line is not operating. Using the technique of Inversion which was discussed in chapter 3, the inverted function of the downtime can be determined as the operation or the running of the production line. The efficiency of this area too can be increased by monitoring the rolling speed. As in the case of downtime, the historical information which relate to speeds also can be saved and can be used as targets for each job. The computer must once again compare the actual rolling speed with these past values and inform the operator if the roll speed is less than the target. The computer must obviously monitor the roll speed before such a comparison and hence the monitoring process must consist of two types of monitoring, one of them being the monitoring of the down time while the other, the monitoring of the line speeds.

4.4.2 Management level

The raw data which is collected from the shop floor is useless in the absence of a proper management system for processing such data. The jobs therefore have to be created before the data collection process so that all the collected data can be processed in connection with each job. These jobs have to be created as and when the customers place their orders and will then have to be scheduled to each line in the most appropriate way so as to minimize back and side tracking.

The management level has also to deal with the finished jobs and process all information so as to prepare periodical production reports which consist of each category of downtime, the profit or loss of each job, the efficiency and a host of other information. Hence the management level comes before and after the shop floor level which is sandwiched (figure 4.1) in the middle.

The third aspect of the management level should be the data base management. Once collected data should be maintained and organized in such a way so that the supervisory personnel should be able to retrieve the data as and when needed. The product codes, groups, descriptions, prices, suppliers and various other information should be available in these data bases. The target for each job can be determined by using these information.



Shop floor and management levels

Figure 4.1

Finally this level can attend to stock control functions for both raw material and the finished products. The relevant information for this section need not be entered again if already available in another part of the data base but the computer can locate, retrieve and use these automatically. The management area will thus become a very large area which would involve an enormous amount of work to make the system complete.

4.4.3 Communications

The system will not be very efficient unless the above shop floor and management levels are integrated in to a single system as explained in the goal recognition. The jobs which are created in the management level must be the ones which have to be set up on the shop floor to be monitored. They must then be passed back to the management level to be processed.

It is essential that this communication must be 100% successful at all times. The communication would fail if the corresponding jobs are not synchronized properly and the whole process of monitoring would be useless although the first half of the management area would not be affected. Therefore it must be noted that the communication area is one which is very delicate and must be handled with utmost care.

4.4.4 System security

Security plays a major roll in an advanced system such as this especially when it has to be a multi user system. One prime rule to remember here is that the whole system must be identical throughout the group of companies while each subsidiary company has it's own products, prices and customers which must be accessible by only the personnel in that company, other than the policy makers of the whole group who must have access to all the data throughout the group. This presents a very complicated problem and to make things worse, the users are not or little computer literate. Therefore they can not be allowed to go in to the normal operating level so as to create, edit or delete files for the simple reason of protecting their own data. The system therefore has to be a closed one where everybody can only run the programs and access data only via application software.

Furthermore, each subsidiary company should have different levels of access to personnel, depending on their job function. For example some users may only read the data while others may read, enter and update data; but only the very senior (ideally the general manager) should be allowed to delete. Therefore the system should in some way identify all the users and prevent unauthorized access to different sections. This is not easy as the programs can not ask for the identification details from every user every time he wants to use a particular program. Hence the application software should be able to interact with the operating system in order to extract the user details. This will require certain privileges and a knowledge of very advanced programming.

By emphasizing the need for security, one might be tempted to use a different set of application software modules for each subsidiary company. This is a very inefficient method since there is no difference between each set of modules. Another shortcoming of this is that the policy makers will not be able to access all data freely. Therefore the software must be planned out and designed in a very sophisticated manner to fulfil all the needs.

Not only the above security but also system stabilization with battery backup will be needed for the protection of data in the case of a power failure or an accidental power switch off.

4.4.5 Networking

The system must essentially be a multi user system, firstly because a number of subsidiary companies are involved and secondly because more than one user per company must have access to the system simutaneously to use the functions to the full extent. Therefore some type of networking must be present.

4.4.6 Staff training

This aspect of the system may appear to be unnecessary but the value of it will be realized only when the feedback is considered. The accuracy of the system can be found out only by usage and therefore the users must essentially be trained on how to use the system. Not only the debugging can be performed but also the system can be improved to a great extent when the feed back of the users is utilized properly. Therefore staff training is a lengthy and an often annoying procedure but is an essential part of designing and building a system like this.

4.5 Model development

The technique of Attribute listing can be used to list out the required characteristics of the model which was discussed so far as applicable to one subsidiary company as follows.

(1) Four production lines

(2) All lines to be monitored simultaneously

(3) Management or supervisory work

(4) Alarm messages

(5) System security and stability

This system as proposed can be represented in a model which can be labelled as Model A (figure 4.2), but the monitored variables can not be passed on to a host computer as simply as this. Obviously some components will have to come between the host and the process so that the variables can be passed automatically to the host which does the calculations and all the processing. These components are as follows.

(1) Sensor

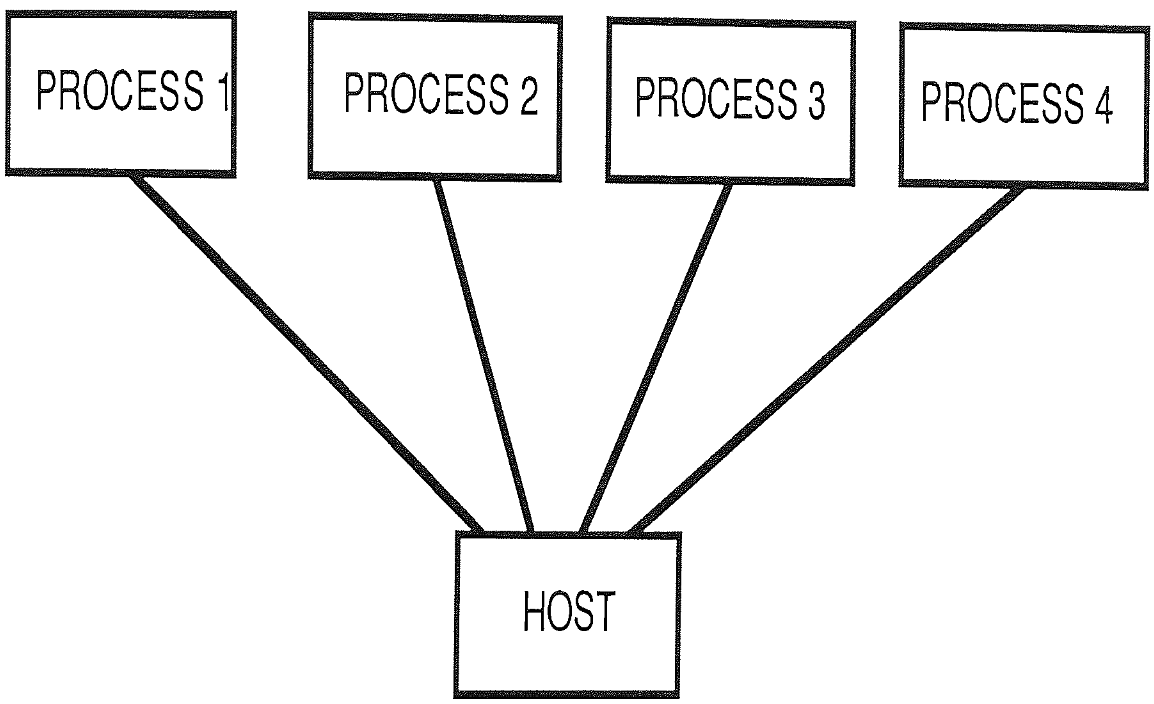
(2) Transducer

(3) Signal conditioner

(4) Multiplexer

(5) Amplifier

(6) Analogue to digital (A/D) converter



The proposed system - Model A

Figure 4.2

4.5.1 Sensor

A sensor is a device which can sense or be aware of the presence of something, for example some process variable. A sensor is therefore a measuring device.(76) A suitable sensor will have to be used on the rolling mill to sense the speed of the production line. The other variable which has to be monitored is the downtime with the different categories. These categories have to be manually fed in by the operator who will have to press a button on his console to indicate the reason although the actual monitoring of the elapsed time during one of these categories is automatic. Therefore any type of a sensor for downtime monitoring is not needed.

4.5.2 Transducer

A transducer is a device which converts a signal from one form of energy to another.(28,76,77) The sensor which has to be mounted on the production line will collect the appropriate variable in some form of energy which is not suitable for a computer. This energy will have to be transformed in to a suitable form, for example an analogue current or a voltage before it can be used.

4.5.3 Signal conditioner

The signal which is converted to the appropriate format is bound to contain unwanted effects due to random noise or vibrations. These will have to be eliminated or else an erroneous value will result. This elimination process is known as signal conditioning(78) and the device is known as a signal conditioner. It is similar to a filter in a hi-fi sound system. There are many types of signal conditioners which are applicable to different systems but the basic principle is the same.

4.5.4 Multiplexer

Multiplexer is a device which converts a number of inputs to a single output.(79) It is not realistic sometimes for a computer to accept many inputs constantly. Therefore these inputs are converted to form a single input and the process is known as multiplexing which can be done in two ways as follows.

(1) Time division multiplexing

(2) Frequency division multiplexing

4.5.4.1 Time division multiplexing

Each input is given a fixed time period in a cycle in time division multiplexing where the single output will be equal to only one input within a period. Therefore the output will be equal to all the inputs in turn within a cycle and can be connected to a computer.

4.5.4.2 Frequency division multiplexing

One cable with a high frequency range is used in frequency division multiplexing and this range is divided in to a number of smaller ranges of frequency. Each range will act as a different channel at the same time and the computer can scan the full range to receive all the input variables from all channels.

4.5.5 Amplifier

The conditioned signals may not have the correct amplitude range which is compatible with the A to D converter which has to be used to convert the signal to a digital form. Therefore an amplifier is used to scale the signal up or down.[28]

4.5.6 A to D converter

A digital computer handles data in a digital form and the signals which come from the shop floor are usually analogue voltages or currents. These have to be transformed in to a digital form before they are fed in to the computer, thus an A to D converter has to be used. (The opposite of this conversion is known as a D to A conversion.) It must however be noted that some computers do the analogue to digital conversion internally and hence the analogue signal can be fed directly, depending on the computer that is used. There are three methods of A to D conversion[80] as follows.

(1) Successive approximation

(2) Integration

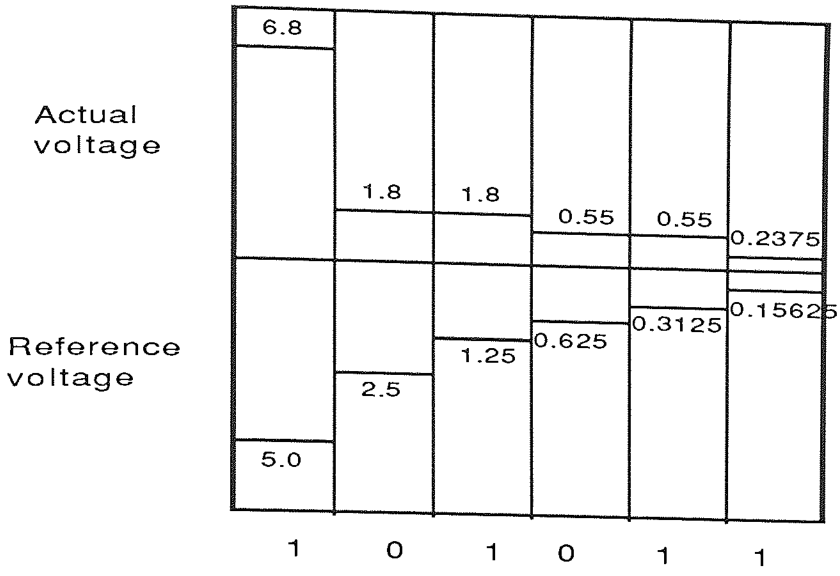
(3) Direct comparison

4.5.6.1 Successive approximation

A reference voltage must first be selected to use this method and has to be compared with the actual voltage. If the actual voltage is higher than the reference voltage then binary 1 will result while binary 0 will result in vice versa. Each reference voltage must be a half of the preceding one while the actual voltage becomes the difference between the previous actual voltage and the previous reference voltage if the previous resultant binary value is 1. The actual voltage is equated to the previous actual voltage if the previous binary value is zero. This is illustrated in figure 4.3 when an initial actual voltage of 6.8 and a reference voltage of 5 are chosen. The time taken to do this conversion is directly proportional to the precision required.

4.5.6.2 Integration

The time it takes for a capacitor to charge to the unknown voltage and to discharge under a known reference voltage (figure 4.4) are measured in this method. Since the time which takes to charge or discharge is directly proportional to the voltage, the ratio of time between known and unknown voltages are equal to the ratio of the two voltages themselves.



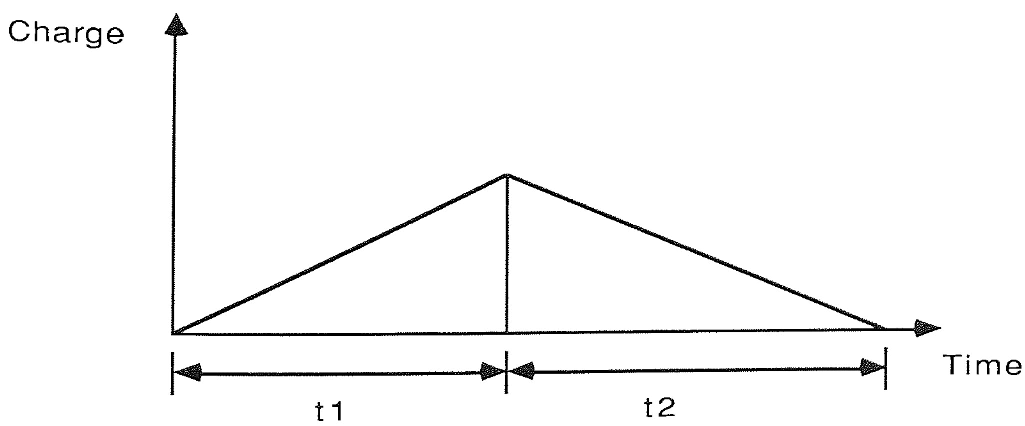
1 x 5.0 = 5.0
0 x 2.5 = 0.0
1 x 1.25 = 1.25
0 x 0.625 = 0.0
1 x 0.3125 = 0.3125
1 x 0.15625 = 0.15625

6.71875 Volts
========

Six digit precision = 101011

Successive approximation method

Figure 4.3

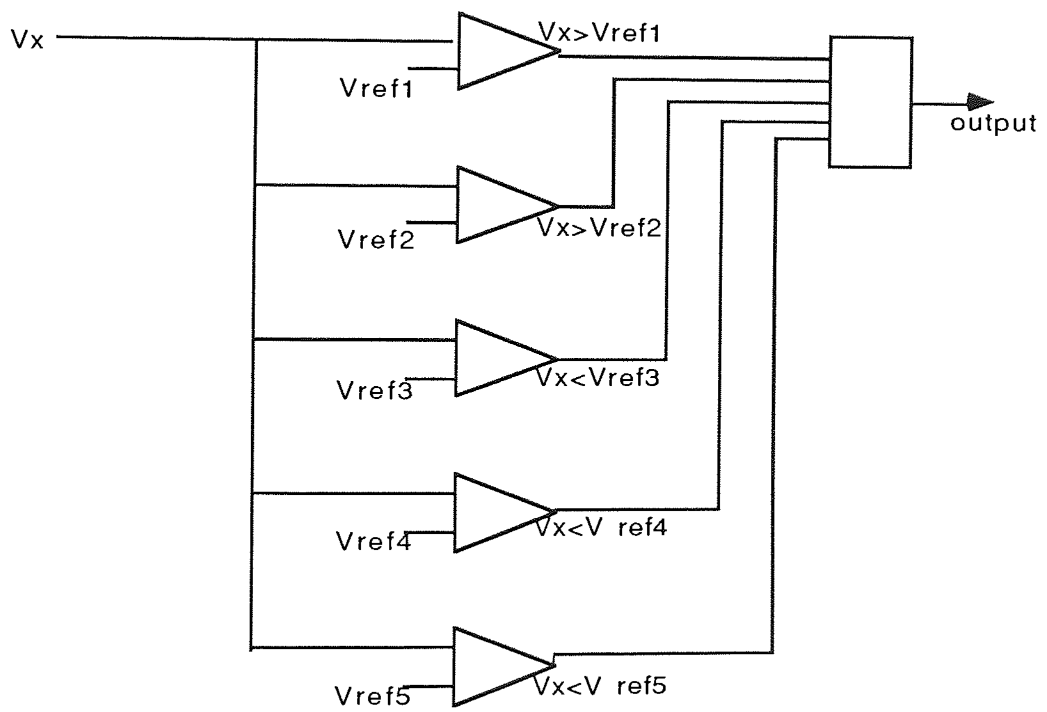


Integration method

Figure 4.4

4.5.6.3 Direct comparison

This method is used when high speed conversion is required and therefore the number of resolutions is less. One has to use 2^{n-1} comparators to use this method where n is the number of required output bits. The comparators have reference voltages in the ascending order which are compared with the actual voltage. The actual voltage can therefore be approximated at the position (figure 4.5) where one comparator indicates that the actual voltage is higher than it's reference voltage and the next lower.



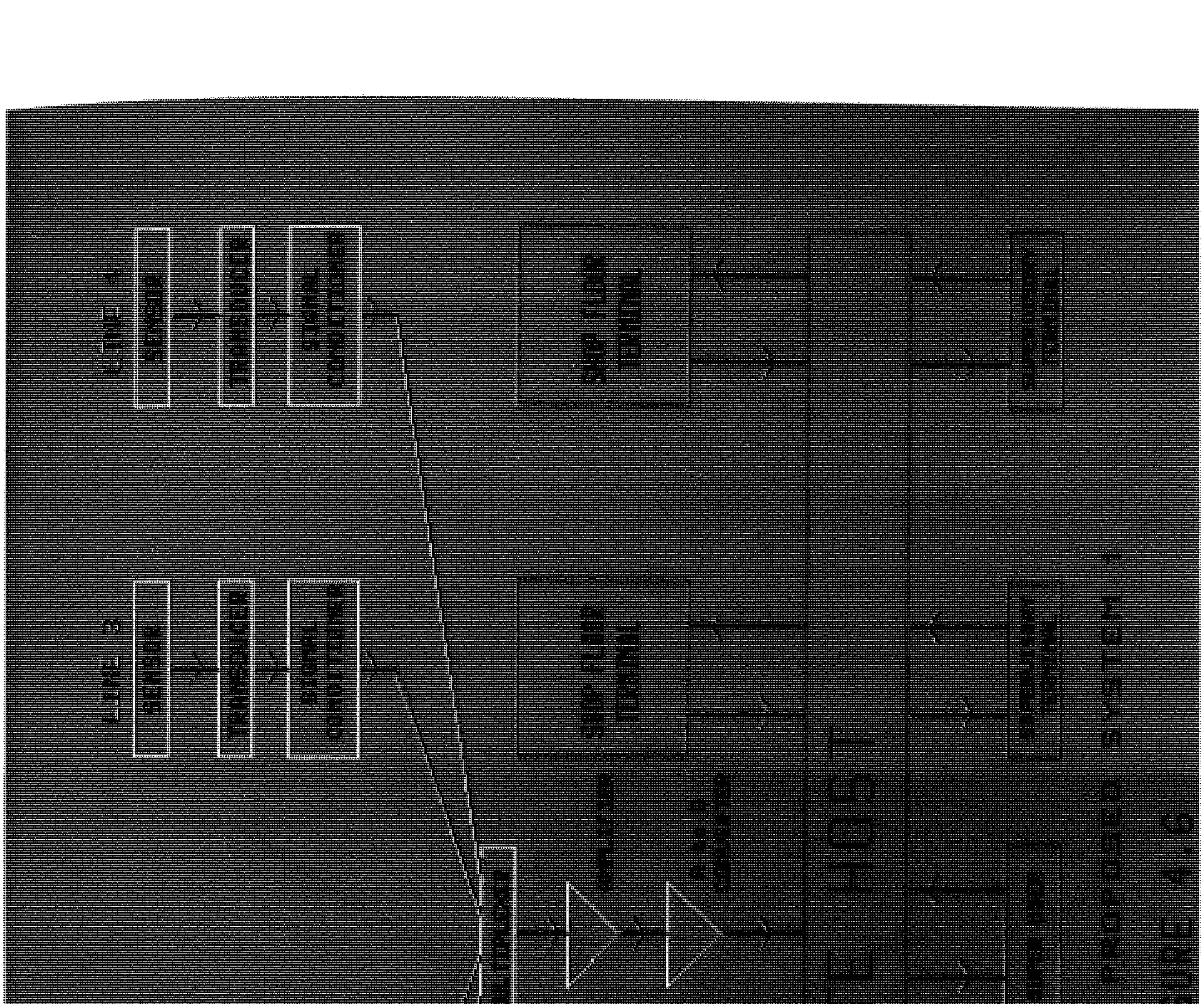
Direct comparison method

Figure 4.5

In addition to the above components, the shop floor terminals must be present in the system for the operators to send manual information. The system must be a multi user system as discussed above as the supervisors or the management must be able to do other tasks such as job creation, scheduling and control. Therefore additional terminals for them to interact with the system must be present. This information is now sufficient to use the technique of Fantasy to extend Model A and build a blue print to propose a system which can be labelled as 1 (figure 4.6).

One of the supervisory terminals in Blue print 1 is named 'super user'. This is in accordance with the system security where the need for different levels of access was explained. It is simply a 'fantasy' at this stage and is not clear whether this has to be done via hardware or software. Therefore at present 'super user' is just a name which indicates that some type of a higher level than the general supervisory level is needed at some stage in the future.

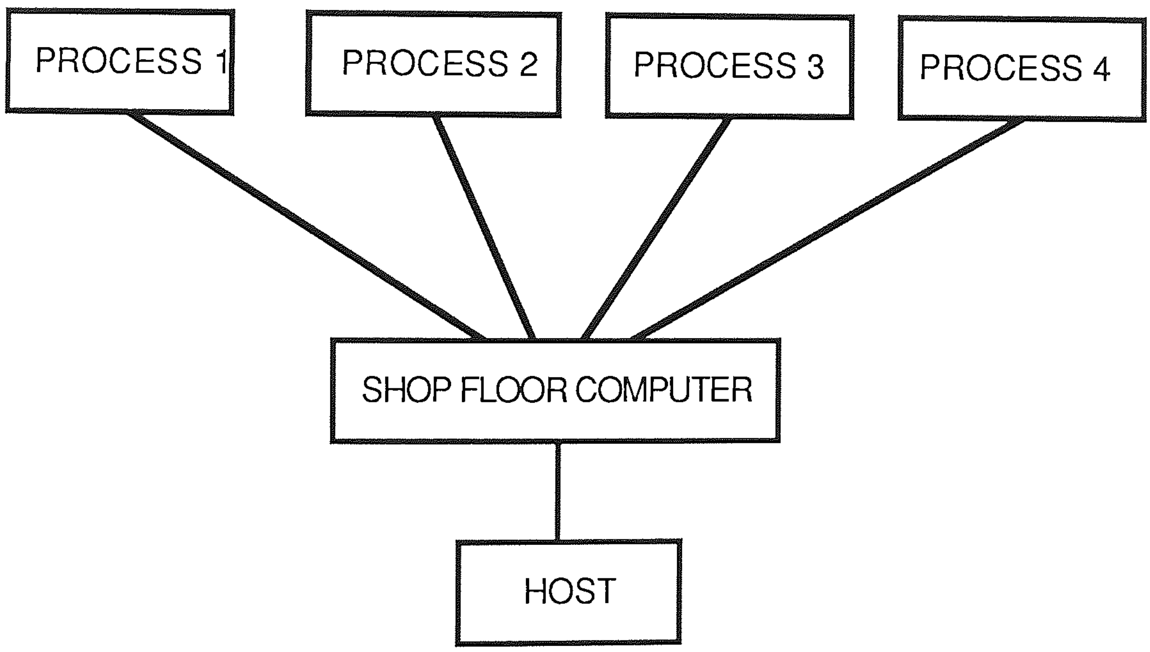
The biggest drawback of this system is that all the work has to be done by the host. The monitoring, calculations, and the message handling on the shop floor which will be added to the vast



BLUE PRINT FOR PROPOSED SYSTEM 1

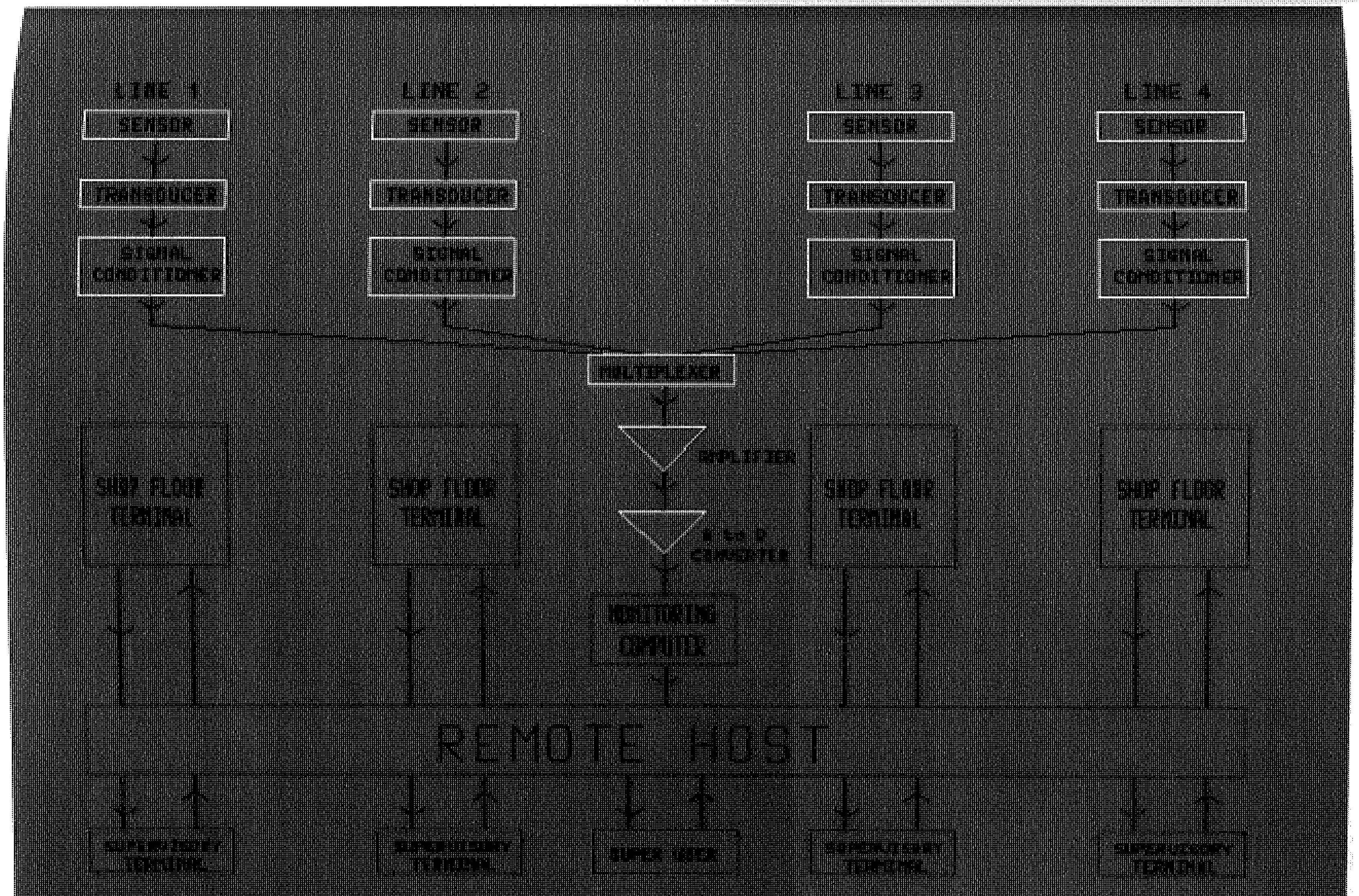
FIGURE 4.6

amount of management work will overload the host and it may crash.(1) Therefore it may be useful to use another computer on the shop floor as shown in Model B (figure 4.7) which is an improved version of Model A. The extra computer can be known as the monitoring computer and this model can be expanded as before to obtain system 2 as shown in figure 4.8.



The proposed system - Model B

Figure 4.7



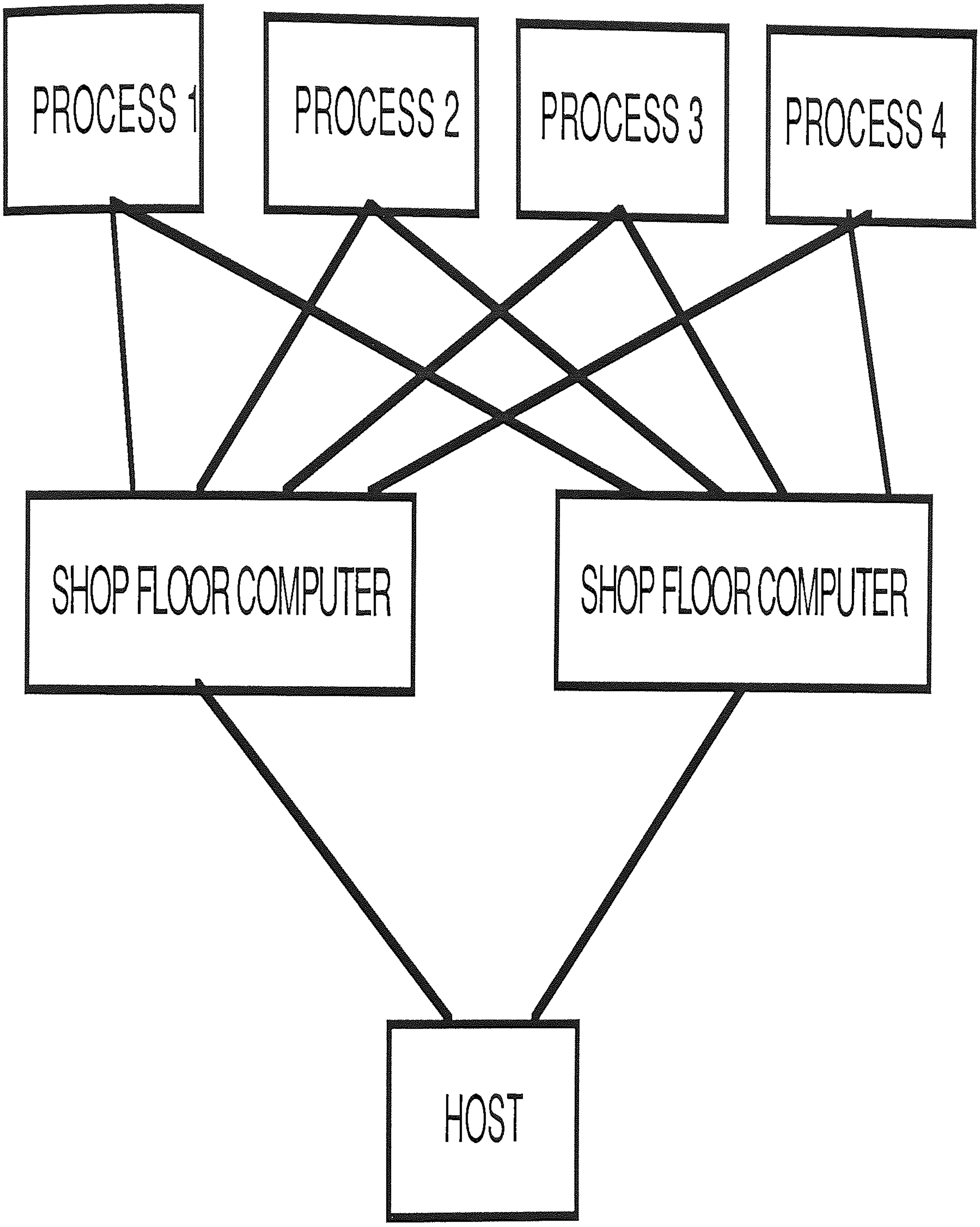
BLUE PRINT FOR PROPOSED SYSTEM 2

FIGURE 4.9

The system as shown in Blue print 2 works as two systems which are integrated together. The shop floor monitoring will be done by the monitoring computer which is located on the shop floor. The shop floor terminals (for manual operations) which are also located on the shop floor have no connection with the monitoring computer but are connected directly to the remote host.

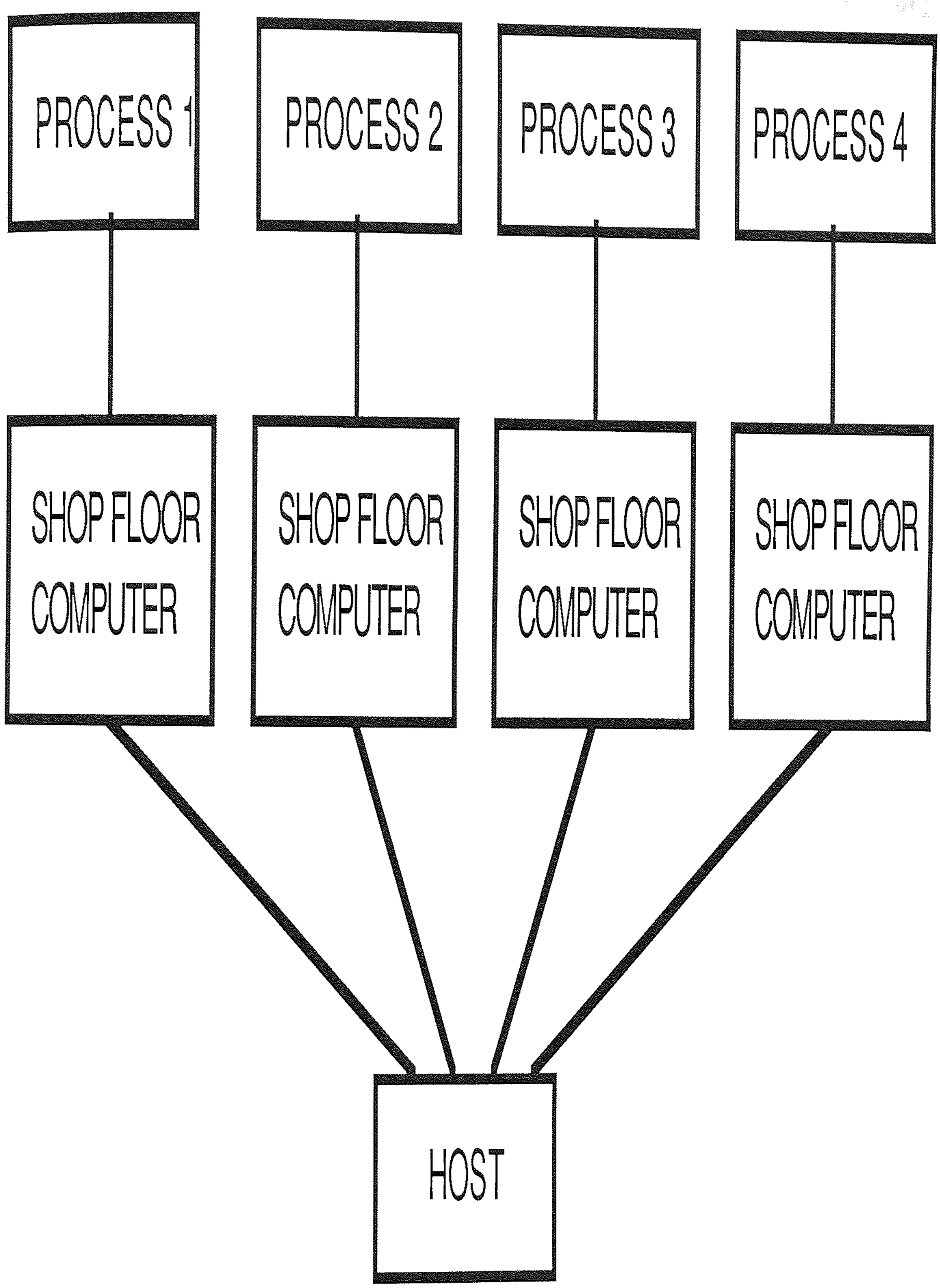
The information which flow from the shop floor to the host can be lost if either the multiplexer or the monitoring computer fails to function and therefore the reliability of such a system can not be regarded as very high. Connection of shop floor terminals directly to the host also might tend to result in synchronization problems since the on line information will have to come through the monitoring computer. Hence models C and D (figures 4.9 and 4.10) can be used as alternatives to eliminate these errors.

There are two shop floor computers in model C and all the information from the production lines go through both of them before being passed on to the host. The host in this case will not only be presented with an extra amount of work to look after both shop floor computers but also 50% of the total work will be redundant at



The proposed system - Model C

Figure 4.9



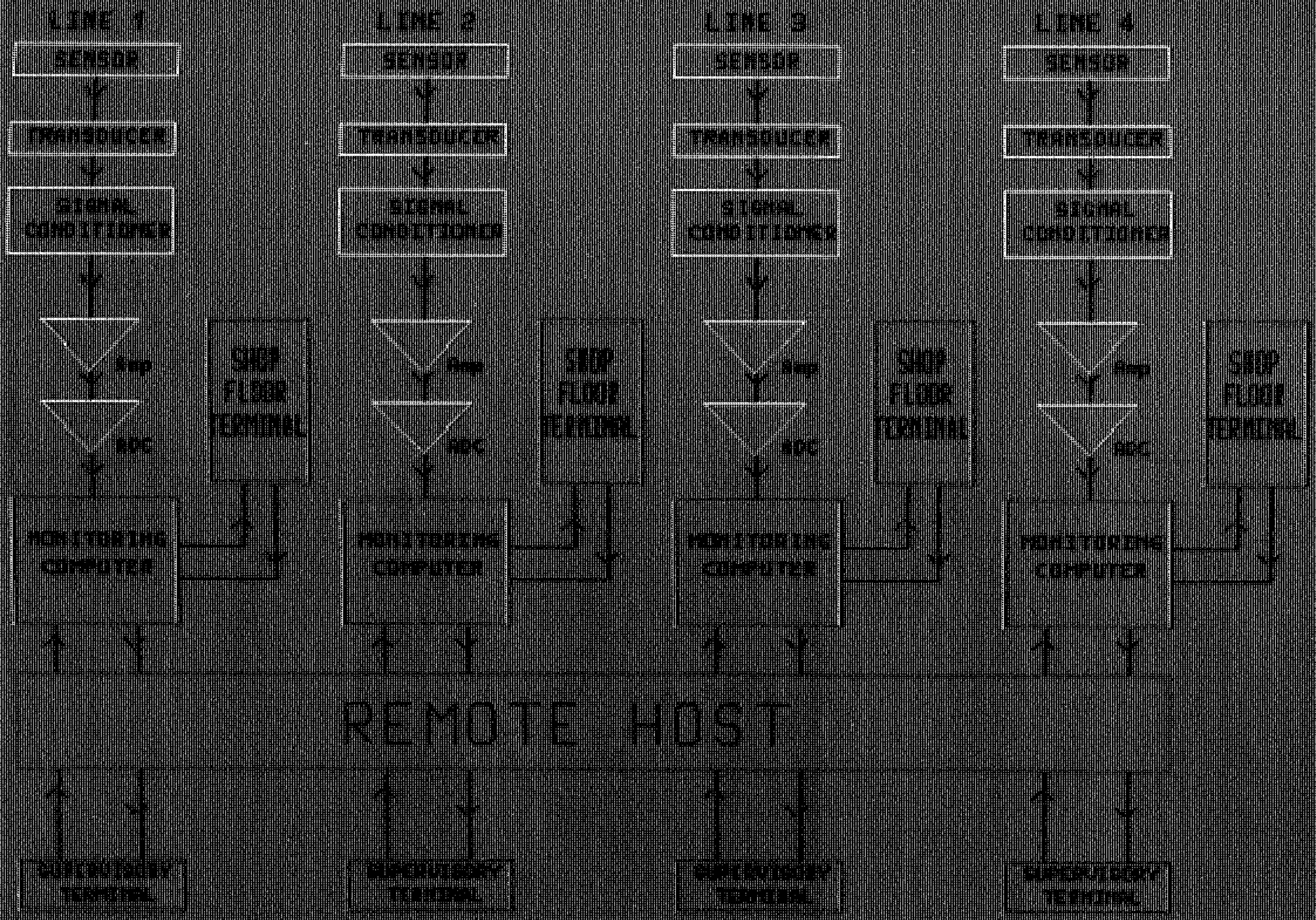
The proposed system - Model D

Figure 4.10

normal working conditions. The reliability in this model is very high as it is highly unlikely that both the shop floor computers would go down at the same time. The manual information terminals must also be connected to the shop floor computers in this case for proper synchronization with the other tasks. One disadvantage of this model is that the shop floor computers would not recognize the source of manual data (i.e., which production line they relate to) unless all the data is preceded by an appropriate signal which gives an indication to their origin. This will not only have to be done for the automatic data which flow from the processes (which will not present much of a problem) but also for the manual data which is sent by the operators. In other words, the operators will have to manually indicate to the computer, the appropriate line from which the information is sent and this can result in a lot of errors.

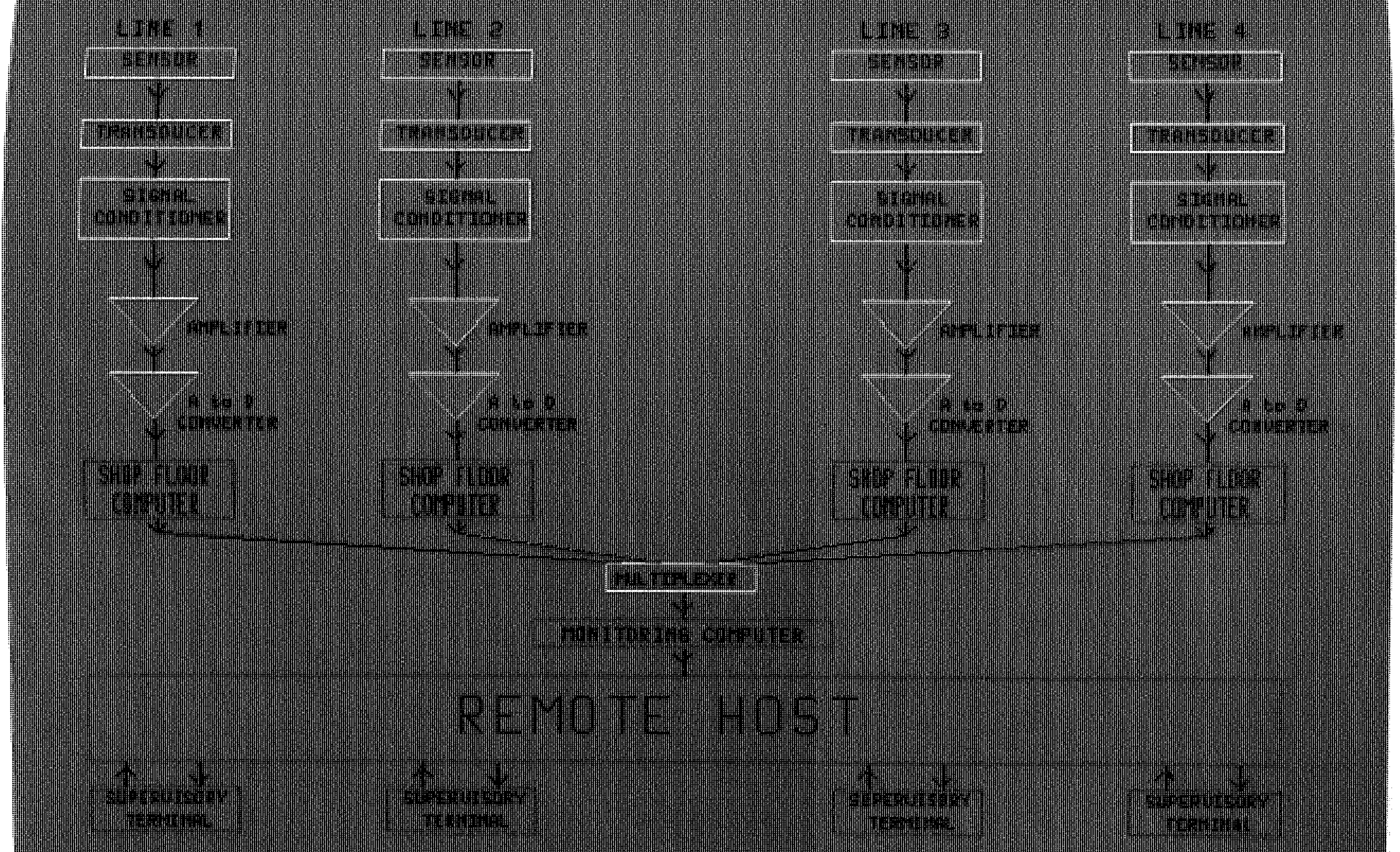
Model D on the other hand uses one shop floor computer to monitor variables for each line (hence can be referred to as a monitoring computer) and also the operators send manual information to these computers via their consoles. This is the model which was approved by the client. The terminals for manual information can either be located separately from the monitoring computers or integrated in them. This model is slightly less reliable than Model C as data which relates to one production line can be lost if the corresponding computer fails to function but there will not be unnecessary human errors as in Model C. The expanded version of Model D is represented in system 3 (figure 4.11).

The system this way looks much better than the previous configuration but it is better to have yet another computer in the long term between the shop floor computer and the host which can be named 'the monitoring computer'. Therefore the computers which were previously referred to as the monitoring computers will have to be known either as shop floor computers or process computers. The reason for needing another computer is that the host may be used by many subsidiary companies and that the total structure may have to come to a standstill in the case of a host failure or software upgrade in the absence of a monitoring computer, whereas each company can carry on independent of the host until it is ready when a monitoring computer is present. This configuration is shown as system 4 (figure 4.12).



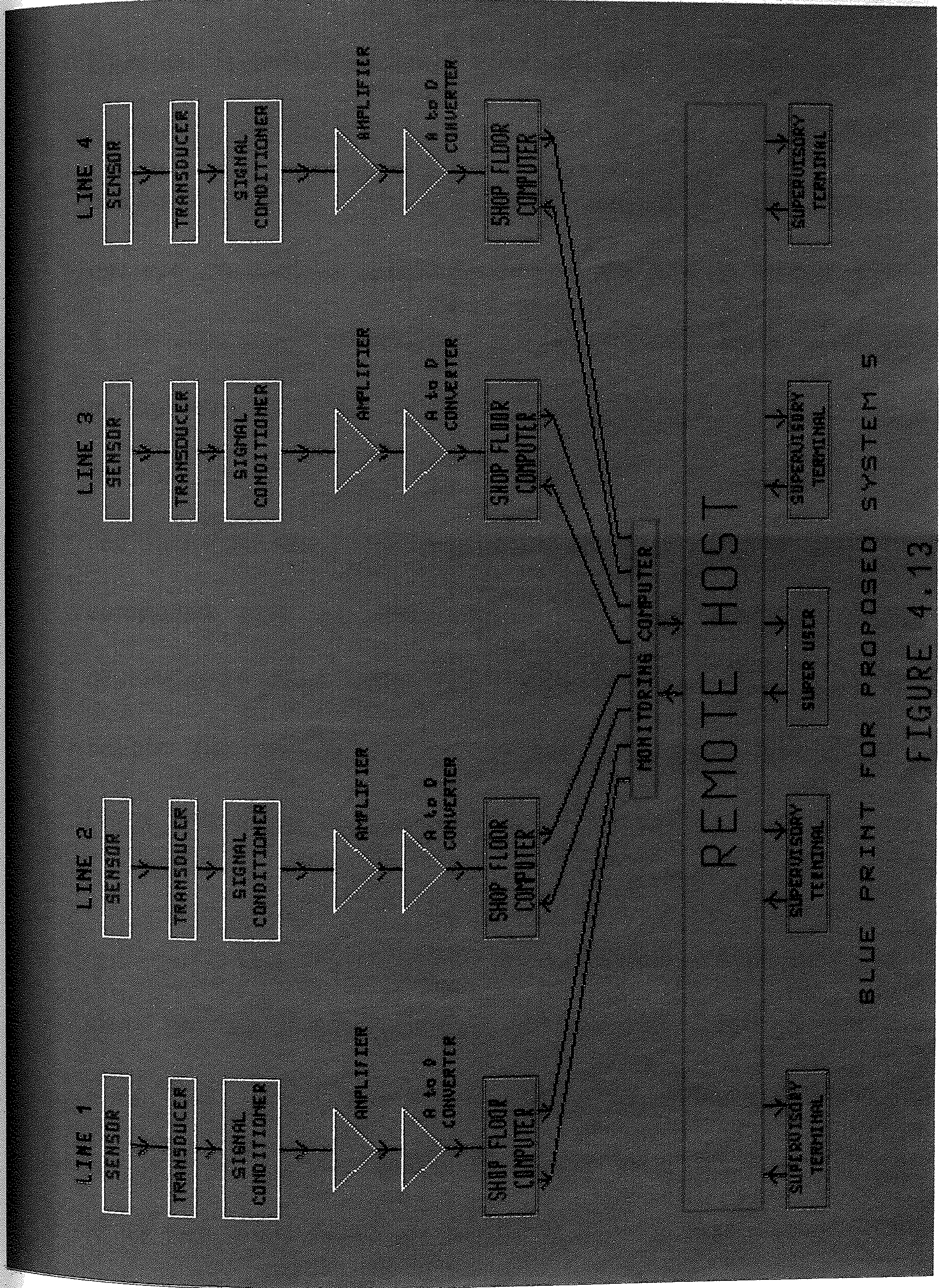
BLUE PRINT FOR PROPOSED SYSTEM 3

FIGURE 4.11



BLUE PRINT FOR PROPOSED SYSTEM 4

FIGURE 4.12



BLUE PRINT FOR PROPOSED SYSTEM 5

FIGURE 4.13

Once again total reliability is not present in system 4 because the data from the shop floor computers are multiplexed before they go in to the monitoring computer. If the monitoring computer is a medium sized muti-user user mini which has at least 5 communication ports then the communication with the shop floor computers can be done using 4 of these ports while the remaining one can be used to communicate with the host as in system 5 (figure 4.13). The system in this case will become more reliable as no multiplexing is done. A manufacturing company however, might not be able to withstand a big capital outlay to implement the system and therefore the shop floor computers (perhaps just one shop floor computer) may be connected to the host directly during the development stage while the middle (monitoring) computers can be bought and included in the system at a much later stage in the future when the company's finances permit.

The three levels of computers which were described above are the process, satellite and the plant levels starting from the shop floor production lines. One plant computer might not be sufficient at a later date in the future when the system is extended to all subsidiary companies. This is quite a possibility because some of the subsidiary companies are not located at the same premises. Hence a corporate computer for the management to summarize overall group performance with a number of plant computers might have to be used. Such a stage may not come in the foreseeable future and it is not the aim of this research to look in to such aspects. The aim of the research however is to explore the possibility of a management and monitoring system for at least one subsidiary company and a minimum of one production line depending on the available resources, while providing for expansion or simple duplication in the future. It is entirely the company's decision to buy various equipment which will be recommended in this thesis. The system which was discussed so far can be represented as a communications centre (figure 4.14) with the following features.

(1) Data banks

(2) Historical information

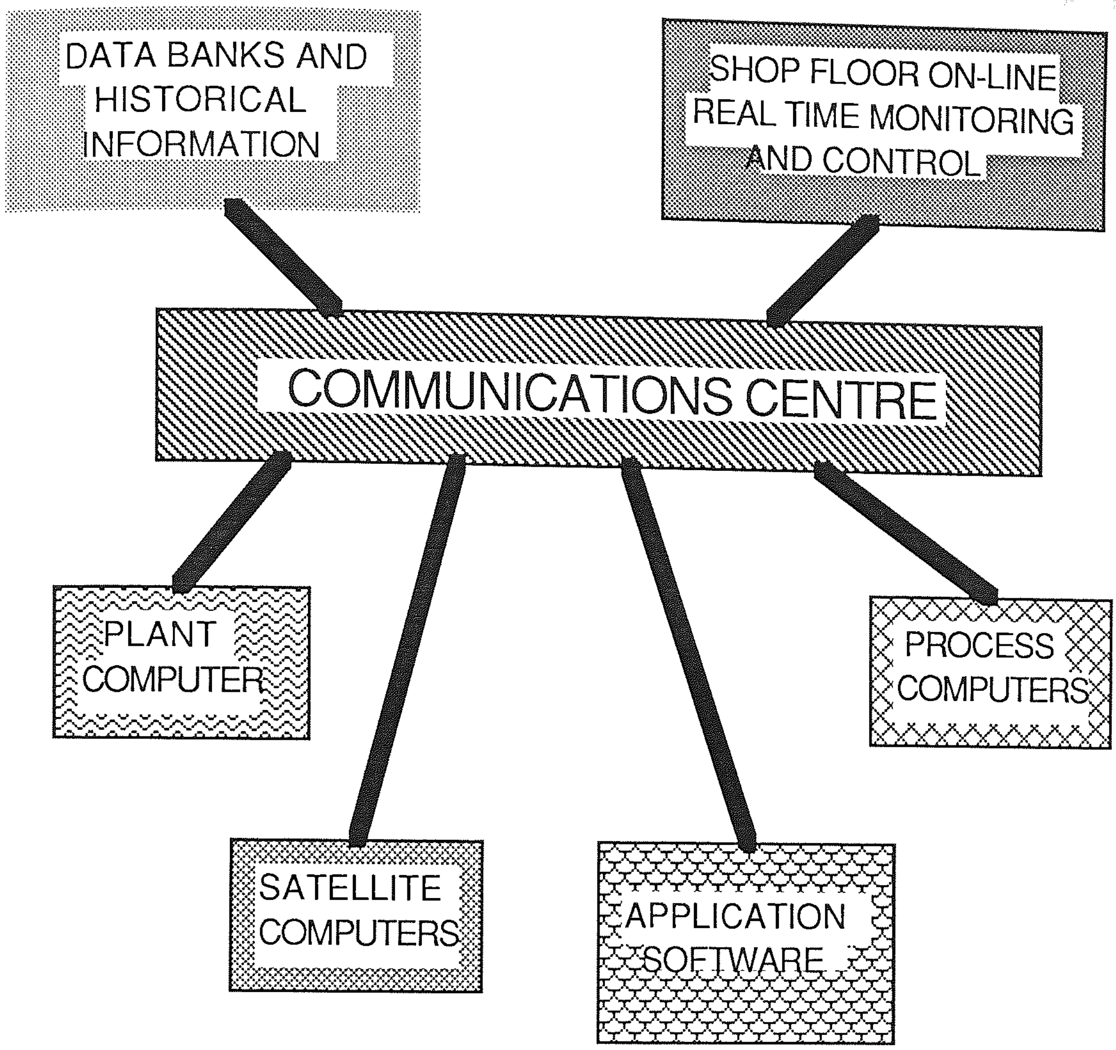
(3) Application software

(4) Shop floor on line real time monitoring and control

(5) Plant computer

(6) Satellite computer

(7) Process computers



The communications centre

Figure 4.14

4.6 Selection of computers

A satisfactory model for solving the problem has now been developed and approved by the company. The next stage is to look at the available computers and to select the most suitable one as the host to develop software. It is appropriate to use the technique of Attribute listing again to look at the requirements as follows before the selection is made.

(1) The computer must essentially support a multi user environment so that many users can log in via remote terminals.

(2) Must have a large on board memory plus a large disc capacity.

(3) The response time must be fast.

(4) Any future versions of system software must support the existing versions.

The choice of computers is rather limited when the existing resources in the university are looked at, and unfortunately the selection has to be made from these. It can be safely determined from the above requirements that a microcomputer is not suitable for the purpose because of the limitation of memory. Therefore the computer has to be either a mini or a mainframe.

The available resources are

(1) ICL Perq 1

(2) ICL 1904

(3) Vax II 750

(4) Dec Rainbow

(5) Dec Professional 325 and 350

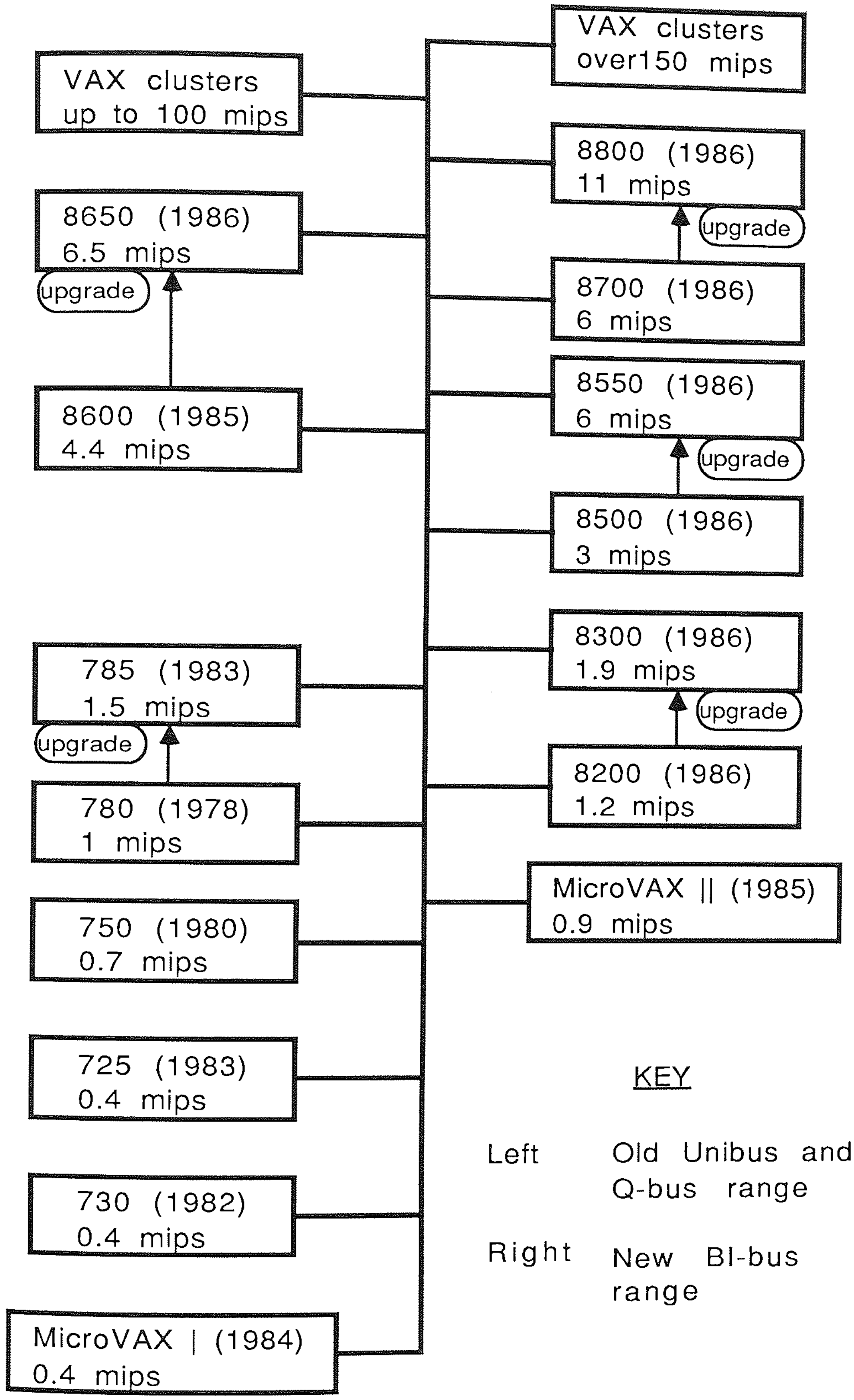
(6) Harris 500 and 800

(7) Different types of IBM PCs

The ICL Perq, IBM PCs, DEC Rainbow and the DEC Professional computers must be eliminated although they seem to have large memories and disc capacities, because they are single user workstations. The ICL 1904 is a very old computer and it can be capable of only batch processing. Furthermore, it was due to be replaced at the start of this research because of it's limited capabilities when compared with the modern computers. This left the choice between the Harris computers and the VAX II 750. Undoubtedly either Harris computer is larger, faster and can support a larger number of users than the VAX II 750.

The VAX II 750 computer is rather an old machine which uses the 'unibus' structure while the new versions use the revolutionary 10 layer 'BI bus' which makes them cheaper and more expandable.[81] Dec user[82] says that the arrival of the BI bus structured VAX 8550 and the 8700 have limited the life of the top of the unibus range VAX 8600 and it's 'turbocharged' brother 8650 to about 7 or 8 months in the front line. The range of VAX computers and their speeds in million instructions per second (figure 4.15) show how the new VAX computers are far superior than the old ones.

At this stage North Staffordshire Polytechnic became the first in the U.K's higher range VAX users by placing an order for two 8300s, one 8200, one MicroVAX II and a VAX 780 to 785 upgrade at a cost of £1.2 million[83]. At the same time University of Aston was planning to replace the ageing ICL 1904 with a VAX cluster of unibus structured two 8650s and a 785; and a BI bus structured Micro VAX II at a cost of £2.5 million. All these computers are compatible with the old VAX 750. Therefore the 32 bit VAX II 750 'super mini' which has 4 Mega Bytes of memory and 577Mb disk capacity was chosen to develop the software.



The VAX range of computers

Figure 4.15

4.7 Selection of an operating system

A number of operating systems have been looked at (Appendix 2)(84,85,86,87,88,89,90,91,92,93,94,9596,97,99) out of which ELN, VMS, VOS and Unix seem to be the ones which support muti-user user environments, but VOS has to be rejected immediately as it is not available on the VAX computers which were selected for this research.

The earlier versions of the Unix operating system were not available on the VAX computers but the 7^{th} edition became available(91) on PDP ll and VAX ll 780 computers. UNIX's dynamical assignment of process priorities can be a very big advantage in running real time data acquisition systems because it can run at a high priority until CPU time is required, after which UNIX imposes a lower priority.(100) The only disadvantage therefore is the unpredictability. The client however was reluctant to choose the Unix system as he was not entirely pleased with some programs which had been developed on an ICL Perq machine which had the Unix operating system.

VMS is by far the most popular operating system on the VAX machines although it is not very suitable for real time applications because of the way it is designed to work. The priorities are static unlike in UNIX and a priority once allocated will not change unless re-allocated by the system manager. The only advantage of such a static system is it's predictability. ELN on the other hand is the recommended operating system for this type of applications although there is not enough documentation.

Since the conceptual model was divided in to several layers as in Marple's decision trees, it is apparent that the real time monitoring is not carried out directly by the host computer. Therefore it is not absolutely essential to have an ELN operating system in the host (although better) since the main task of the host will be management while carrying out 'indirect' monitoring of the production lines using the information which is received from the other computers. VMS operating system was finally selected for the host after considering above factors and also the absence of the ELN operating system within the university, while keeping all options open for a real time operating system for shop floor computers.

4.8 Selection of a language

A number of different languages have been looked at (Appendix 3)[101,102,103,104,105,106] and many seem to be rather unpopular at engineering applications. It will not be suitable to select such a relatively unknown language however suitable it may seem to be, because of either the non availability of commercial software or the difficulty in future expansion. Considering the fact that the client has to be able to expand the system to wherever they desire, it is advisable to select a general purpose language which is widely known. Pascal, Fortran and Basic are the only such suitable languages out of the ones which were discussed and all three are available on VAX computers as compilers.

Out of the 3 languages, Pascal seems to be the best because it is known to allow programming in a systematic way. The storage aspects of Pascal show that it has a fairly static view on allocation. This is quite acceptable in a teaching point of view but can not be said as fully reliable as applicable to day to day usage of a large data base. Commercial software is also not available in Pascal to such an extent as in Fortran or Basic which seem to be the most popular languages in the industry. This leaves only those two languages out of which the final selection has to be made. Table 4.1 has been prepared to compare and contrast these two languages to select the most suitable.

The table 4.1 shows that Basic is better than Fortran in many aspects while the advantages of Fortran are the relative high speed of performance and the easy transportability between machines because the software is independent of the machines. Finally a test was carried out to compare the speeds of both languages by running a simple program (written in each language) to multiply all integers from 1 to 1500 by 2 and write on the screen (table 4.2). Both programs were compiled to run on a VAX II 750 computer and the program which is written in Basic took an average of 58 seconds at a busy time when 9 users were logged in the system while the Fortran program took an average of 90 seconds. At another time when only 3 users were logged in, the Fortran program took 47 seconds to execute while the other took only 31 seconds.

	FORTRAN	BASIC	Advan.
1.	A decimal point can not be used in a real variable	Variables can be mixed. Hence less operator errors	Basic
2.	Field width must be defined and no extra characters will be saved.	Field width is not necessary and the complete string is saved.	Basic
3.	The string "253 " when converted will ouput 2530000.	The string "253 " when converted will output 253.	Basic
4.	Known to have high speeds.	Speeds are known to be slow.	Fortran
5.	Software independ-ent of machines.	Software dependent of machines.	Fortran
6.	Expensive.	Not expensive.	Basic
7.	Every new statement must start in a new line.	Each line can have more than one statement.	Basic
8.	Different statement for each jump.	Single statement can do many jumps.	Basic

Fortran Vs. Basic

Table 4.1

Fortran program	Basic program
DO 10 I=1,1500	10 FOR I=1 TO 1500
WRITE(6,*),2*I	20 PRINT 2*I
10 CONTINUE	30 NEXT I
END	40 END

Equivalent Fortran and Basic programs

Table 4.2

This test showed that the Basic program ran on the VAX II 750 computer faster than Fortran program although this test alone is not sufficient evidence to claim that any Basic program would be faster. The results of this test and the table 4.1 were presented to the client for him to make a final choice and Fortran was chosen because it is assumed that Fortran programs are easily transportable than Basic programs.

A design specification (Appendix 4) was made at this stage using all the above information and the approval from the client and the authorities of the university were obtained. Then a critical path analysis (Appendix 5) was carried out and a time schedule (Appendix 6) was made for the project. These steps were taken only as simple guide lines to ensure that the progress is made in the desired direction and to take corrective action in the case of a deviation. They can in no way be used to prognosticate the outcome of the project accurately, and in this type of a project, different parts of the programme can be expected to be a long way out of the planned schedule while only the total amount of work and time are the only aspects which can be reasonably close to the planned amount. One other comment which must be made is that the 24 activities which are listed in the critical path analysis were summarized to obtain only 19 in the time chart as the latter is used mainly to keep within the time limits rather than the direction.

Chapter 5

Management level 1

5.1 Introduction

Chapter 4 explained how the model was effectively built and Blue print 5 showed the different levels of this model where the top end of the model being the shop floor level and the bottom end being the management terminals. It was also explained that some management software is essential to have some meaning to the data which has to be collected from the shop floor. Therefore the intention of this chapter is to show how the problem was approached by working in a 'bottom up' manner by starting at the bottom end of the model (i.e., the management level) and progressing towards the top. (the opposite of this is the 'top down' approach)

5.2 Data bases and their management

A data base is one of the most important facilities which can be provided by a computer system. It is so important for some people that it is the principle justification for acquiring a computer system. A data base can be defined in many ways and Laurie[107] says that it is simply a collection of lumps of information stored on a computer while Date[108] says that it is a computerized record keeping system. Mayne[109] extends this definition to give more details by saying that it is a collection of stored data organized in such a way that all user data requirements are satisfied by the data base. He goes on to say that in general there is one copy of each item of data although there may be controlled repetition of some.

A data base can be analogous to an organized set of conventional drawers or folders in which the data is kept. Humans have to do this organization in a manual system while the computer does it via the application programs in an automated system. Therefore a data base management system is a set of general purpose programs which allow access to the data to read, write, modify, delete and append.

There are ready made data base programs which are commercially available to carry out these tasks and some of them are DBASE[110] and INFO.[111] These are not only very expensive but are not flexible enough to be used with complicated applications.

Hence it is much better to design one's own data base to suit one's requirement providing one has the necessary knowledge and patience to complete this complicated task.

5.3 Initial considerations to build a data base

A data base which contains a large amount of data will be of little use unless the data is structured in a meaningful way. The data base management must therefore provide data structuring facilities which are capable of expressing the often complex relationships which exist between data items.

The initial consideration is to identify the items of data which need to be stored while they can reside in different sections of the data base in the most logical manner but should be retrievable by any section.

The next consideration is the character fields or field widths of the individual items of data. It is most important to identify the maximum required field and allocate an equivalent field for each corresponding item. The total field may not be possible to be displayed in every section or program when this item of data is extracted, but it is vital that it should exist in the data base as a full item and must be displayed at least in one of the sections or a program without being truncated.

The third consideration is the method of record identification. i.e., the attributes which are necessary to extract the records must be identified before the data base is designed. This is no easy task as the designer can determine one characteristic to be used for this purpose while the actual users would prefer to extract data using another. It therefore must be determined essentially after a market research.

The fourth consideration of data base design is that the data base or any individual item of data must not be governed by the extraction parameters. The data therefore must in no way be changed to suit the method of retrieval.

Finally, the method of access is a very important feature in a data base. It was mentioned in chapter 3 that all the previous designers who carried out roll design[5,6,7] for the client have used the sequential access method. The author of this thesis could not find the justification for this since the direct access format is faster and more flexible as explained in the same chapter. Therefore it was decided to use this format for the data files. This method was seen to be usable in a VAX || 750 computer through Fortran language.[113]

5.4 Special considerations

Design of a multi user data base is very complicated and it must not be forgotten that many users can use the data base simultaneously. The data files therefore must be accessible by more than one user at any time. The special keyword 'shared'[113] has to be used to allow for this in defining all the data files.

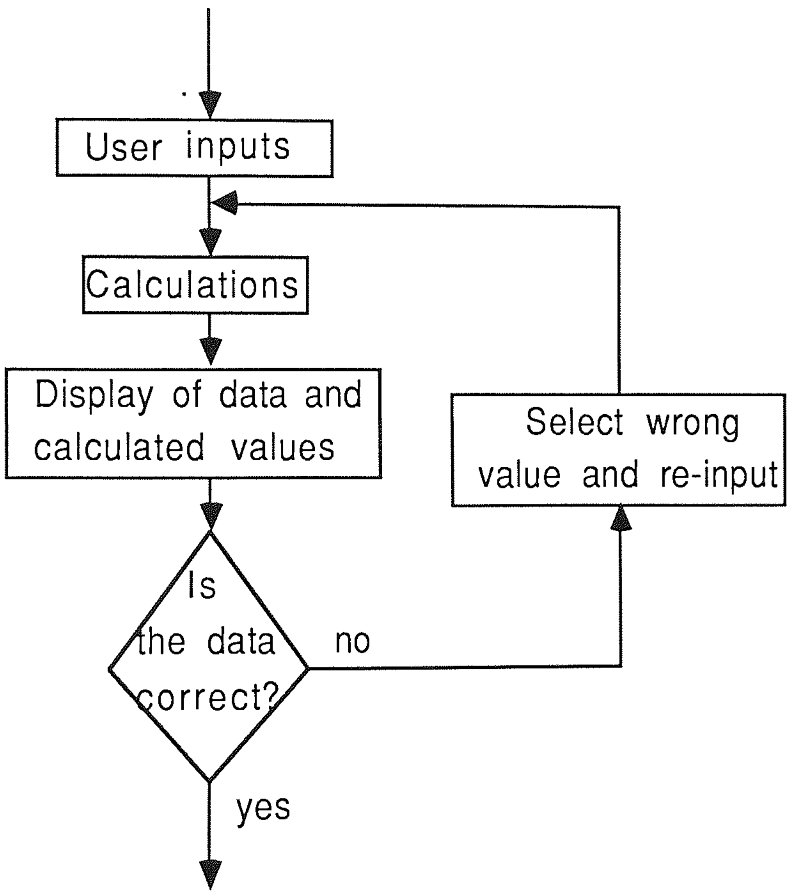
File names also must consist of some logical pattern. The VMS operating system expects the file types[114] as in table 5.1 to be used but it is not compulsory although the usage of the same convention will make the identification of files easy. (For example, the application software module for customer data can be named 'CUSTOMER.FOR' while the data file can be named 'CUSTOMER.DAT')

Type	Description
BAS	Basic source file
COM	Command procedure
DAT	Data file
EXE	Executable image
FOR	Fortran source file
JOU	Journal to recover an aborted file
LOG	File to log submitted job details
OBJ	Object file after compilation
PAS	Pascal source file
TXT	Text file

File types

Table 5.1

The user should have a provision to make corrections in virtually every operation in a user friendly data base (particularly when making new entries) before the data is saved. The ideal way is to display all the user supplied data and the calculated values before asking the user to either confirm that the data is correct or to select an incorrect value to be corrected. Ideally the user should be able to select them by pressing numeric keys which are easy to locate rather than locating any other key. The calculations must be done every time a correction is made and this procedure must be repeated (chart 5.1) until the user verifies that the data is correct. The data should be saved only after that. It should not be attempted to save the data as the user enters them because the time taken to write each record in to the file will then be longer and as a result, a user can try to write to a record while another user is also writing to it. The consequences of this can be quite disastrous.



Data confirmation

Chart 5.1

Another good practice is to have menu driven systems and to build escape sequences at different parts of the program so that a user who prefers to abandon an operation after starting does not have to complete it. For example, if a user selects the creation of a new record option at the menu and realizes that he has to attend to some urgent task, then he would require to abandon the current task. An escape sequence allows him to escape from creating the record to enable him to either exit form the program or to go to another section.

5.5 Customer data module

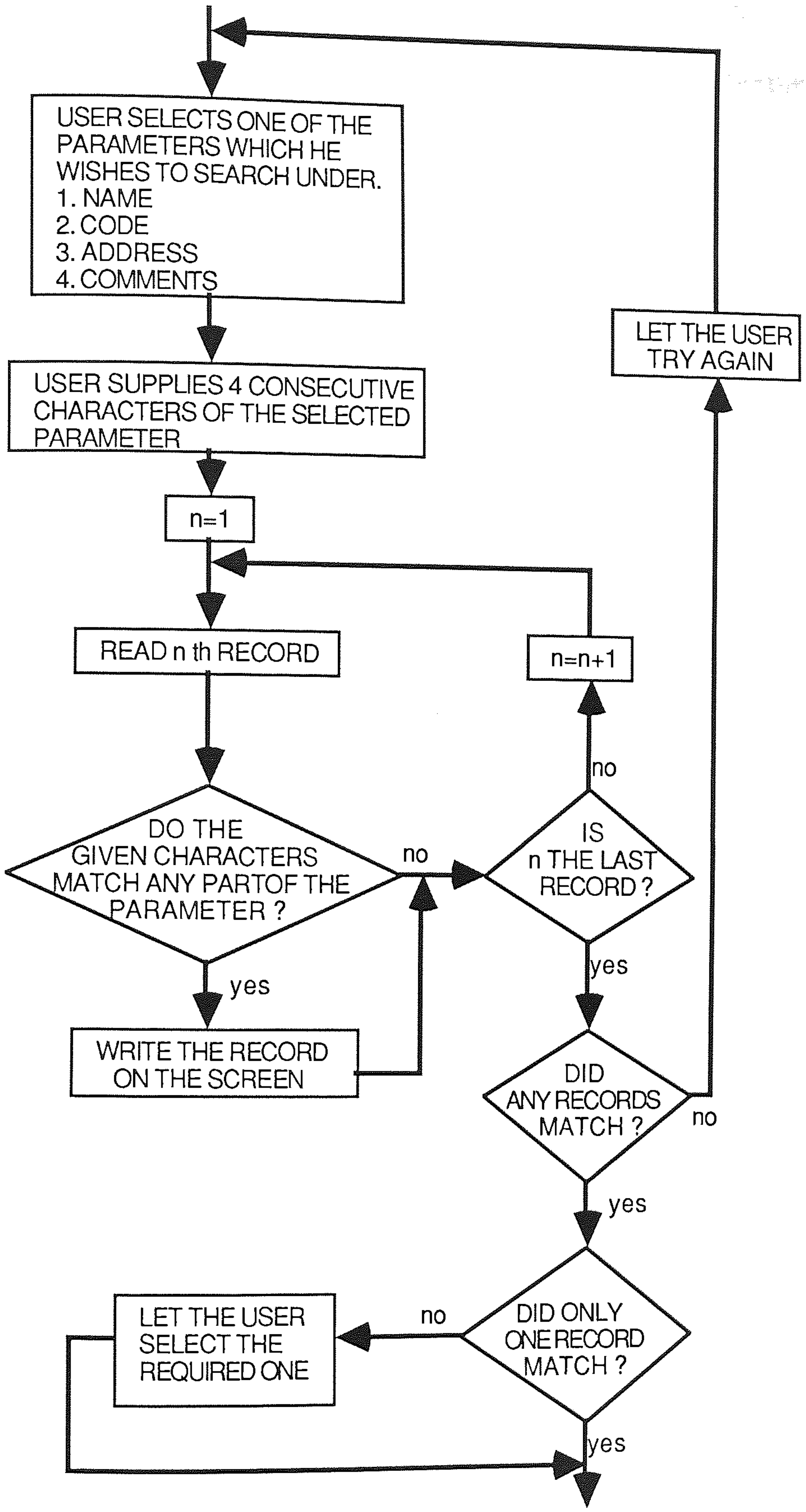
Any manufacturing company has to have customers to sell their products. The customer data can also be simpler than any other type of data and computerizing these is a good starting point in creating a data base. The most important characteristics are the customers' names and addresses, but it might be useful to have some type of a coding system for future expansion purposes. The financial and accounting departments could use these codes to prepare invoices or to maintain individual customer accounts in future. It is not necessary to determine a code for each customer at this stage since this aspect is only a provision for future expansion. Other important items which can consist in a customer data file can be the customer status, credit details, and outstanding debts. It is therefore useful to have another variable for such details which can be named 'comments' for future use.

The four parameters, name, address/telephone, code and comments are sufficient to be the characteristics of the customer file. The field width of each must now be determined. It was realized that no customer name was longer than 34 characters after checking most of the customer names of the company. Therefore a field width of 46 characters was set aside for this variable after leaving a margin of approximately 33% for any longer names. Following the same principle, the maximum length for the address variable was determined as 80 characters and a width of 105 was allocated for the comments. The customer code presented a more serious problem because most potential users suggested that it should be used to identify records in order to retrieve them.

Some previous work on small data bases for the company revealed that Liossis[115] preferred to identify records by the record numbers. This is quite useless for a large data base as the users can in no way remember the number of the record where each individual item is saved. Therefore the customer code is certainly a better key for this purpose but it presents the problem of determining the field width for it. A useful width is 16 characters but it is rather inconvenient to type 16 characters every time a customer record has to be extracted. This is exactly what was said by a person at a session where the Delphi technique was used. His approach is to keep the codes to a minimum because of this problem. This however is a very inefficient way of planning a data base management system as the length of the code simply has to be governed by the fact that it has to be used as the parameter for identifying the record. This will be even more serious if the identification parameter is the customer name which has to be used in the absence of a customer code. In a practical point of view, the code or any other variable must be as long as it is required by the actual purpose that it serves. It might even be better to have a longer length than actually required to suit future expansions.

A clever way to achieve both will be to have as long a code as needed and use only a part of it to identify records and extract all matching data. If there is more than one item then the user can select the correct one after viewing all matching items first. This method allows the user to view a group of partly similar codes at the same time rather than selecting them one by one. This is quite easy with commands like INDEX[116] in Fortran and INSTR[117] in Basic which allow to match a string with any part of a longer string. Usage of such commands introduces more flexibility to the system and therefore the record retrieval can be done not only by using the customer code but also the name, address and comments by supplying a limited number of any of these variables (chart 5.2) rather than typing a full length string.

The disadvantage of using such a procedure via Fortan is that the user supplied shorter string has to have a fixed length. If the number of characters supplied by the user is less than the declared number then a match will not be found because Fortran replaces the null characters with spaces to keep the length of the string to the declared length. Therefore the length was decided to be fixed at 4 characters. It must be commented that Basic does not have this problem and hence the user can vary the number of characters he wants to input, whenever he wants to look for a match.



Retrieval of a record

Chart 5.2

The customer file was built using this feature and additionally hard copy facilities, writing new data, updating, escape sequences and a host of other utilities were provided in a menu driven system. One other important feature of this module is, it does not allow duplication. This is done by checking to see whether any fully matching records exist every time an attempt is made to enter a new record.

The data file was appropriately named CUSTOMER.DAT since the name of the source file is CUSTOMER.FOR and the channel number for the data file was chosen as 19 while the length of a record was fixed at 80 bytes.

5.6 Gauge tolerances module

It was revealed from the initial discussions with the client, that most of the gauge tolerances are those of British standard and that these have to be entered manually every time a job's details are passed on to the shop floor. Therefore it was decided to computerize this data (although not planned initially) so that they can be extracted when required by supplying a part string or a value as in the customer file. It was also decided to create this module as a general purpose module so that the data can also be entered and updated at any time as in the customer file.

The module therefore is somewhat similar to the customer file and was named 'GAUGE' with '.FOR' for the source file and '.DAT' for the data file using the usual convention. The main variables of this file are mean gauge, maximum gauge, minimum gauge and the material type such as Zintec, Stainless steel etc. The former three are real variables while the last is a character variable unlike all character variables in the customer file. This module too does not allow duplication while the data can be retrieved by supplying one of the real variables or a part of the character variable. Further software was added to keep the data in the ascending order of mean gauges regardless of the order in which the data is entered. The channel for data in this module is 31 while the record length is 20 bytes. The usual facilities of hard copies, full display of data (Appendix 7) and corrections are all available in the module.

5.7 Sales pricing card module

This is a very long and a complicated module where all the information of any product such as it's characteristics, involved operations for productions, targets, the costs and the selling prices which are based on different lengths are maintained. Planning to create this module showed the need for a product code. This was studied to a great extent, and after a number of discussions it was decided to set up a product code (Appendix 8) which has a length of 16 characters.

The normal convention should be to have one sales pricing card for each product (i.e., one product code should appear in the file only once). This convention can not be strictly adhered to because the same product can be sold to different customers at different prices depending on various factors. Therefore the software was designed in such a way that there can be a number of sales pricing cards for any product but each card with a different customer name. The duplication is thus prevented by checking both the product code and the customer name and disallowing more than one card to have both these variables identical.

The user does not have to go through all the cards which have the same product code in the case of a major change in a product, and change the details manually. A facility to use the string 'stock' as a customer name has been provided and, if any change is made in such a card then the computer would show all the cards which have a matching product code and ask the user whether to change them too. The user at this stage can also do a selective change if he wishes and this allows an enormous amount of flexibility. This facility was also extended to the creation of new cards where if such a card is created then the user can duplicate the values in any number of cards for different customers. This has become a very useful feature.

The user has to provide only 4 consecutive characters of an existing customer's name in order to supply the customer name for a pricing card, and the program checks the customer file although it is a completely separate file which must be accessed via it's own application software module under normal circumstances. The user is then presented with a list of all matching names for him to select or reject. He can also specify a new customer name and the computer in this case prompts the user to input all details which then are automatically written in to the customer file. Therefore manual updating of the customer file is not necessary. The gauge tolerance file is also accessed in the same way and details of any tolerance can be extracted and be written in to the appropriate record of the sales pricing card by specifying only the mean gauge. The tolerance file also gets updated at the same time similar to the customer file.

The user can carry on entering data even if he makes a mistake at any stage because the entered values are displayed when he finishes and is requested to either confirm that the values are correct or to select any incorrect value. The computer carries out the calculations from the start in the case of a correction, and presents the new data which can once again be corrected if the user wishes. This goes on in a loop until the data is confirmed to be correct. The user can also abandon the operation at various stages by keying in the code 99 as the answer to various questions.

All the major information of a product appear in one page of screen while the second page consists of all the actual details such as rolling speeds, setup and strip times and the line number on which the jobs were done. These values are used to calculate targets. Initially the targets are the same as the estimated values of rolling speed, setup time and strip time, but any better subsequent performances than the targets become the new targets.

The user can use the pricing card like using a calculator to analyse the data without actually altering them although that too can be done should he wishes. The computer displays the percentage change of price based on the original one as a result of a change during the analysis.

All the other usual features like the hard copy facility, varied selection modes, numeric key selection, the display of the number of records and the date of last change are all available in this module while a revolutionary feature is that it checks to see whether there are any incomplete records whenever any user enters the module. If such a record is found then the computer displays the incomplete records one by one requesting the user either to complete them or to skip. Obviously the user finds it rather annoying to go through a long list of incomplete records every time he tries to access the module and therefore is unlikely to keep incomplete records. The user also does not have an excuse to say that he did not complete some records because he did not know that they existed. This will encourage the user to adopt the good habit of maintaining completed records. The value of this feature will further be seen during job creation and stock control which will be discussed later. Appendix 9 show a selected screen of this module. The module has been named PRICARD with a fixed record length of 350 bytes and a data channel of 18.

5.8 Line preference module

Some extra information about the production came to light as a result of constant discussions with the client's staff. This information showed that some production lines are preferred for some jobs while some jobs can not be done on certain lines. Another category is that some jobs can be done on certain lines but they are not the preferred ones. Analysis of this data resulted in the conclusion that there is no rigid rule by which the computer can make a decision on scheduling a job on to a particular line. Therefore the need to computerize all such data was recognized.

The line preference module was created to maintain such information and the module keeps all the jobs under product codes where each product code indicates on which line it is preferred to be done, can be done or can not be done. The computer can then select the preferred line first for any job and try to schedule it on to any non preferred line only if the former is busy. This module also has been prepared to the same professional standard as the others and consists of all the normal features. The name of the module is LINE while the record length is 20 bytes and the data channel is 32.

5.9 Company holidays module

The job scheduling has to be done automatically as per design specification and this is a real time task. If the jobs are scheduled for periods which are covered by holidays then the scheduling will be completely meaningless. Therefore the company holidays must be entered in the computer prior to scheduling. A module was prepared for this and the data can be entered, updated or deleted via a menu as in the earlier modules and the name of the module is HOLIDAYS. The data channel of this module is 37 and the record length is 20 bytes.

5.10 Jobcard module

This is the module which creates jobs by compiling similar orders. One job can have up to six customers and each customer can have up to 15 different orders (different lengths) of the same product which add up to 90 different orders per job. Once again the customer details are extracted from the customer file using the same principle of requesting for only 4 characters of a name as before. The product details, tolerances, descriptions, prices, targets and most other necessary information is extracted by reading the appropriate sales pricing card. The user is allowed to increase or decrease the actual targets for the shop floor display if he wishes. The customer section of this file includes the invoice numbers, packing and special instructions, required delivery dates and the lengths of the finished products. These details have to be entered manually while the selling prices for each customer and the total job are calculated from the information which is extracted from the sales pricing card. These prices do not get printed on the paper which is sent to the shop floor.

If the pricing card for any customer is non existent then it becomes impossible to extract the necessary information to create the card. This type of a situation is quite likely to be encountered with, although the users have to be advised to create the appropriate pricing card before the job card is made. Therefore the program displays a message to the users to the effect that the pricing card is non existent and also writes an incomplete record to the pricing card file. The effect of such a card was discussed in section 5.6 and the corresponding situation is that the job card is also incomplete. Unlike in the pricing card module, the user is not shown the incomplete records as soon as he enters the job card module prompting him either to complete them or skip. Instead, if incomplete job cards are found then the pricing card file is scanned to see whether the corresponding record has been completed. If it is completed then the required data is passed on to the job card file. This activity is quite transparent to the user and is extremely useful.

The length section is another important section of the module, and if the customer has ordered in imperial units then these are converted to S.I units. Both units are shown against the customer in this case while the imperial units are simply ignored if the order is in S.I units. All the customer orders are compiled in the length section and the lengths to be rolled are shown in S.I units in ascending order. This section is re-compiled and re-arranged every time a user makes an alteration.

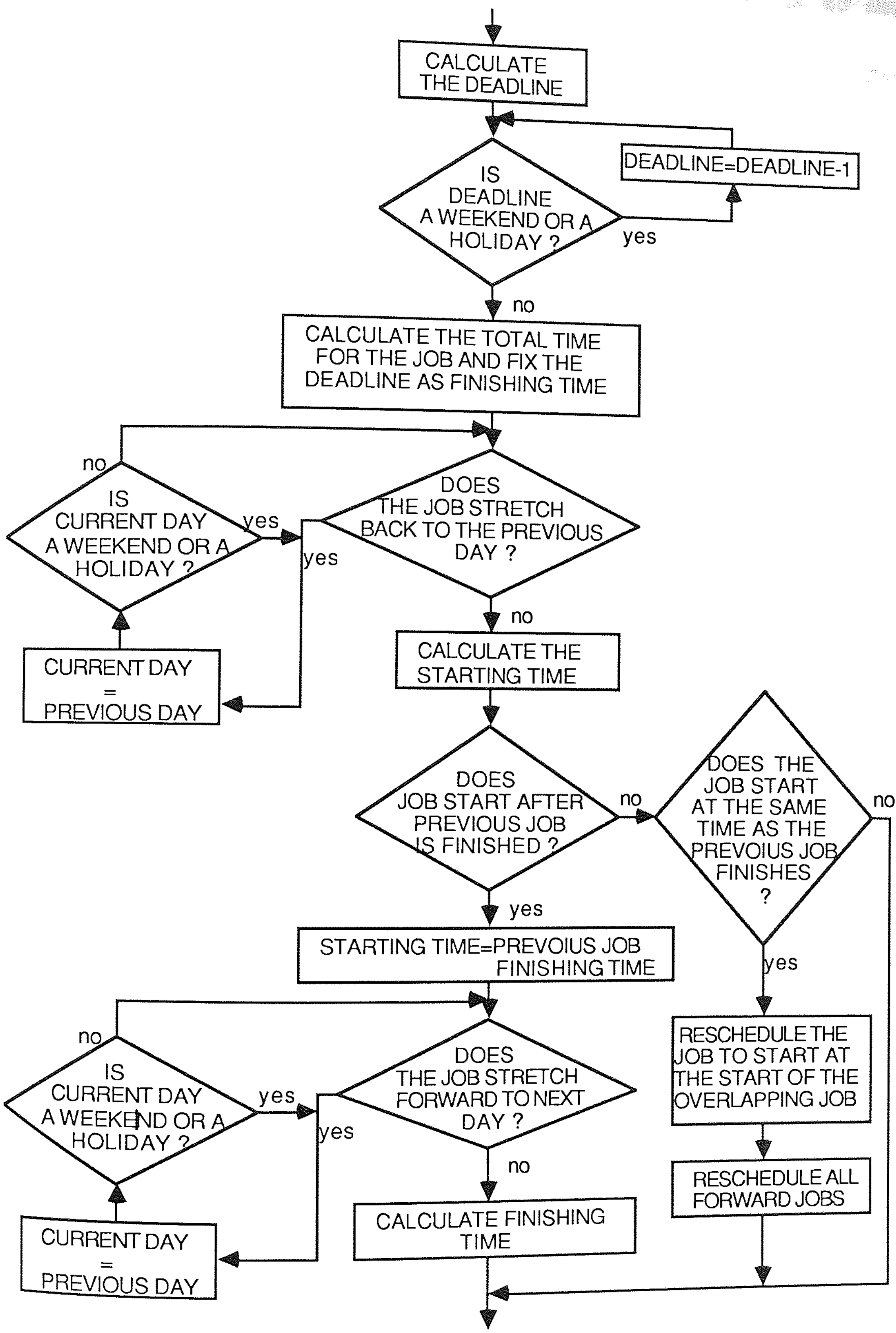
The jobs after being created have to be scheduled but the delivery dates will have to be looked at for this purpose. The day before the earliest required delivery date in a job should be the deadline for the job to be finished since it is not economical to break jobs to suit individual delivery dates. If the calculated deadline falls on a Saturday or a Sunday then the actual deadline should be a Friday. Furthermore, the actual deadline should be the last working day before a holiday period if the calculated deadline falls within this period. The limitations of the VMS operating system which is not designed for such real time tasks can be seen clearly at this stage. While it is possible to find the day of the week via Digital Command Language (DCL) by a very long process with difficulty, Fortran has no such facilities. Therefore this had to be done by involving some powerful service calls to the operating system. The actual scheduling becomes even more daunting after calculating the deadline because of it's very complex nature.

The total length of a job must be calculated before calculating the starting time of a job while the finishing time can be considered as the deadline. This has been done using the expected levels of performance (targets). The scheduling has been done on the basis that there are two 8 hour shifts (0600 hrs to 1400 hrs and 1400 hrs to 2200 hrs) on each working day. Once again the week ends and the holidays (using the already prepared company holidays file) have to be carefully compared for each day the job stretches back (chart 5.3) from the deadline. The problem does not end here at this point as one of the following 3 situations is encountered with.

(1) The job is scheduled perfectly to start at the time which the previous job finishes.

(2) The job is scheduled to start after the previous job on the line is finished, but there is a gap between the finishing time of the previous job and the starting time of the current job.

(3) The job can not be started after all the other jobs on the line are finished when the calculations are based on the deadline as the finishing time.



Job scheduling

Chart 5.3

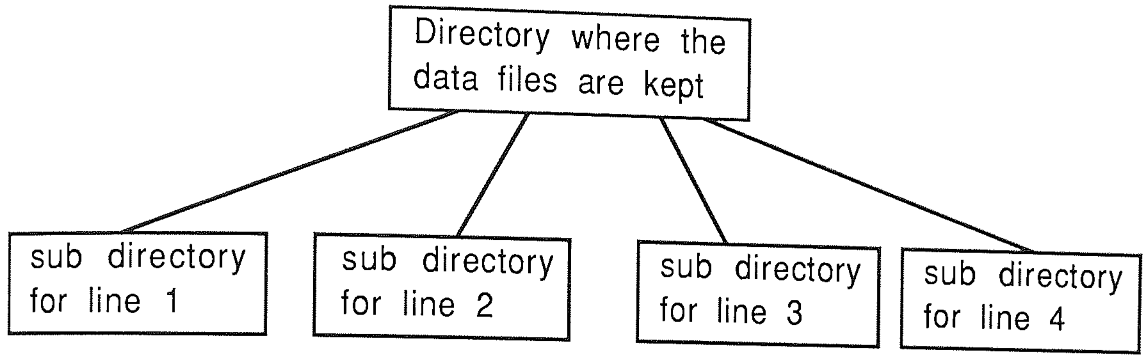
The first situation is the ideal case and there is no need for any action to be taken. Such a situation is highly unlikely to exist unless there is no required delivery date in which case the job is scheduled to start at the finishing time of the last job on the most preferred line.

The second situation is rather complicated as the starting time of the job must be the finishing time of the previous job to have no gap between jobs. Therefore the finishing time must now be calculated on the basis of the staring time being fixed. Then all the previous week end and holiday checking must once again be carried out to find the new finishing date.

The third situation is the most complicated out of the three. Firstly all other lines in order of preference must be looked at so that the job can be scheduled to meet the deadline. Failing this, the job must be scheduled at a position where either the deadline is not met or some jobs are pushed forward in order to meet the deadline of the current job. The finishing time for the current job and the new starting and finishing times of all the other jobs which have been pushed forward have to be calculated again.

The whole process is much more complicated than it can be stated here but it has been achieved by very complicated programming and the interaction with the operating system routines. The details are displayed for the user's confirmation each time a job is scheduled. If he is not satisfied then he can specify a new starting time manually and instruct the computer to either calculate the finishing time or to allow him to specify it too. This manual override facility allows the users to schedule jobs during weekends, holidays or late and early hours where normal work is not done. It is possible that the user might accidentally schedule a job to a space which is occupied by another job since he in this case does not look at the previous jobs. The computer then informs the user about this, and if the user confirms that it is what he wants, then the job whose space has been taken up and all the subsequent jobs are pushed forward accordingly. One other characteristic of the module is that no job which is automatically scheduled does not start after 2145 hrs even if the previous job fishes after this time but is scheduled to start at 0600 hrs on the following working day.

All the scheduling details are written in to a separate file to show the status of all four lines and this file can be accessed via a separate application software module. The job details are also written in a special format in to separate files under their job number (e.g., JOB1.DAT, JOB2.DAT etc.) and these are stored in separate sub directories (figure 5.1) for shop floor usage.



Subdirectory for each production line

Figure 5.1

Finally another important feature of this module is that it allows similar jobs to be presented as tied jobs. Tied or otherwise each job has a unique job number which is generated by the computer but in the case of tied jobs, the first has no strip time and the last has no setup time while any jobs in the middle have no setup or strip times. This is particularly useful when an order is received which is similar to an already created or running job. The old job is then rescheduled to finish at an earlier time to accommodate the zero strip time and the new job is scheduled to start immediately after the old one. Any other jobs which have been originally scheduled between the old job and the new one are pushed forward (with a warning message) regardless of their deadlines because economical performance is even more important than meeting the deadlines sometimes. Any number of jobs can be tied this way.

One data file was not sufficient for the job card module due to the large amount of data, and therefore two such files with the names JOBCARD1.DAT and JOBCARD2.DAT were prepared with data channels 11 and 10. The record lengths of these are 100 and 250 bytes respectively. Appendix 10 shows a Jobcard.

5.11 Scheduling module

It may be questioned why a separate module is needed for scheduling when this is done in the Jobcard module where a manual override facility also exists. It must however not be forgotten that the Jobcard module is a very long one and the display of all the information about the jobs is not suitable to get a clear impression about the loading on different lines at one time. The automatic scheduling or manual override in the Jobcard can be done only at the time of creation of a job and the jobs are also not in the order of the schedule making it difficult to re-schedule jobs even if the facility is built.

Scheduling module summarizes information of scheduled jobs and the users see what jobs are scheduled on which line and all the relevant information at a glance as on a conventional scheduling board. The users are further allowed to re-schedule any job at any time and all the previously discussed checks are done while any appropriate jobs are either pushed forward or pulled back to close gaps. Any changed details are not only directly corrected in the Jobcard file but also in the files which are located in the sub directories as discussed above. If the job is scheduled on to a different line then the data file is removed from the earlier subdirectory and is located in the one which is appropriate to the new line.

The module creates 4 data files, one for each line by naming them SCHEDULE1.DAT, SCHEDULE2.DAT, SCHEDULE3.DAT and SCHEDULE4.DAT although this is transparent to the user. These files are not kept in the line sub directories but in the usual directory where the data files are kept. The record size of each data file is 25 bytes and the data channels are 1,2,3 and 4.

5.12 Operator data module

This module was prepared mainly to introduce some security for the shop floor operations by maintaining all the details of the shop floor operators. It can also be used for other management purposes or to replace the existing personnel files.

The module was prepared to be very similar to the customer file but replacing customer codes with the operators' clock numbers. Another slight variation is that there is an extra variable for the telephone numbers in addition to the comments. The name of this module is 'OPERATOR' and it has been allocated the data channel 42 and 80 bytes for each record.

Chapter 6

Shop Floor Level

6.1 Introduction

Chapter 5 described all the management modules which had to be prepared prior to shop floor data collection in order to have a meaningful data analysis. Those modules have dealt with all the tasks up to the end of job creation and scheduling. The next step is to monitor the created jobs to measure their performance. Since the jobs have been prepared with all the necessary information including the expected levels of performance (i.e., targets), it becomes possible to compare such information with the actual performance parameters once they are collected. This chapter will discuss how this real time on-line data acquisition and monitoring are carried out assuming that the previously created jobs and their details are already available on the shop floor as per the technique of Fantasy, ignoring how the data has become available.

6.2 Data Acquisition

The key to monitoring is to have a fast and reliable data acquisition system on the shop floor. The tendency under normal circumstances, will be to buy a DEC based system for this purpose because a VAX computer was selected to do the management operations. This can limit the system to quite an extent and therefore the monitoring system must be looked at, in a point of view where the compatibility or even the fact that some data is available in different computers is totally ignored at this stage. Burch[118] says that there are four main areas of data acquisition which can be put to effective use; namely speed, intelligence, memory and software.

6.2.1 Speed

The speed is a very important consideration for needing a data acquisition system because it is the key factor which allows the management to take corrective action. Today's semi-conductor devices provide speeds which were not possible in the early days.

6.2.2 Intelligence

The intelligence of a system can vary with the requirements but it is essential that any system is intelligent enough to collect the data and process them in the appropriate way.

6.2.3 Memory

The memory of a system should be sufficient to maintain the acquired data until being processed. This period can be a shift, a day, a week or even a longer period depending on the type of the system.

6.2.4 Software

Software is the tool for making the system function. All the processing, calculations and even the acquisition of data into a system has to be planned carefully by software.

Having established that the above areas are needed, it is then required to see how these can be used in a real time environment. As it was described in Chapter 4, a real time environment gives a faster response than a time sharing environment whereas the latter would have an adverse effect on the speed.

These requirements show that the progress must be made in the direction of microprocessor based systems where speed, memory, and intelligence can be obtained to the desired level. Wallace[119] says that the trend in data acquisition over the last few years has been towards 32 bit multi tasking mini computers. Such a mini computer is the 32 bit VAX II 750 but we have already determined that the usage of a microcomputer on each line will be more effective, economical and reliable than a bigger computer. MacDonald[120] agrees with this theory and says that microcomputers are being used for remote monitoring of hundreds of points.

Most of the micro computers are buffered[100] and this feature can be used to eliminate the operating latency (the time between a peripheral requests the services and the time which it actually gets it). The computer should empty this buffer fast without letting it overflow. Another approach to the data logging is the modular approach[121] where it should include the following.

(1) Conventional micro-processor and input output facilities such as a keyboard and a display.

(2) Removable solid state memory module.

(3) A plug in personality module.

This approach is more flexible than any other approach because the memory and the personality module can simply be changed to suit the requirements or to link the loggers to different measuring instruments. It however can be more expensive to allow for such an extent of flexibility. It may be argued that such an approach is more suitable for a system under development because the memory that is required or the type of measuring system that has to be used can not be determined exactly; but it is unlikely that a small company will be able to withstand the extra expense.

6.3 Requirements

Having looked at the shop floor data acquisition above, it is now necessary to look at the requirements of the system.

(1) Must interface to the real world to collect data at high speeds.

(2) Must act as an intelligent front end to process these data and carry out the necessary calculations and comparisons.

(3) Generate alarm messages.

(4) Communicate with a host.

(5) Allow manual entries via a dedicated keyboard.

The system should have a high intelligence in addition to the above basic requirements and therefore the software must be developed in building blocks[122] to carry out these tasks.

6.4 Line Speeds

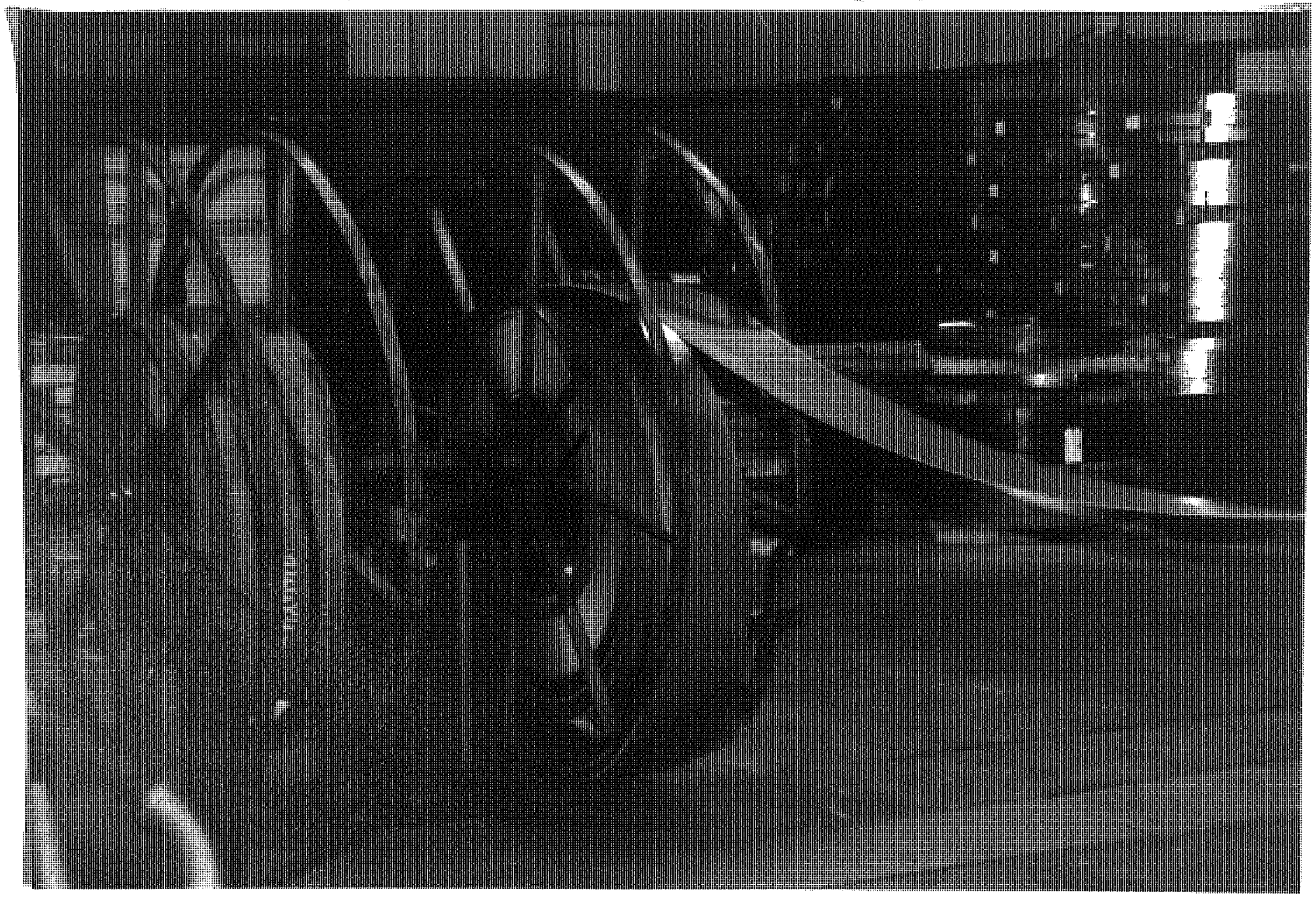
The major task of the shop floor level is to monitor the rolling speeds of each production line which has to be done automatically. This task must not only be done constantly but also must be accurate so as to inform the operator and/or the management in the case of any errors. This system has to be developed by selecting a suitable sensor to monitor the speeds.

One method which can be employed for this purpose is to mount a seismic velocity transducer[123] on each production line so that the vibration could be measured relative to a point in space. The speed of the production line can then be calculated because the measured vibration is directly proportional to the instantaneous vibration velocity.

An alternative method which was considered is to attach a gear to the coil holder. The coiled stock is wound around a large circular shaped holder which is fixed on to a base. The circular holder is pivoted to the base at the centre on both sides and therefore rotates while the coil is being unravelled (plate 6.1). If a gear is attached to this holder, then the gear itself would rotate while the rolling operation is being carried out. The angular velocity of the gear can be measured by using an angular velocity sensor[124] and the rolling speed of the line which is proportional to the angular velocity of the gear can be calculated.

The greatest disadvantage of the first method is that it may not be suitable to be used on the shop floor where other vibrations are present. The measured vibration might include other random vibrations even after conditioning the signal.

Both the methods measure a variable which is proportional to the rolling speed in an analogue form which has to be digitized as explained in Chapter 4 to be used for the required purpose. The rolling speed can also vary from a maximum to zero because the operator has a manual override facility to stop the rolling mill to clear the finished product area as explained in Chapter 2. The methods which were discussed above can not take this into consideration as they would expect the rolling mill to function in a near uniform way under normal operating conditions.

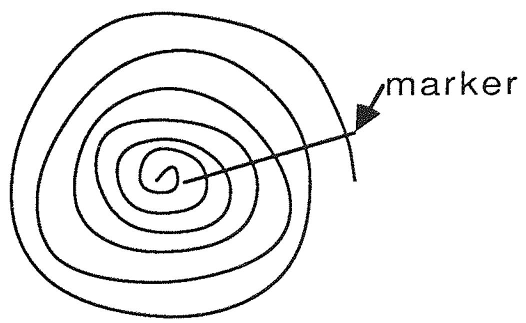


Coil holder

Plate 6.1

The non uniformity of speed gives rise to another problem, i.e., the production speed might be far slower than the instantaneous rolling speed. It is in fact the speed of production which has to be improved for better productivity rather than the actual rolling speed. Monitoring of the roll speed is useful only if there is a rigid relationship between the two. The production speed depends on the number of metres rolled within a certain period of time. This is a digital quantity and therefore will be a more accurate measurement than the two analogue measurements above.

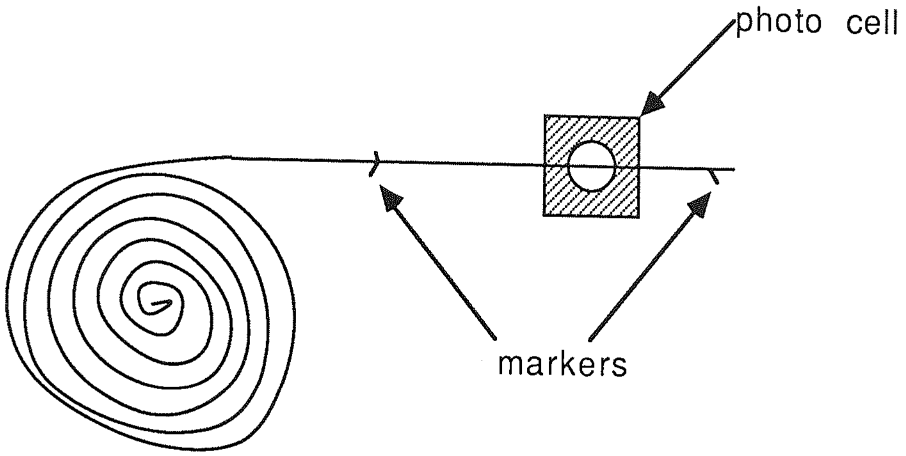
To carry out this measurement, the coil of raw material can be marked with some kind of a marker which is visible to a photo cell which can be located in the close proximity of the rolling mill. The wound coil can be marked by drawing a line from the centre to the outer radius (figure 6.1).



Coil Marker

Figure 6.1

The number of markers which are present when the coil is unravelled is directly proportional to the total radius of the coil and inversely proportional to the gauge. The number of markers can be counted using the photo cell (figure 6.2) and the total length passed can be calculated using the gauge of the coil.



Marker Count

Figure 6.2

An alternative method is to use the relay which is located at the end of the mill (to perform the cutting off operation (as described in Chapter 2) to trigger off a signal (pulse) every time it operates. This method is better than the earlier methods not only because it gives a digital count but also gives a direct count on the number of units produced. It is also less complicated than using markers and photo cells.

One disadvantage of this method is that the relay is energized more than once for each length for some jobs to perform auxiliary operations like piercing and notching. However this number is constant for any particular job and therefore can be computerized and can be extracted for each job. The production speed can be calculated as follows.

The length being rolled	= L metres (data)
number of press operations per length	= m (data)
number of pulses received during t hrs	= n
number of lengths produced during t hrs	$= {}^{n}/_{m}$
total length rolled during t hrs	$= {}^{n.L}/_{m}$ metres
therefore the production speed	$= {}^{n.L}/_{m.t}$ m/hr

The computer can do this pulse count directly, providing it has a digital interface to receive them. This method seems to be the most feasible one and it was the one which was preferred by the client.

The theory is that computer should calculate this production speed periodically and if less than the pre-determined target then the operator should be informed. An extra facility that can be added here is to expect an acknowledgement from the operator and send another message to the supervisor if the acknowledgement is not received within a certain period of time. Sending an alarm message to the supervisor (i.e., to the host computer) interrupting any other work he is doing at the time is a complicated process and will be discussed later under communication.

Since the piece count is automatically done by using this method, it would be quite easy to inform the operator if he has over produced although such a case would be unlikely in a production environment where wastage is a severe damage to competitiveness.

6.5 Press Operations Data Module

This module has been prepared and added to the data base in the host computer to maintain the number of press operations for each length under each product code. It was constructed to be similar to all other modules and all the usual facilities have been included.

It was found during the preparation of this module that a scaling factor (which also depends on the product and the length) is used to calculate the operators' bonuses. It is also common knowledge that number of roll passes per product becomes greater with the increase of length. Therefore the two items; the number of passes and the scale factor were also included in the module for future use. This module was named 'PRESS' while the data channel was fixed as 19 with a record length of 60 bytes.

The module 'JOBCARD' was also modified accordingly to extract the 3 variables; number of press operations, scale factor and the number of passes for each length for a job. These details are also written to the line sub directories along with other details of the job (as described in Chapter 5), so that they can be passed on to the shop floor.

6.6 Downtime

The second category to monitor is downtime which is made up of several categories. The computer must essentially assume that it is under speed monitoring mode unless informed to be a downtime by the operator. This is a disadvantage because it would go on monitoring the production speed in the case where an operator has forgotten to inform of a downtime. However, this would be seen as a production speed of zero which obviously is under the pre set target. The computer would then display a message to the effect that the speed is too low, in which case the operator can inform the appropriate downtime reason. This would show a slightly reduced average production speed at the end of the job than the actual one but will not be a major problem.

The operator should have a console which consists of a number of buttons, each of which to be dedicated to a particular downtime reason. Each button can be labelled to indicate the reason which is allocated to it and the operator can press any button to indicate the reason for downtime. The computer recognizes the reason by using the particular ASCII code which is generated by the button and can record the downtime under that category. Therefore the computer must stop monitoring the line speed and only calculate the downtime for each reason until cancelled. It can go back to the speed monitoring mode when the operator presses the appropriate button. This shows the need for a button to cancel a downtime reason. Additionally, the same console can be used to enter the number of units produced, the weight of a coil, the gauge and several other items of information. This means that a numeric key pad is also required in addition to the other keys.

6.7 Operator Console

All the reasons for downtime have to be listed out in order to determine the size of the operator console. A button for each category is required and table 6.1 shows that there are 15 downtime reasons and therefore 15 buttons are required for these. Two more buttons for cancelling any downtime reason and start/re-start rolling would also be needed in addition.

The numeric keys which were described above also should not be forgotten and it is logical to assume that numeric quantities can not be entered by one key stroke. Hence an 'enter' key is required. A 'delete' key is also useful for the operator to correct any mistakes before pressing the 'enter' key.

Code	Reason
1	Seting up
2	Strip down
3	Coil change
4	Length change
5	Waiting for information
6	Faulty rolls
7	Defective tool
8	Machine fault
9	Tool trials
10	Reject material
11	Material shortage
12	Meal break
13	Downtime without a reason
14	No work
15	No labour

Downtime Categories

Table 6.1

Some other functions which must be included are 'job finished' and 'suspend current job'; the latter being the escape facility in the case of a material shortage or a serious fault. This function also must be used at the end of the day when the job is not finished. The inverse functions of these would be 'load new job' and 'load suspended job' respectively. The computer would normally expect to load another job (either new or previously suspended) after finishing or suspending a job. This may not be the requirement at the end of a day when the process has to be shut down. Therefore another button ('shut down') is needed for this function. Yet another useful function which can be included is 'operator changeover' as this can happen at the end of the first shift where a second operator would simply take over the job while there is no need to suspend and reload it which has an adverse affect on productivity.

One other important function would be to acknowledge any alarm message which is displayed. This would require yet another button and undoubtedly the operator will be bewildered at all this. This is a good time to use the technique, Empathy to approach the problem in the point of view of the operator so as to be sympathetic to his needs. It is however not possible to reduce the number of buttons by incorporating two functions in one button which makes it even more complicated, and the designer could be cornered at this point. The technique, Inversion can also be employed here according to which the number of buttons must be increased even further, but this time solely for the benefit of the operator. A special button can be incorporated here so that it can be pressed to display the amount of bonus which has been earned for a particular period and this would please the operator to quite an extent.

Therefore the number of functional buttons is 24 in addition to the numeric keys, enter key and delete key which make a grand total of 36. Each functional key has to generate a unique ASCII code (other than those which are generated by the numeric keys) for the computer recognize its function The allocated ASCII codes are shown in table 6.2.

The total of 36 keys must not be scattered on the console in any order because it will be extremely difficult to identify them at a glance even though they have to be labelled. They must be grouped in a logical manner and each group must have a different colour for easy identification.

The numeric keys must definitely be grouped together and be located away from the functional keys. The 'enter' and 'delete' keys can be positioned in close proximity to these.

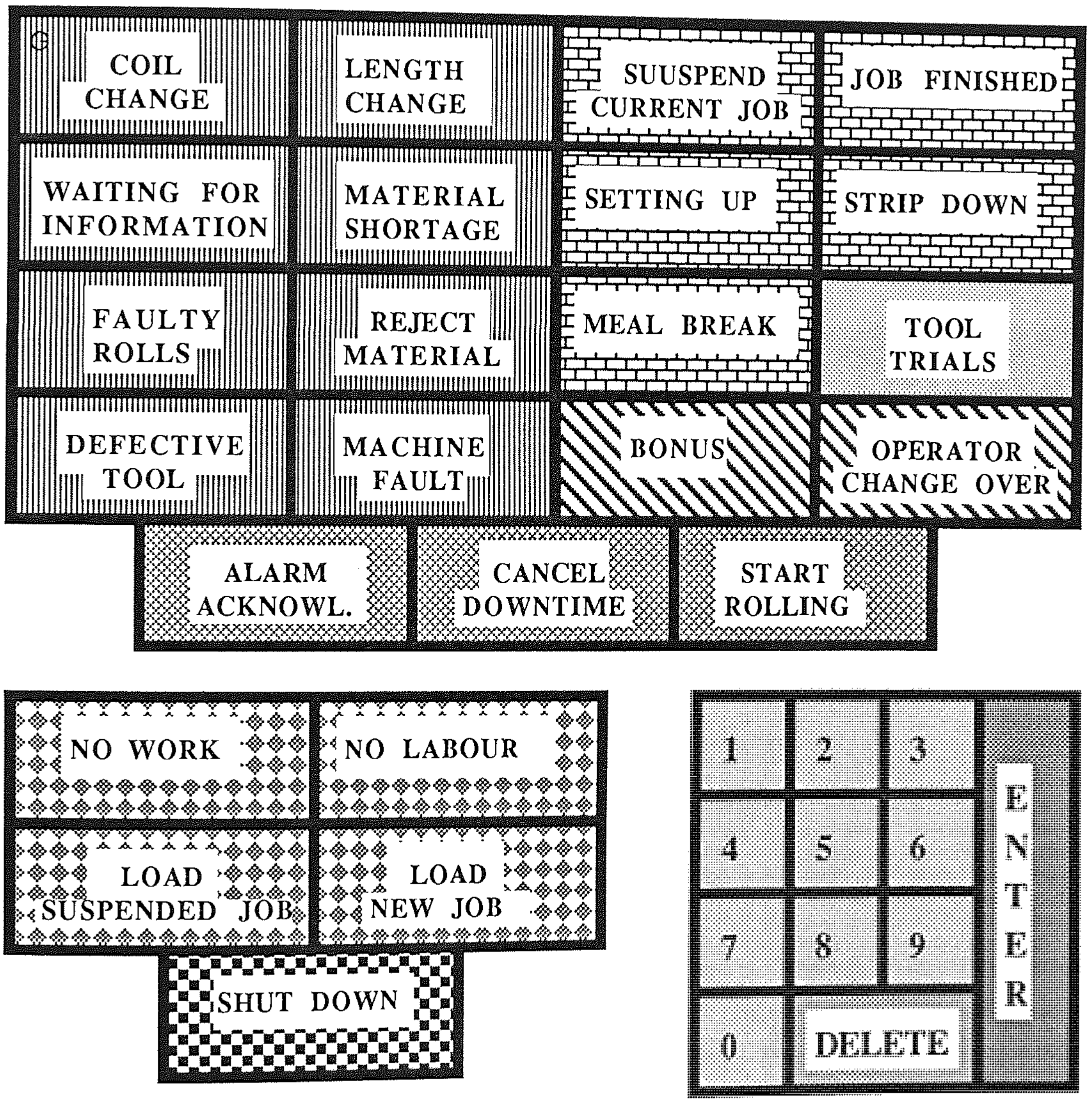
'Setting up', 'strip down' and 'meal break' can not be considered as real reasons for downtime because these have to be included in any job and can be positioned away from the rest of the downtime keys. Additionally the keys for suspending a job and finishing a job can also be positioned with these. The buttons for cancelling a downtime reason, starting/re-starting rolling and the acknowledgement of alarms can be common (figure 6.3) to all downtime reasons.

No.	Reason	ASCII	Hex
1	Seting up	65	41
2	Strip down	66	42
3	Coil change	67	43
4	Length change	68	44
5	Waiting for information	69	45
6	Faulty rolls	70	46
7	Defective tool	71	47
8	Machine fault	72	48
9	Tool trials	73	49
10	Reject material	74	4A
11	Material shortage	75	4B
12	Meal break	76	4C
--	(Downtime without a reason)	77	4D
13	No work	78	4E
14	No labour	79	4F
15	Operator change over	80	50
16	Cancell downtime reason	81	51
17	Start/Restart rolling	82	52
18	Suspend current job	83	53
19	Job finished	84	54
20	Alarm acknowledged	85	55
21	Bonus	86	56
22	Load new job	87	57
23	Load suspended job	88	58
24	Shut down	89	59

Allocated ASCII codes for the buttons

Table 6.2

The reasons 'no work' and 'no labour' are also not real downtime reasons and usually these reasons will be indicated outside of jobs. Therefore these must be isolated from the main group of keys while the three keys for 'loading a new job', 'loading a suspended job', and 'shutting down' can be included in the same group as these.



Grouped keys on the operator console

Figure 6.3

The two keys for operator change over and displaying the bonus do not fall into any category and can form another group. Finally the key for 'tool trials' must have a different colour because it is used only in the case of a new job. The rest of the functional keys can form the main group.

6.8 Specification

The above information is sufficient to build a picture of the device for monitoring. The following specification for such a device can be compiled by summarizing all the discussed points.

(1) The device should have a parallel communications port in order to collect data at high speeds.

(2) It should consist of a central processor unit and all the necessary hardware which is capable of collecting the incoming data and processing them to a required format to carry out comparisons. It is not envisaged that the required memory would exceed 32k, considering the fact that one device monitors only one process.

(3) Generation of alarms messages would require a small display. While a full size visual display unit is not suitable for this, a single or a two line LED (Light Emitting Diode), VFD (Vacuum Fluorescent Display) or an LCD (Liquid Crystal Display) display would be ideal.

(4) The device should have a serial communications port for communications with the remote host as parallel communications are not suitable over long distances.

(5) The keyboard also need not be a full sized one and therefore a smaller remote keyboard with 36 keys which can be located external would be sufficient. Hence an additional communications port, either serial or parallel should exist on the device to connect the keyboard to the processing unit. One port which is capable of two way communication is suitable to accommodate both the keyboard and the display since the former is used to send signals to and the latter is used to receive signals from the processing unit. It is also a fact that both these devices can be bought as a single integrated unit.

(6) The system should have a battery backed RAM for data protection.

6.9 Available Systems

A number of shop floor data collection systems are available on the market today and it is worth looking at some of them and understanding what they do.

Instem's dMACS 200[125] is one such system and uses the motorola's 68000 processor. It provides facilities for multiple sequences, analogue to digital conversions and timers. The system is a stand alone one but the programs can be developed either on a portable programming terminal or on the host computer. The system is supplied with a two line by 40 character display and a 'QWERTY' style keyboard with a hand held terminal which is connected via a standard serial port. A micro PDP II host computer is also supplied with the system.

This system sounds appealing because of the two line display and the micro PDP II host computer which is compatible with the VAX range of computers. However the 'QWERTY' style keyboard is not suitable as explained before.

Kewill systems[126] provide a data collection system which has shop floor terminals with battery backed RAM which can operate both on-line and off-line. These terminals have only six function keys in addition to the numeric keys and they are supplied to be compatible with hosts such as IBM PC XT, Dms HiNet, Televideo or Apricot-Point 32 and Xen. While providing a bar code reading facility, this system does not appear to be flexible enough to provide the required facilities for the client.

Burr Brown's[127] TM 900 factory data collection system is another one which provides shop floor collection terminals. It supports standard ASCII communications while running a 16 bit 8088 processor which is combined with two 8 bit Z80 processors. Instead of having a character display, this unit provides LEDs for different functions.

One other system which closely resembled the specification was Retriever Technology's[128] PMS where terminals which can provide up to 64 user definable keys (including numeric keys) and 2 line by 16 character LCD display. The system is provided with a host computer which is General Automation's Zebra model 1350 or 1750. It has a 256k to 1000k memory and runs on a 10 mHz MC68000 16/32 bit processor. The operating system is 'PICK' while it has 5 MB cartridge disk and 4 to 13 communication ports.

All the above mentioned systems are provided as complete systems while the user is not allowed to make modifications on his own. These systems work only in a manner which is determined by their vendors while some of the requirements are available. Even the functions and record formats are pre determined by the vendors and the flexibility is minimum although the cost of such systems are very high. Buying such a system with all the hardware such as host, terminals and peripherals will not only make our tailor made software and hardware useless but also will halt any further expansion other than via the same vendor. The objective of this research will be lost if such a system is bought and instead, it is more flexible, economical and reliable to extend the system which was developed so far by buying only the hardware components and building them to the necessary standards.

6.10 Process Computers

It was mentioned in Chapter 4 that the process computers must be attached to the process to collect data. This is a broad statement because the term 'computer' can involve a wide range of products. While it is not practical to be a large computer, it can be either a Single Board Computer (SBC) or a Programmable Logic Controller (PLC) as opposed to a conventional microcomputer.

6.10.1 Single Board Computer (SBC)

A single board computer[(129)] offers the lowest cost approach to program development and is usually equipped with a hexadecimal keyboard, some function keys and some LEDs which display addresses and data. A limited display is also normally available and a typical example of a single board computer is a SDK-85 development board. The memory of such a computer is limited and therefore an assembler is not available. Hence the programming has to be done by using machine code which can be entered as hexadecimal numbers. The difficulty in developing programs in the hexadecimal format makes a single board computer best suited for educational and training purposes where only limited sized programs are required although a single board computer has the same power as any other computer.

6.10.2 Programmable Logic Controller (PLC)

Programmable logic controller is a new type of device which came in to being only in the mid 70s.(130) They are used to replace old relay based control systems and were originally designed as hand held units with on/off controllers which acted in isolation.

The programming was the biggest disadvantage of these controllers in the early days as this had to be done by 'ladder diagrams' which are based on Boolean statements and are limited as opposed to high level programming. Companies like Telemechanique(131) have provided new methods to overcome these problems.

PLCs were originally developed to perform the sequence and timing of operations but they seem to be merging towards microcomputers now(132) and hence can be used as low cost general purpose computers. The latest versions even support high level programming. Latest programmable controllers can be bought from companies like IMO(133), Hitachi(134), Mechman(135) and Omron(136) while two situations where PLCs have been used for data collection are IPC- ISSC(137) and APT Electronics in Reading.(138)

While trying to mimic microcomputers, the PLCs are still in their developing stage and it can be predicted that there will be quite a lot of improvements within the next few years. A complicated application like collection of data and on board processing therefore seem to be better suited for a conventional microcomputer rather than for either a SBC or a PLC although undoubtedly these will be used for such tasks in the future.

6.11 Equipment for Development

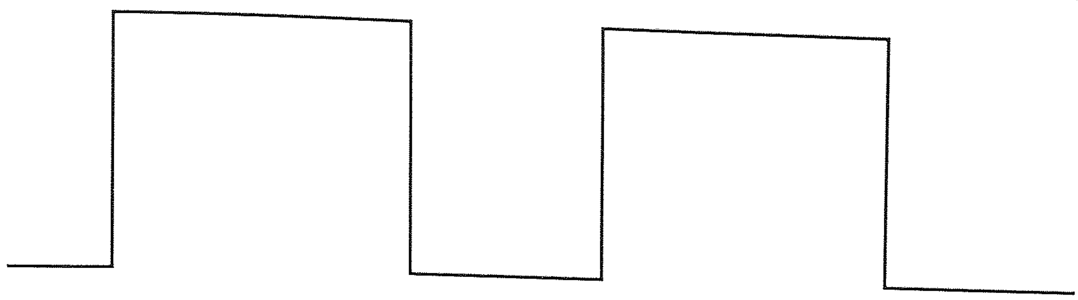
The Apple Macintosh and the BBC seemed to be the most suitable computers after looking at the available conventional microcomputers in the University. More than 50% of the people preferred the Macintosh during a brainstorming session for the choice between these two, while some of them were even sarcastic enough to say 'Is BBC a computer ?'

Obviously the Macintosh is the larger machine which claims to have a memory of 512k as opposed to the 32k on the BBC and can even be considered a mini rather than a micro. However, the operating system is on a floppy disc which has to be inserted everytime it has to be started up and this start up procedure is painfully slow. It takes up nearly an entire disc because it is over 300k. A higher level application also takes up a lot of memory and hence another drive is needed. Furthermore one has to be rather suspicious about the claimed size of memory because firstly, only very small programs are allowed with a message 'disk full' most of the time and secondly, the computer seems to read each page from the disk when scrolling through a program rather than keeping the whole program on the volatile memory. This gives the indication that the claimed 512k memory is the disc memory at one time rather than the on-board memory. Furthermore, it has not got a parallel communications port to collect data from the shop floor.

The BBC microcomputer on the other hand is much faster than the Macintosh and this speed is possible because the 16k ROM based operating system is located in the machine. The languages are also located in the machine as 16k EPROMS and start up allows the user to go directly to a language within a few micro seconds. The response times and disc access times are also much faster than those of the Macintosh while the user has a full 32k of on board memory in addition to a possible 1600k of disc memory (with a dual drive) for speedy execution of programs. Furthermore it has got all the required hardware for collection of data and communications. One other major advantage is that the operating system commands can be executed directly within a language and this makes the BBC computer stand out in a class of its own. Hence it was chosen to develop the software.

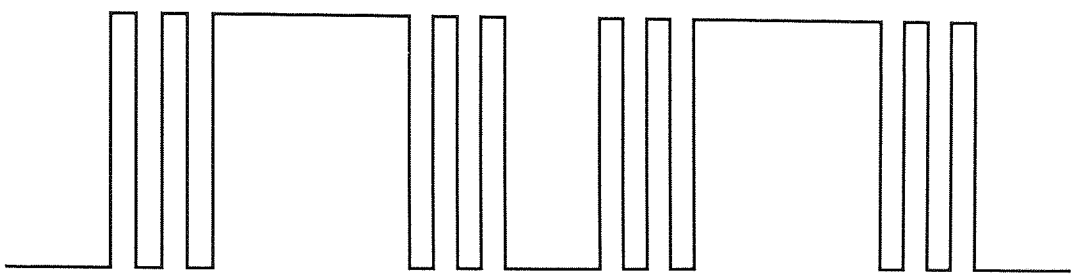
6.12 Circuitry and Interfacing

Section 6.4 described how to use the cutting off relay to calculate the production speeds by creating a train of pulses. Theoretically these pulses are symmetrical and can be shown in figure 6.4. However a mechanical switch would create pulses with a bouncing effect as shown in figure 6.5. Hence a number of pulses will be counted for each leading edge and the trailing edge of a pulse and the resultant will be erroneous.



Theoritical pulses

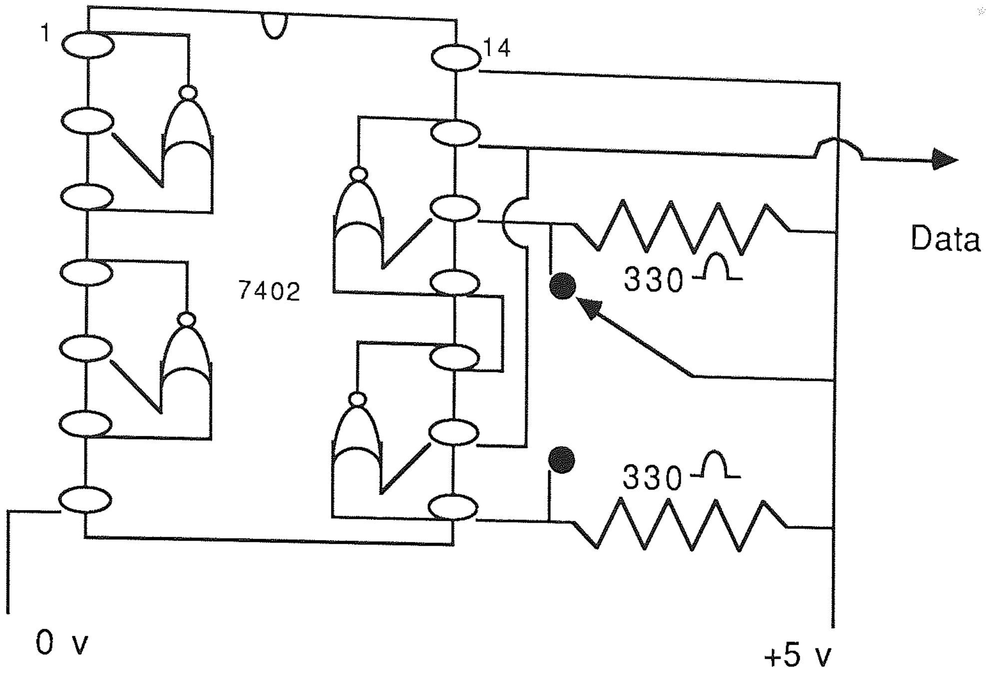
Figure 6.4



Actual pulses

Figure 6.5

This effect must be eliminated by using a debounced circuit (figure 6.6) by using two NOR gates in a TTL (Transister transister logic) 7402 chip (quad 2 input NOR gate). A similar circuit can also be made by using a 7400 chip (quad 2 input NAND gate).



Debounced circuit

Figure 6.6

The debounced signal can be fed directly to the BBC microcomputer via the interface which is known as the 'user port'. This port is connected to a 6522 VIA (Versatile Interface Adaptor).

6.13 6522 VIA

As its name suggests, it provides a broad range of peripheral control facilities and computers can be interfaced to the real world activities quite conveniently using this adaptor. The 6522 is a fully TTL and CMOS compatible, 40 pin static chip and it provides for independent interrupt control.[137] It has 20 input output lines which can be configured as either inputs or outputs. Four of these lines are for handshaking while the remaining 16 are data lines. These lines are usually grouped together in to an A side and a B side[49] which can be used as 2 separate ports.

The port A on the BBC microcomputer is used for the parallel printer port while the B side is connected to the user port. User port which is a 20 pin port (table 6.3) consists of eight data lines two handshake lines, two +5V lines and eight 0V lines.

The data which come from the press relay can be fed directly in to a data pin PB0 to PB7 of the user port after debouncing. This port is mapped in to the memory of the BBC micro computer[139] at the hexadecimal location FE60 (decimal 65122) and since the BBC microcomputer has an interrupt driven operating system, this memory location is updated as a background job during every clock cycle regardless of the foreground job. The contents of this location can either be read via assembly language or directly by any higher language such as BASIC which is the default language on the computer.

Pin no.	Function	Description
1	+5 v	5 volt supply
2	CB1	hand shaking line 1
3	+5 v	5 volt supply
4	CB2	hand shaking line 2
5	0 v	earth
6	PB0	data line 1
7	0 v	earth
8	PB1	data line 2
9	0 v	earth
10	PB2	data line 3
11	0 v	earth
12	PB3	data line 4
13	0 v	earth
14	PB4	data line 5
15	0 v	earth
16	PB5	data line 6
17	0 v	earth
18	PB6	data line 7
19	0 v	earth
20	PB7	data line 8

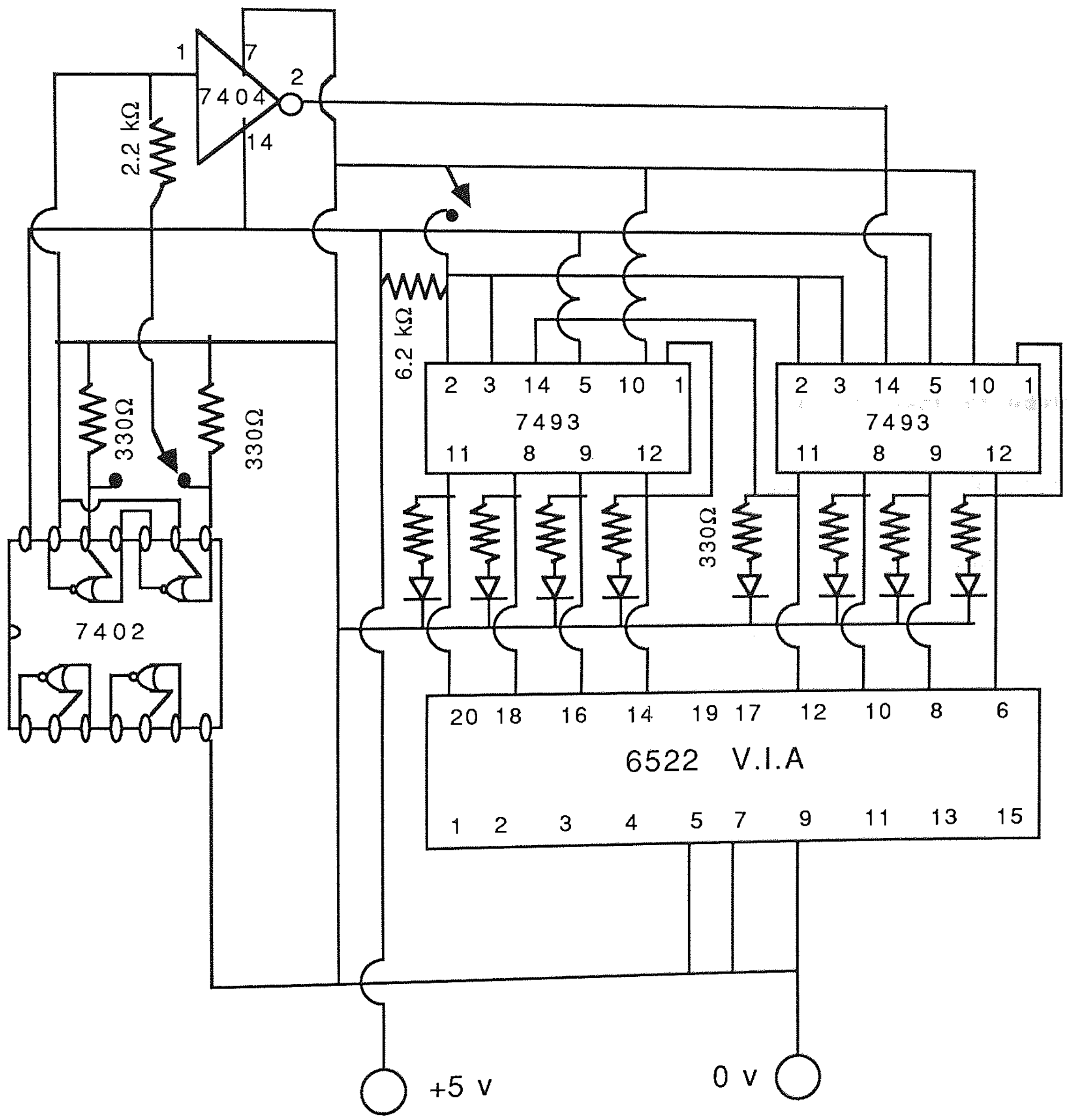
Pin Configuration of 6522 B Port

Table 6.3

Each data line in the 6522 B port can be either 1 or 0 (high or low). The data line which is used becomes high when the pulse is being received (i.e., by the leading edge) and will be low when finished (i.e., by the trailing edge). This sequence continues when the pulses arrive continuously. The computer is fast enough to read all these pulses when they arrive if it is doing only that but it can miss several of these while attending to other tasks such as calculations and comparisons.

This causes a big problem and not only the production speed but also the number of produced units will not be accurate. It can be eliminated by doing the counting by hardware as opposed to software because the hardware count will proceed regardless of the work which is done by the software. The total value of the eight data bits is mapped in to the location FE60 as explained above and therefore the total value can range from 0 (when all bits are low) to 255 (when all bits are high). A count of 255 is quite sufficient (in fact too much) for the computer to attend to other tasks without losing any pulses. The maximum production speed which has been recorded so far is 2013 m/hr[140] where the product length is 2.7 metres and the press operates only once per length. Therefore 255 pulses would be received in 20.53 minutes.

If the counting is done by an external hardware circuit then the computer can read the count when it is ready without affecting the flow of pulses. The pulse count can be carried out by using two TTL 7493 chips (figure 6.7) each of which can do a 4 digit binary count.

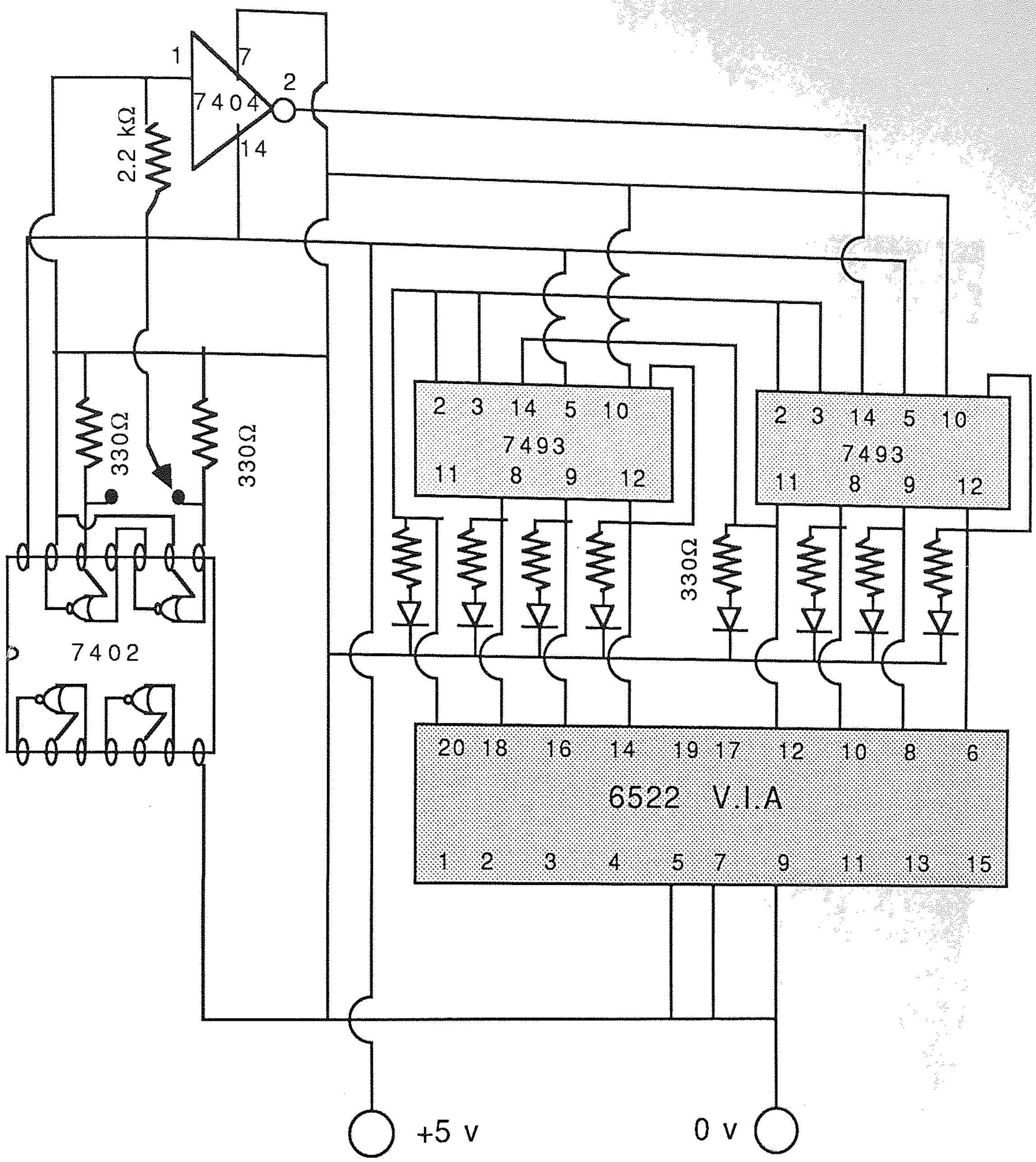


Pulse counting circuit

Figure 6.7

The LEDs in the circuit are optional but help to check the accuracy in the development stage. The first switch is for the pulses while the second one is for resetting the count. The +5V can be drawn out of the auxiliary power supply at the rear of the BBC computer while the switch which generates pulses should be connected to the relay which was described in chapter 2.

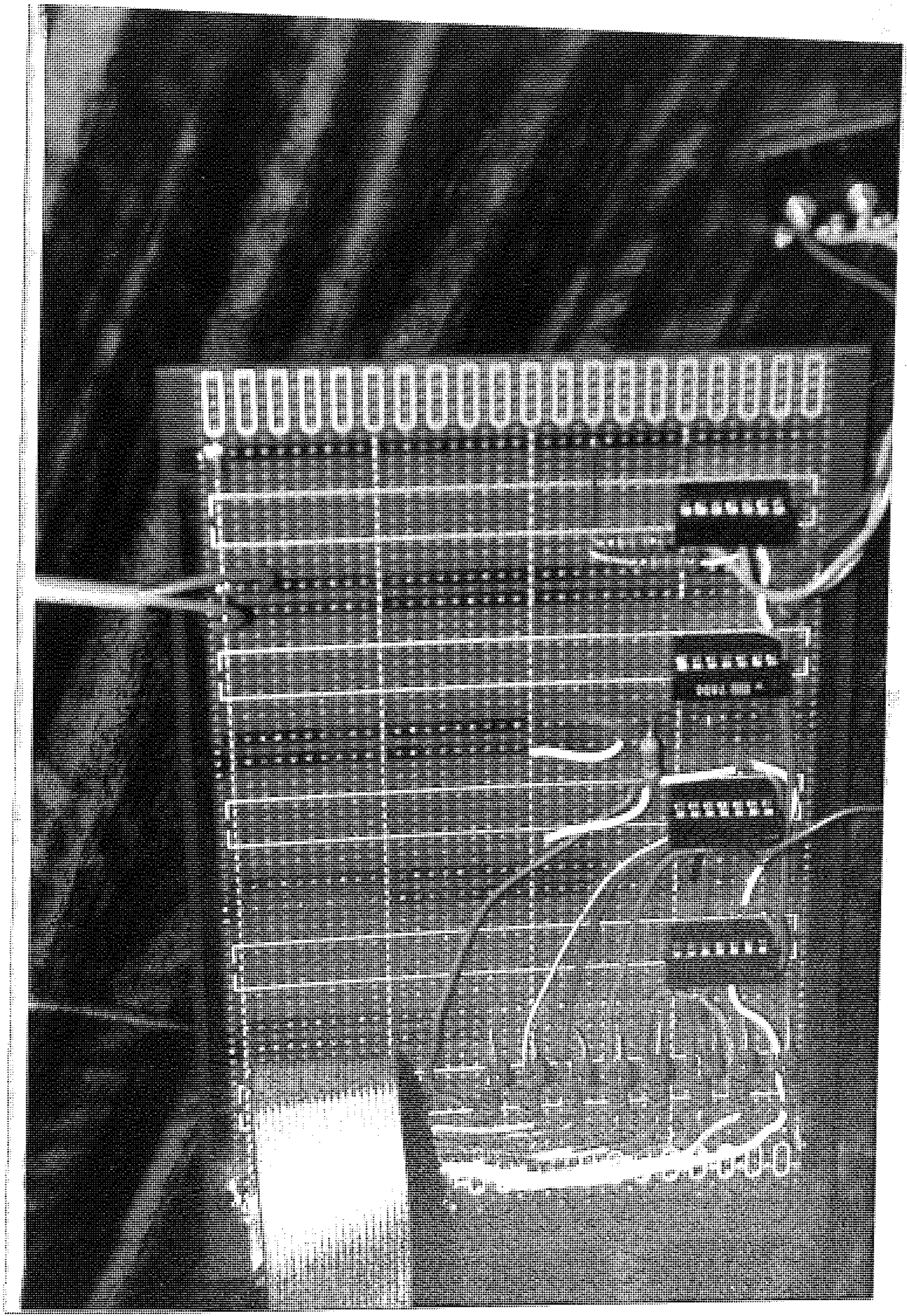
The pins 2 and 3 of the 7493 chips which are connected together should be high for counting while they have to be low to reset the count. The second external switch in figure 6.7 does the task of setting and resetting these pins but it is not practical to have such a configuration when the development stage is finished. The computer should first read the value in the appropriate memory location and then zero it at once to be ready to receive the next pulse and carry on with the task. This was done by using one data line of the 6522 since the minimum time for a count of 255 is 20.53 minutes. Even a count of 127 with 7 bits would take a more than sufficient 10.22 minutes. Therefore pins PB0 to PB6 were used to receive data while line PB7 was configured as an output (figure 6.8 and plate 6.2) to be connected to the switch.



Pulse counting circuit with auto reset

Figure 6.8

Since all the data pins are configured as inputs by default, the last one has to be defined as an output by using the data direction register which is mapped to the memory at FE62.



Counting circuit

Plate 6.2

6.14 Operation of the Process Computer

The operation of the process computer starts at the end of each shift and the operator should enter a selection which indicates one of the following options by pressing the appropriate button on the console.

(1) Load a new job

(2) Load a previously suspended job

(3) No job

(4) No labour

The two latter categories are downtime categories and the computer in this case keeps track of the time between pressing one of these and the cancellation key. The first two categories are different only in the amount of data which has to be downloaded.

The computer goes to the setting up mode after loading a new job and displays the message 'setting up' on the screen (if the setting up target is more than zero) until the operator cancels this. The setting up has a pre-set target and the computer constantly compares this target with the accumulated time for this down time. It sends a message to the visual display unit as soon as the target is exceeded and goes on scanning the keyboard input buffer to see whether the 'message accepted' button is pressed. It sets a 'trigger' when an alarm message is on the display and resets it only if the message is acknowledged.

If this trigger is still set after five minutes then it sends a message to the serial communications port so that the supervisors are informed. (The handling of these messages will be discussed in Chapter 7). The trigger is then re-set and the computer carries on by sending another message to the operator after another five minutes if the error is still on. The ASCII code 7 (Appendix 7) is included in all the messages so that an audible 'beep' will be sounded in the computer.

It is not practical for the computer to enter in to the rolling mode directly after cancelling the setting up mode because it is possible for any other downtime category to occur. The computer therefore enters another category called 'downtime without a reason' with an ASCII code 77. This category is just like any other downtime category until a valid key is pressed either to start rolling or start another downtime.

The operator gets a chance to enter the length which he wants to produce on starting to roll for the first time. This has to be entered through the numerical keys by pressing the length number as in the job card. The computer prompts again if a non existent length number is entered. If the correct number is entered then it resets all the pointers and initializes the data direction register FE62 with decimal 128 (96 in hex) to set bit 7 while all other bits are reset. It then sets bit 7 of memory location FE60 by placing 128 and then resets it by placing 0 to be ready for counting. It is not necessary to mask the bits 0 to 6 during this operation as the value of them must not be preserved.

The software then carries on in a cycle by looking at the keyboard buffer to see whether any key has been pressed, adding the contents of memory location FE60 to a counter (counter 1) and resetting the location. The production speed (i.e., the instantaneous speed for the past five minutes) is also calculated at five minute intervals by using the contents of counter 1. The content of counter

1 is then added to counter 2 (which is used to calculate the accumulated amount of units for each length) and counter 1 is reset. The resultant speed is compared with the rolling target and if the actual value is more than 10% below the target then a trigger is set and an alarm message is sent to the screen. The total produced amount is also compared with the required amount at the end of five minutes and alarm message is displayed if the required amount is exceeded. Additionally, the total expected number of hours to complete the job (based on the current average speed) the current status, amount produced so far and other relevant details are sent to the serial port.

The computer carries on its normal operation of updating counter 1 after this by using the contents of memory location FE60 and scanning the keyboard input buffer. If the trigger is set which means that an alarm message is on, then it waits for five minutes for the 'alarm acknowledged' button to be pressed and sends message to the serial port if not pressed. It then resets the trigger to carry on.

The 'length change' downtime category is different from the rest and the computer prompts for the amount of units produced and the new length number each time this category is selected. 'Coil change' is also slightly different from other categories of downtime. The computer asks for the amount of coils and the total weight at the start of each job. The number of coils is decremented each time the 'coil change' button is pressed and the gauge reading is requested from the operator until the number of coils becomes zero. Then it prompts for the number of coils in the new lift and the total weight.

The weight which is returned to the stock has to be given by the operator when a job is finished or suspended so that the computer can calculate the used weight. All the remaining values of counters 1 and 2 are used to calculate the produced amounts of each length and the information is written into a file along with all other information relating to each type of downtime and total rolling time. The name of this file consists of the job number preceded by either 'FIN' or 'SUS' for finished jobs or suspended jobs respectively.

6.15 Bonus

The bonus for each week is calculated on the basis of the total length produced and the scale factor. The total bonus therefore consists of the total length produced on all four lines multiplied by individual scale factors.

The total bonus for a shift can be calculated within the shop floor computer since the scale factor for each length is downloaded with the other details of a job. This bonus will then be different on each line and this will be confusing. The operators need to know the total bonus for the week for the whole company and this should be displayed on all 4 lines when requested. Therefore the calculated value has to be sent to the host to be added to the previous total each time a bonus calculation is done on any line. Then the new value has to be sent back to all four process computers. The software was designed in such a way that the total bonus is downloaded at the start of each shift to all lines and that the bonus calculation is done at five minute intervals during rolling, i.e., at the same time the line speeds are calculated. Each line then sends the calculated value to the host which adds it to the total and sends the final value back to all four lines at the same time. The process computers collect this value and it is displayed everytime an operator presses the appropriate button.

6.16 Weekly Downtime

The downtime quantities have been prepared in such a way that they are shown under each job. However, the management need to see the downtime for a period regardless of the job numbers. It is also a fact that the categories 'No job' and 'No labour' can not be shown under any job. These must essentially be shown in the periodical reports only.

Therefore the total downtime for all four lines must be monitored in a similar way to the weekly bonus. The same principle has been used for this so as to download the quantities to each process computer at the start of a job. The only difference is that they do not get updated every five minutes. Instead, they get updated at the time of shut down and the different values are collected from all four lines and are totalled by the host.

6.17 Operator login and Changeover

It is necessary to enter some code to start the computer for security reasons and it was decided to use the clock numbers of the operators rather than entering the names because the names require a full sized keyboard. The application software module which was developed on the host was used to extract the operator details for the shop floor. The shop floor computer prompts for the clock number when the operator selects either 'load new job' or 'load suspended job' at the start of each shift. This is then compared with the corresponding items of the main data base and if matched then the operator's name is extracted. The process computer then extracts the first name from the string by searching for spaces (e.g.,. CLIVE BROWN) and greets the operator with a message similar to Hello Clive. It is only then that the operator is requested to enter the job number of the next job to be downloaded.

The time at which the operator is logged in is recorded and the total time is calculated by recording the time he logged out. The computer calculates the time which the first operator worked during changeovers and this is added against his name to a weekly working details file in the host before allowing the next operator to log in. The total length which the operator produced during that time and also his total bonus are also added to the appropriate positions of the same file. The management therefore gets a chance of not only using the host to calculate the basic wages but also the bonus payments.

The same procedure is carried out when the shutdown button is pressed and the computer then displays a message requesting the operator to switch the computer off at the end of the day, shift or the process.

6.18 Selection of Hardware

6.18.1 Processor Unit

Appendix 11 shows some of the equipment which is available for developing tailor made systems. One interesting observation which can be made from it is that most of the systems are based on the following micro processors.

(1) Zilog's Z80

(2) Rockwell's 6500 series (6502)

(3) Motorola's 6800 series (6809)

(4) Intel's 8080 series (8085)

From all the listed equipment, Control Universal's Cube(141,142,143,144) and Cambridge Micro Systems second processor board(145,146,147,148) evolved as the most suitable choices. Both systems are racking systems which are based on the 6502 micro processor and support BBC Basic with some extensions. A battery backed RAM of 32k is also available on both systems. The Cube system seemed to be the better choice because a keyboard with 24 keys and a two line display is available. The 24 keys are sufficient for functions but a further numeric keypad is essential to enter quantities as explained above.

Therefore the Cambridge Micro Systems' 6502 second processor board which is supplied without a keyboard had to be selected. This system allows the software to be developed on a BBC micro computer and be downloaded on to the second processor. The second processor card comes in a racking system which has its own TTL compatible +5v power supply and is interfaced via a 6522 chip to the BBC's interface which is called the tube port. This is quite convenient because this 6522 chip becomes redundant at the end of the development stage and hence can be used to plug the shop floor signals directly in to it. The socket however is a 40 pin socket as opposed to the BBC's 20 pin socket because it uses both A and B sides of the port. One other difference is that the port B is mapped in to the memory at the location FC00 while the data direction register of this port is mapped at FC02.

This second processor card handles all processing when running via the tube port while the inputs and output are the only ones which are streamed through to the BBC. The previously developed program was modified to use this board and to suit the new memory locations. The system performed well although a reduction of speed was observed. This was expected because all the inputs and outputs are handled via the tube.

6.18.2 <u>Keyboard</u>

The latest technology has brought out membrane keyboards to replace conventional keyboards. The DES 86 exhibition which was held at the National Exhibition Centre in Birmingham (in September 1986) showed fine examples of these and Star Microterminals' panel mounted terminal PM10[149] was one.

The keyboard is a TTL compatible simple matrix board and the keys can be arranged in any order to generate ASCII codes. An integrated one or two line LED, LCD or VFD display is also provided with this unit and it can be connected serial or parallel to any processor. This unit is ideal for the shop floor and a keyboard with a single line by 20 character VFD display was selected[150] after some discussion with shop floor personnel about the shop floor ambient lighting conditions.

The keyboard/display unit was connected to the 6502 2^{nd} processor by using a serial card which was attached to the racking system but it is not possible to select it as default input and output devices unlike the BBC's keyboard and display. Therefore all the software had to be modified in order to drive this keyboard and the single line display. Not only the messages had to be cut short but also the normal display message (such as setting up or rolling) had to be restored after an alarm message is displayed because all the messages use the same space.

Each key which is pressed by the operator generates an ASCII code in the processor but is not displayed as on the normal

BBC. The display had to be obtained by looping each character back to the keyboard/display unit by software. The 'delete' key also presented a problem because it did not delete the previous character although it generated the ASCII code 127 which is the universal code for 'delete'. The code 08 was available in the unit to move the cursor back one space. Therefore deletion also had to be done in three steps by sending the code 08 to put the cursor back one space after receiving the code 127 and then send code 32 which is the equivalent of the space character to overwrite the last character. Finally the code 08 is sent again to position the cursor back to be ready to print the next character at the appropriate position.

All the inputs which are sent from the keyboard also have to be received as single characters and have to be evaluated after the code for 'enter' (13) is received.

6.18.3 Four Channel Serial Card

The specification of the required device was described in section 6.8 where the need for interfacing ports was explained. It was already explained that the parallel 6522 VIA is available to be used on the turnkey mode. Two more ports are required for communication with the host and for the keyboard. The necessary hardware for the ports are supplied by Cambridge Micro Systems on cards which can simply be inserted into the racking system. These cards are supplied with hardware for 4 ports but a 2 port card is not available.

Therefore the 4 channel serial card[151,152] was purchased and channel 0 was used for the keyboard while channel 1 was used for communicating with the host. This serial card consists of two SCN2681 Dual Universal Asynchronous Receiver/Transmitter (DUART)s which make up 4 channels. The operating mode and the data format of each channel can be programmed independently. Additionally each receiver and transmitter can select it's operating speed independent of any other device.