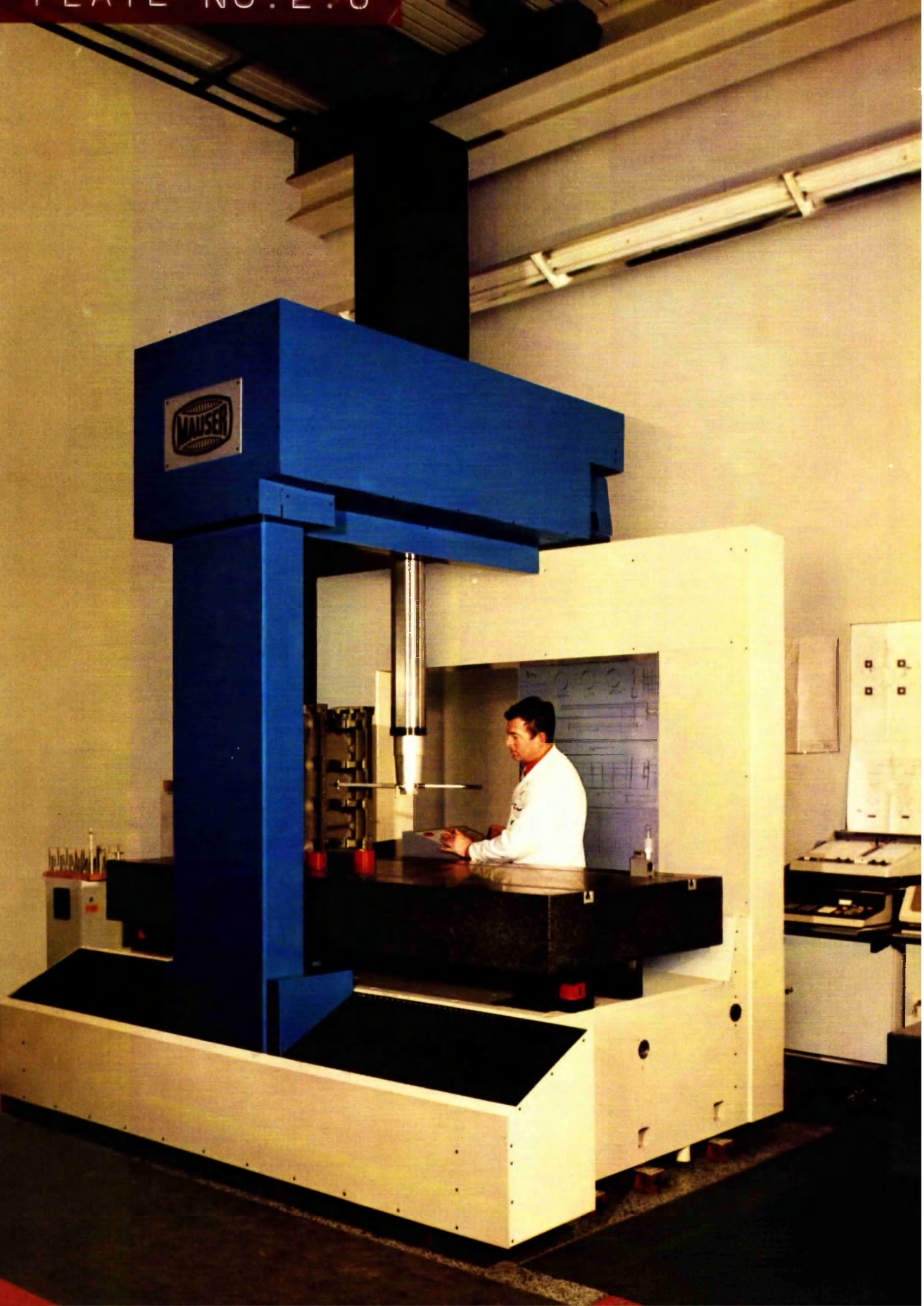
PLATE NO. 2.



NEW TECHNOLOGY IN MANUFACTURING INDUSTRY.

BY

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ACKNOWLEDGEMENTS

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ABBREVIATIONS

C. M. M.	Co-ordinate Measuring Machine.
C. C. M. M.	Computer-assisted Co-ordinate Measuring Machine.
D. C. C.	Direct Computer Controlled Co-ordinate Measuring Machine.
N. C.	Numerical Control.
C. N. C.	Computer Controlled Numerical Control.
D. L. Y.	Direct Labour Yield.
R. O. I.	Return On Investment.
S. I. P.	Societe Genevoise D'Instruments De Physique.
$\pm$ .001"	Plus or minus tolerance of one thousandths of an inch in length measure.
lbs.	Pounds in weight measure.
Kg.	Kilograms in weight measure.
R. P. M.	Revolutions per minute.
mm.	Millimeter of length measurement.
μ m.	The micron or a millionth of a meter in length measurement.
λ	A wavelength of light symbol.
MH_z	Light frequency in mega hertz.
x axis	Movement in a plane 180° horizontally.
y axis	Movement in a plane 90° horizontally.
z axis	Movement vertically to the plane.

SUMMARY

o This thesis is concerned with the problem of new technology in manufacturing industry. Increasing attention is being focused on the possible consequences of new technology as it begins to penetrate the various factors or elements within firms. Claims of massive unemployment and growing dissatisfaction with people de-skilled by automation have been made by various authorities and organisations, yet little recorded research has been made on this subject to provide evidence of the real effect and problem of new technology.

o Two types of new technology are studied in this research project. The first technology is that of the numerical control machine tool which having been introduced in the 1950s was slow to develop in the 1960s and has now become of major prominence in manufacturing industry. The research investigates the problems associated with this technology and the effects it has had on industry. The second technology is that of the co-ordinate measuring machine, an entirely new technology developed out of the wake of numerical control machine tools and part of an advance in measuring technology never before seen in the field of metrology or manufacturing.

o A model of the enterprise is proposed which shows a linking relationship between 6 key factors namely, organisation (structures), management (decision-making), strategies (objectives and plans), machine shop environment (the technology), control systems (return on investment) and people (behaviour). Each of these factors are examined against established theoretical bases, prior research and the findings from this project.

o From a brief description of the development of measuring machines and the invention of the co-ordinate measuring machine, the investigation consists of a logical analysis in 5 steps of

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manufacturing plants experiencing change due to the introduction of new technology. The first 2 steps examine the single manufacturing plant for the effects of numerical control machine tools and the effects of co-ordinate measuring machines. The third step is the investigation of a multinational organisation for the effect of co-ordinate measuring machines in 23 plants. The final 2 steps in the investigation analyse a large number of manufacturing firms using and not using co-ordinate measuring machines to determine any differences in organisation structures, strategies and people, then concentrates the study on firms using co-ordinate measuring machines to ascertain the overall effects on this larger population of manufacturing firms.

- The objectives of the thesis are two-fold: the investigation of a very major and critical development in industry, and the research for constructive conclusions which would create positive contribution to manufacturing industry. The outcome will show that manufacturing industry has to make radical changes if it is to maximise on the advantages of new technologies.

CHAPTER 1 - INTRODUCTION

1.1 - THE NEED AND IMPORTANCE OF THIS RESEARCH PROJECT.

The technique by which technical advances, ideas or inventions are converted into products, processes or services has become of increasing concern in recent years, and with respect to the far reaching consequences of technological changes, most business leaders would prefer to have a steady rate of progress in technology, a smoother evolution which can comfortably be absorbed by the company or industry. Yet progress has been anything but smooth. In fact, technological life has been characterised more by revolutions than by evolution.

In particular there has been a great interest in the consequences of new technology on the working lives of people in industry over the last five years. It has been remarkable how a contrast has been struck between the vehemence of those who claim, for example, that new technologies and micro-electronics in particular, will have a catastrophic effect on employment and the inadequacy of the analysis underlying the certainty of that prediction. Indeed the limited prior research in this whole subject is even more remarkable despite the high level of attention being given to it by the following authorities:-

- Government.
  Government has established several bodies such as the National Enterprise Board, Central Policy Review Staff, Advisory Council on Applied Research and Development and other groups, whose key objectives include the development, harnessing and use of new technologies in manufacturing industries.

- Trade Unions.
  Trade Unions have established special working parties to study the consequences of new technologies on employment in industry. This subject of new technology was the topic of a major debate at the opening day of the 1979 Annual Congress of the Trade Union Congress.

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- Universities.

  The Department of Human Science and Advanced Technology (HUSAT) research group at the Loughborough University of Technology had set up a research programme in September 1979 to be concerned with human factor problems, particularly in methods of applying advanced technologies.

  The Science Policy Research Unit at the University of Sussex are conducting studies on the impact of microprocessors on employment and the Cranfield Institute of Technology are advocating more specific roles for universities and polytechnics on the whole question of introducing new technologies.

- Management Consultants.

  P.A. Management Consultants have been engaged by the Department of Industry to conduct the micro-electronics awareness campaign among mechanical engineering companies in Britain.

- Employers.

  Employers are trying to stimulate growth in new technology applications by discussions through their associations and the Confederation of British Industry.

- Professional Institutions.

  Institutions such as the Production Engineers, British Institute of Management and others have made new technology in manufacturing industry a major theme in their 1978 and 1979 manifestos.

A fuller description of the concerns of all of the above bodies as directly related to new technologies is given in Appendix A.

The Importance of this Research.

The importance of this research is not only critical but it is also very timely at this point in the development of manufacturing industry. The importance of research into the consequences of new technologies is paramount to the needs of the following:-

- o Manufacturing Industry.

  The future needs of manufacturing industry have to be identified in terms of potential shifts in employment, productivity, investment and growth, to mention but a few elements which will be affected by new technologies.

- o Government.

  Government authorities require more constructive evidence that would assist them in the dilemma which shows massive unemployment due to new technologies on one hand, and a relatively unknown situation of the job creation potential of new technologies on the other hand.

- o Trade Unions.

  Trade Unions at plant level have to be convinced of the need for new technologies although it may result in the displacement of some of their members on the short term. National Trade Union Officials support new technology as they recognise the alternatives of not remaining competitive from an international aspect. Further evidence is necessary by research of this kind to provide more knowledge of the potential longer term consequences of new technologies.

- o Universities.

  While there has been some prior research in the literature on the subject of technology as it relates to organisations, economies, people and other factors, there has been limited prior research on the whole question of impact of new technologies in manufacturing industry. This thesis will serve to add to this knowledge already gained by these aforementioned limited prior researches, therefore the results or outcome will be important to university and other academic authorities.

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Technological Change, Employment and the Economy.

Since the Industrial Revolution, there have been substantial shifts in the pattern of employment, but the economy as a whole has adapted to technological change and to an ever-expanding labour force. Indeed technological change has always been a major source of economic growth and rising real incomes. This should be equally true of new technologies. Growth can come -

- Through an improvement in productivity, e.g., better quality control on production lines by the use of measuring machine technology.
- By making possible new or improved products.

The long term effects of new technologies on employment is complex and uncertain. Higher productivity implies less employment for the same level of output. On the other hand, if the opportunities provided by new technologies are seized, new, improved or cheaper goods and services will become available. These will create larger markets at home or overseas and this in turn would benefit the balance of payments and give scope for reflationary action but, and it is a vital but, all depends on industry's ability to remain fully competitive internationally in the sectors most affected.

1.2 - THE PROBLEM WITH NEW TECHNOLOGY.

A number of forecasts appearing in the press have given the employment effects of new technologies such as micro-electronics as a rise in British unemployment to 3-5 million. These forecasts have (a) overestimated the speed at which these new technologies are likely in practice to be applied in Britain, and (b) underestimated the possibilities for job creation through new applications. This forecasted increase in unemployment is very similar to the number of jobs lost in the contracting sectors of British industry over the last fifteen years (1961-1976). (1) - Therefore the predicted rate of change is not unparalleled, but, as in the 1961-76 period, everything will depend on whether job creation matches job reduction. Industry may well have major employment problems in the next fifteen years due to demographic effects and the higher proportion of women in the labour force. Industry may indeed have employment problems but at this stage there is insufficient research yet to convince that micro-electronics or other new technologies will be a major factor for the worse, unless the general prospects for employment create increased unwillingness to accept technological change. This may seem a relatively complacent view on the dangers of technological unemployment but the all important variable is the adaptability of the British economy.

Most comment from industry and the trade unions recognises:-

1. That British industry must adopt the new technology as quickly as her competitors (faster if possible), and
2. That, in welcome contrast to many other advanced technologies, micro-electronics for example, does not involve a heavy capital investment in a small range of industries. It involves instead very widespread applications, many of which may appear small in themselves. It will be the decisions of thousands of local managers and local trade unionists, as stated previously, responding to the possibilities for their own companies and plants, that will largely determine the rate of change.

In some fields where new technologies such as micro-electronics will have a major impact, Britain is relatively strong and flexible. Britain has a strong background in computer programming and has been highly

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successful in exporting services (financial, technical, educational). The real employment gains will accrue to those countries which can translate new technological innovations into new, attractive, inexpensive products for mass consumption. This is where Britain has been in the past, relatively weak and British manufacturers slow to modify their products and their production processes. The main objective of British manufacturers must be to speed up this rate of change in the future.

The job loss effects with any new technology tend to be more immediately demonstrable than possible job gains which may be widely diffused. One way of shedding further light is by looking at individual cases in industry, commerce and the public services where the effects of new technology applications can already be seen.

The predictions about employment that are now being made on new technologies were being made twenty or so years ago with earlier generations of computers. The Civil Service has used computers for a number of years and a study of the employment effects shows how wrong those predictions were.

The justification for the use of computer systems rather than manual systems has been heavily dependent upon the staff savings they are said to make possible. An example of this is the computerised payment of unemployment benefit. By 1977-78 some posts, mainly clerical, had been saved, partly offset by some 450 computer related posts. (1). This picture is repeated in other computer installations, but taking a wider view, there has been between 1970 and 1977 a growth from 170,000 to 200,000 staff in categories most likely to have been affected by computer installations.

The reasons for this paradox, the more the computers, the more the staff, are not hard to find. In some cases the computer applications have themselves suggested new areas of work and new services that

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government departments could develop, with benefit to the community. In other cases the staff freed by computer applications have been absorbed in new services, not of themselves computer related, which could not have been developed at all had computers not freed them. In 1977 the numbers of staff actually engaged in computer operations was about 14,000 and the numbers "freed" by computers were several times that figure, yet the total numbers employed in the areas affected had risen significantly. In short, the conclusion is that the employment effect of computers in the Civil Service has been at best to restrain the growth of clerical employment and certainly not to reduce it.

In an engineering factory, the main effect of installing a microprocessor based production control system has been a reduction in the length of the production cycle. This has enabled exports to be increased through greater confidence in bidding for orders. There have been reductions in clerical labour required to operate the production control system, but the most substantial direct economies have come about through a reduction in the amount of work in progress.

Reports on the application of new technologies have laid stress upon the distinction that has to be made between applications to products and to processes. One case study was therefore directed towards the car industry where new technologies associated with, for example micro-electronics, may be expected to make their impact in both areas. In the car industry the majority of applications on the production side have been concentrated upon such areas as design, testing, monitoring, production tooling and so on, where they have few manpower implications. There are, of course, some production line applications where these are applied piecemeal in existing production lines, the manpower effects are slight, indeed these applications are often made in order to overcome labour shortages on the production line (e.g., paint-spraying and body welding).

Where entirely new production lines are laid down manpower implications may be greater, but it is impossible so far to isolate the particular effects of micro-electronics from those of other technological advances although this thesis will attempt to isolate these effects. Furthermore, whether the numbers employed will actually fall will depend crucially upon market conditions, British market share, and so on.

These summaries of case studies do not pretend to be a systematic survey, but they do suggest the need for caution in any simple predictions about the effects of new technologies on employment because -

- Applications rarely involve the straightforward substitution of labour or (more expensive) capital by new technology. More often the main motives are the reduction of stock levels and savings in raw material and energy, improvements in quality and reliability, better information for control or the solution of technical problems.

- New technologies such as microprocessors are usually installed as part of a process of automation and mechanisation. The major changes will not necessarily be on the numbers employed but on the organisational structure and product range.

- The penetration of new technologies into products and processes is a great deal less advanced (in competitor countries and in Britain) than many people assume. Far from being immediate, as has been suggested by some commentators, the technological changes in most industries are likely to be evolutionary rather than revolutionary, and the consequent employment effects are likely to be slow to show themselves and in most areas to offer reasonable opportunities for planned adjustment.

Balance of Skills

Probably the most direct effect of the more widespread use of new technology in manufacturing processes and in services will be on the balance of skills. As manual assembly gives way to automated assembly, especially in batch production, the production worker will become increasingly distanced from the production line. He will have the opportunity to acquire new skills and the freedom associated with white-collar work. There will also be scope for re-organising clerical operations in order to provide greater job satisfaction; for

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instance, clerical workers in some gas boards now have terminals on which they can call up information to answer customers' queries, without having to refer the customers to other departments.

Not all workers will be freed from the constraints of the production line. Indeed, in some cases, new technologies will allow new areas to be automated with the familiar unpleasant consequences, such as reduction in the range of skills and tasks in each worker's job, the possibility of being paced by the machine, and the need for shiftwork to make full use of expensive capital.

Some of the new occupations which will emerge will be difficult to fit into existing structures and the present lines of distinction may come under pressure. Power and responsibility may be redistributed between the levels of a job-hierarchy; for instance, computerised diagnostic systems could bring a transfer of responsibility away from the junior hospital doctor on the one hand, upwards to the specialists who compile the information and on the other hand, sideways to the general practitioner who may carry his own diagnosis further through this aid. The labour management problems associated with changes in technology may form a considerable barrier to the adoption of new systems.

1.3 - THE OBJECTIVE OF THIS THESIS.

This thesis has two major objectives -

1. To investigate the problems associated with the introduction of specific new technology into manufacturing industry.

2. To derive and evaluate constructive conclusions from the investigation which would be of a sound contribution to manufacturing industry.

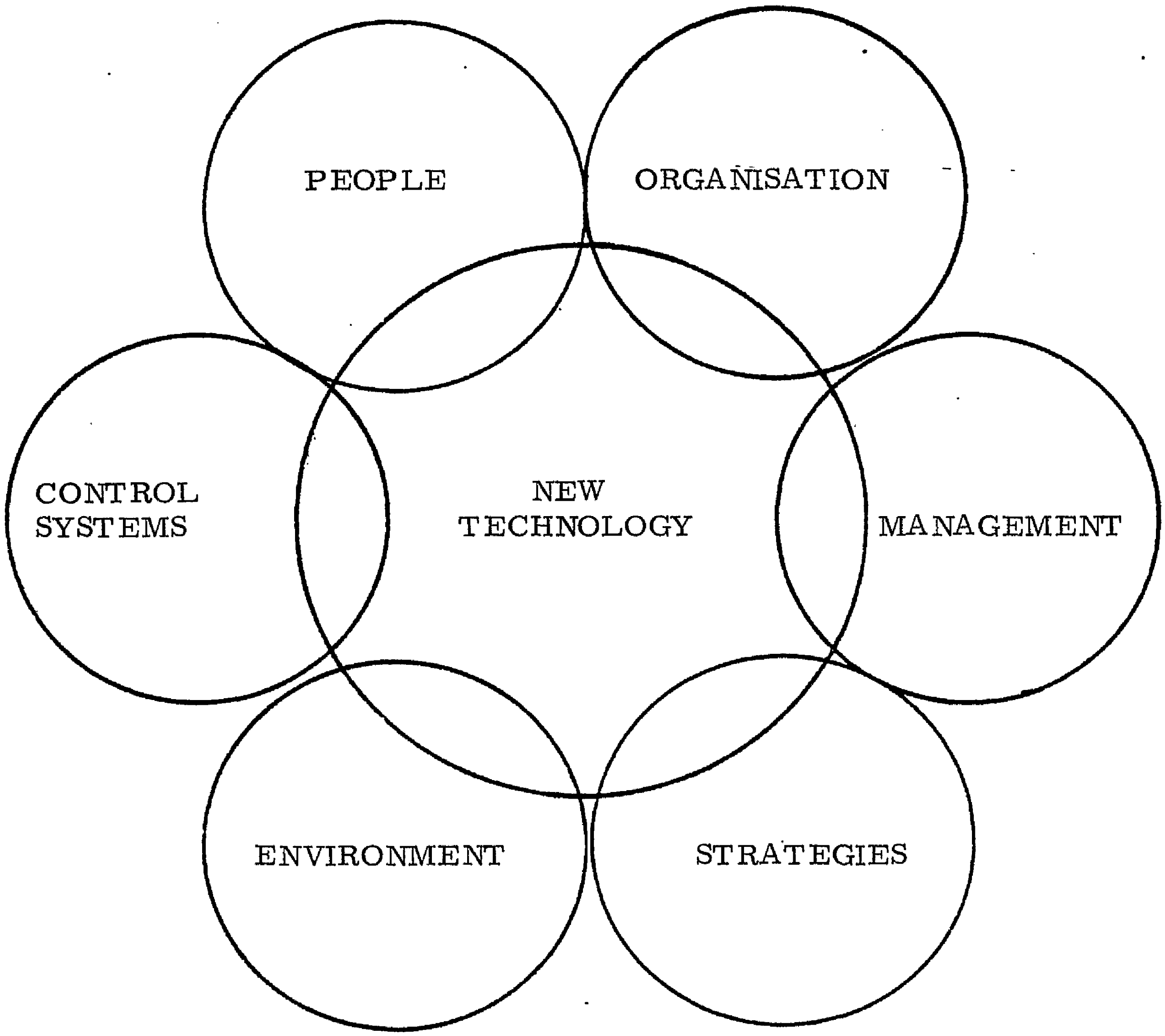
To achieve these 2 major objectives, it is necessary to develop a theoretical model of the enterprise and then to relate the practical findings of this research to the model. This model of the enterprise as illustrated in Figure No: 1.1, attempts to show the linking relationship between new technology and 6 specific factors of the whole enterprise. The specific aims of the research will therefore be to address each one of these factors from the analysis of the study of new technology in process manufacturing. This thesis argues that new technology will have an impact on these factors, such as to cause some degree of change. The 6 key factors of the enterprise as shown in Figure No: 1.1 are defined as follows:-

Organisation Structure.

Organisation structure is defined as the framework in which the enterprise functions. It is the division of labour which draws a distinction between span of control and hierarchy of managerial levels for various firms, related to organisation levels in the concept of tall and flat structures. A flat organisation is one where there are few levels relative to the total size of the organisation, while a tall organisation has many levels. The span of control is the number of immediate subordinates whose work is interrelated and reporting to a superior. The lines of authority both direct and functional are the chains of command through which the top levels of the organisation relay instructions to the lower levels of the structure at which point instructions are converted into action. Information flow lines are the means by which data is transmitted vertically and horizontally in reciprocating directions. Workflow disciplines are concerned with direction and activity surrounding /...

FIGURE No: 1.1

A MODEL OF THE ENTERPRISE
LINKING SIX FACTORS TO NEW TECHNOLOGY



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manufacturing of a component within the organisation. Informal and formal organisation is the distinction between the established authorised structure and that of the unofficial organisation,which is neither written nor procedurised.

It is not the purpose of this research to argue with the established theories of organisation structure related to the above elements, but it is the prime intention that observations be made of these elements to establish if any changes are apparent, due to the impact and problem of new technology.

Management.

The management group are defined as the people mostly concerned with planning, organising, co-ordinating, motivating and controlling the elements of the enterprise. In this instance the research is concerned principally with composition, attitudes and support for new technology, thereafter with degree of involvement, acceptance and creativeness related to new technology.

Strategies.

Strategies are defined as the formation of objectives for the enterprise and the method by which the objectives can be obtained through short and long term plans with consideration of resources currently available. Strategies also embrace the policies adopted for education and training for current and future needs and the attention given to teamwork and team leadership towards meeting needs created by new technologies.

Machine Shop Environment.

The environment in this research is that physical environment directly related to the nature of the technology central to the study. What is the growth of the technology in terms of individual units in any one firm? What systems are used to select and specify that technology? How is the technology located within the machine shop environment and what are the practices adopted for maintenance of these new technologies within the firm?

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Control Systems

One established system of control related to all technology acquired by a manufacturing firm is that of return on investment analysis. This technique will be described by actual case study examples and will be shown how it reflects the effect of new technology on the enterprise.

People

This research examines the observed effects of new technology on all levels of people within the firm. In particular it identifies shifts in employment, skills, resistance to change, integration of tasks, job satisfaction, status and inter-personal and inter-group relationships together with other elements affected by new technology under the general heading of people.

Format for the Presentation of Observed Effects.

Each chapter of this research thesis with the exception of Chapters 1 and 2, will be concluded with a table identifying the observed effects of new technology. Each table will have a heading describing the broad title discussed in that chapter followed by an analysis of those effects under the following defined sub-headings as shown in figure No: 1.1 namely,organisation structure, management,strategies, machine shop environment, control systems and people. These above sub-headings are described for this project as factors and are further broken down into specific components to be discussed under the sub-heading of elements.

Factor.

Six factors as previously defined and displayed on the model shown in figure No: 1.1 namely, organisation structure, management, strategies, machine shop environment, control systems and people.

Elements.

The elements identified within each factor are those items which have been observed to be subject to some degree of change directly due to the introduction of new technology. The detail on each of these

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elements is fully described within the text of each chapter, and in the concluding section prior to the summary results of that chapter given in the aforementioned tables entitled "Observed Effects of New Technology".

Change Type:

Four types of change are considered, viz.,

One Step - where the observed effect of new technology resulted in a definite change in the aforementioned element.

Cumulative - where the change was a series of small impacts or effects on the elements which resulted in a gradual change to the element.

Continuous - where the change was made over a longer less discernible period of time, perhaps not resulting in a complete change to the element.

Nil - where no change was observed in the element.

Effect:

The observed effect of each change to the specific element is described briefly by one or two words within the contents of each summary table.

New Technology and Innovation Defined:

To clearly define the term "technology" as it applies to this research project, the following definitions of types of technology and a definition for innovation are given below:-

New Technology.

New technology is defined for this research as that technology which emphasises the sort of machinery the enterprise uses and the way it is linked together. It is essentially that technology which is used to generate the product or service within the enterprise. Hickson(2) described this as Operations Technology with the objective of identifying the manufacturing activity and differentiating it from other types of technology within the enterprise.

Innovation.

Innovation is defined for this research as the adoption of a change which is new to the enterprise.

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1.4 - RESEARCH DESIGN USED IN THIS PROJECT.

One criterion for judging the utility of any research design is its ability to rule out the possibility of alternative explanations. The author is the key participant in the exercise and has determined that the major objective is to satisfy the hypothesis on the effects and problems of new technology in industry. A scale of priorities was established which would serve to systematically research the hypothesis. These priorities included a need to search for prior work on this specific subject and to read extensively the literature related to the chosen topic. The findings of this research on prior work will be discussed later in this chapter. The next stage was the decision on the design itself, in this respect it was established that some form of control and experimental group test would be used, together with a series of case studies followed by a large population field study. Data would be collected from one organisation to determine the factors which lead up to the acquisition of the new technology and the effects of this technology on that organisation up to date. This would be followed by a personal face to face interview with two separate groups of people in that same organisation, one group being a control group not exposed to the new technology, while the second would be the experimental group wholly associated with the new technology.

The next phase was to research a multinational organisation of 23 separate manufacturing plants and collect data from a second experimental group wholly exposed to the new technology. This would then be used as comparison data. The final stage would be a worldwide survey of user and non-user firms of the new technology to try to establish an industrial pattern of impact and effect.

This was the pattern of priorities laid down. There were of course alternative courses of action, the research could have been contained locally, i.e., West of Scotland Industry and a close and personal face to face research of companies with and without the new technology under question, but the nature of the technology would have made

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this research much too narrow apart from the fact that it would have taken longer despite the geographical advantages. Another alternative would have been to widen the concept of the new technology and include a whole variety of new type equipment, but this may have resulted in difficulties in ascertaining causal linkages on the impact and problem of one particular technology from another.

Could there be an alternative hypothesis? Indeed there could be a null hypothesis if, for example, the new technology was absorbed into the current organisation structure with no effect or problem.

The Hypothesis.

The model used to generate a testable hypothesis about the impact and problem of a new technology introduced into industry and, in particular the machine shop, was based on the assumption of causal linkages between specific factors in the enterprise. Since the new technology was being accepted by the management into the machine shop as additional assets, then the management would look for a measured return from the new assets. If no changes were made in, for example, the organisation structure nor in the production processes, then this return on assets would be minimised and indeed prove to be counterproductive. The model would seek to measure the changes in attitude, perception and behaviour of individuals using the equipment and managing the equipment. It would investigate the changing relationship between users and supplier of the technology, finally examining the theoretical advantages of the equipment against the actual advantages found by the user of the technology.

Direct Measurement Test.

As a consequence of the new technology one would expect to find positive changes in organisation structures, alterations to production systems and processes, a sound return on investment and a relationship to product quality effectiveness.

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Research Strategy.

The author selected a specific vehicle to try to prove the hypothesis. This vehicle is an entirely new technology introduced recently into industry namely, the co-ordinate measuring machine. The major reason for this selection was that so-called new technology found in industry especially the machine shop is generally a development of a previous technology. A basic metal turning lathe becomes a copy turning lathe, becomes a numerical controlled turning lathe, becomes a computer-controlled turning lathe, the original turning lathe concept has not actually changed, only the means of control. Even the development of computers from the mid 1950s has moved almost logically through a process of new generations from punch cards to floppy disc packs.

The co-ordinate measuring machine is different. Indeed the immediate predecessor technology to it was probably used by the early Egyptians and this was the basic surface plate or table. The co-ordinated measuring machine or CMM could be defined as "a machine which has its own 'surface plate' with measuring gear attached. Its co-ordinate axes are square in their own relationship and square and parallel with the surface plate and its measurement is independent of any fixed reference point within the measuring envelope or to any master". (Black, S. 1977 - see Ref. 8).

The research strategy was to be based on a technology which was reasonably free of contamination and question as to the degree of innovation and therefore the effect of its introduction into industry could be measured, validated and defined as a reliable sample of the effect and problem of any new technology into industry.

1.5 - THE STRUCTURE OF THIS THESIS.

Immediately following this introduction, chapter 2 presents a full description of the new technology which is central to this research project. This chapter describes the development of measuring machines tracing the history of individuals and companies who pioneered the early models culminating in the invention of the three co-ordinated measuring machine. To further explain the relationship of the measuring machine to other methods of measurement, a brief outline is given of eight basic systems of metrology commonly used in industry today. The discussions on the co-ordinate measuring machine is completed with details of the current "state-of-the-art" technology available to manufacturing and other industries. The reason for the inclusion of this chapter in the research project was to explain the peculiar and specific nature of this new technology prior to any research of its impact on the enterprise. This practical description of the new technology is an attempt to clearly illustrate the concept of the co-ordinate measuring machine.

A pilot study concerned with introducing new technology into a single manufacturing plant is the basis for chapter 3. This pilot study which incorporates 9 real case studies,in some respects is a foundation study for this total research thesis, and attempts to establish the strategies used to introduce new technology, control systems used to measure the new technology's effect on the plant and the consequences of new technology related to people at all levels working in the plant. This pilot study concerns itself in the first instance with numerical controlled machine tool technology and not measuring machines. The reason for this approach was an attempt to firstly set parameters of impact on the enterprise with a technology, which, although also relatively new to manufacturing industry, has had some limited prior research, and secondly to illustrate clearly, due to increased productivity from these advanced machine tools, why measuring machine technology became a necessity within the machine shop. It is argued here in chapter 3 that the introduction of numerical controlled machine tools as a new technology, had much greater and wider importance, than the management who introduced it had even considered or foresaw. The consequences of this were a series of reaction by various people within the enterprise. It is therefore a previously stated objective of the outcome of this study that manufacturing industry can be better prepared to meet the pressures created by new technologies through the knowledge gained from such research.

Chapter 4 opens the study into new measuring machine technology by once again researching the single manufacturing plant and tracing the development of this technology from an identified need through to selection and implementation. The subsequent effects of this new technology on the organisation structure, management and people are described in detail with the support of an attitude survey conducted on the craft inspectors who were most closely associated with the new technology. Chapter 4 concludes in a similar manner to all chapters from 3 to 8 with a summarised observed effects of new technology on the model of the enterprise, as previously illustrated in figure No:1.1. Having established some practical results from chapters 3 and 4 against the theory asserted on the impact and problem of new technology on manufacturing industry, chapter 5 opens the research to a wider geographic sphere by studying a multinational organisation of 23 individual manufacturing plants located in different sites around the world. The frame of reference remains the same in this research of several plants as it was for the single manufacturing plant, in that the model of the enterprise is researched for impact and problems on each of the six major factors previously identified. The essence of the results obtained from the multinational study is the emergence of differences and similarities of effects on organisation structures, and in particular, behavioural changes in inter-group and inter-personal relationships as a comparison to the single manufacturing plant studies.

Chapter 5 introduces a further aspect to the research by drawing a comparison between American and non American based manufacturing /...

plants on the factors of this research. This analysis attempts to discern that with a given similar technological base structure, does the advent of new technology have any different effect on the enterprise, due to nationality or other differences. In other words, does the stated theory that new technology will have an impact on the enterprise hold good for any manufacturing plant in the industrial world?

The results of a large field study of manufacturing plants in Europe and America are presented in chapters 6 and 7. This field survey was designed to investigate firms using new measuring machine technology and firms not using this type of technology. The objective of this approach was firstly an attempt to discover particular differences between these user and non-user firms in terms of organisation, management and business strategies, and secondly to analyse the user firms for the overall effects of new measuring machine technology on each of the six factors contained in the model of the enterprise. Chapter 6 therefore researches all of the firms in the field study and goes into some detail on organisation structure to ascertain differences in the following:-

1. Division of labour through the use of specific position titles from one organisation to another.
2. Hierarchy of levels and span of control within the structure of the pyramid.
3. Manpower ratios comparing various employee payroll numbers against a datum of craft inspectors.

Chapter 6 further researches types of production used by the firms in the field survey in an attempt to discover if there is any significance with production type and technology employed. Two other specific aims of chapter 6 are concerned with the comparison of firms using and not using new measuring machine technology, in terms of major technical changes made in these firms over the last two years and the consequential effects of these major technical changes on the established production system. Basically this analysis sets out to

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determine if firms which are currently using new measuring machine technology are technically more progressive than firms not using new measuring machine technology, and if this is so, in what way are they more progressive? The penultimate chapter 7 completes the investigation and research of the field study by a study of those firms which are using new measuring machine technology. This section of the thesis details the specific technology used by these firms and then attempts to show the reported effects of this technology on all of the aforementioned factors of the enterprise. Both chapters 6 and 7 are again concluded with a brief summarised observed effects of new technology on the enterprise.

The final chapter of this research thesis is a brief summary of the overall research, arguments and conclusions as described in chapters 2 to 7. An attempt is made in this chapter 8 to evaluate the success of this research in meeting its stated objectives, that is, in investigating the problems associated with the introduction of specific new technology into manufacturing industry and in the deriving and evaluation of constructive conclusions from these investigations which would be of a sound contribution to manufacturing industry.

The appendices to this research thesis contain important supportive material which is designed to relate to each chapter throughout the research. Appendix A details the concern shown by various established authorities within Britain on the whole question of harnessing, utilising and organising of new technology. Appendices B to D present background information on the new measuring machine technology including a detailed technical survey by the author, on the worldwide source of co-ordinate measuring machines, which was part of the origins of this research. Chapter 3 has supportive material in appendices E and F which contain an interesting extract from a publication on the attitude of the Trade Union Congress to the question of negotiation of new technology agreements with firms. Appendix F contains a copy of the format used by one firm for the

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calculation of return on investment analysis, which is an important feature of the discussion and findings from chapter 3. The research of the single manufacturing plant in chapter 4 has appendices G to L covering details of the return on investment analysis made for the acquisition of the co-ordinated measuring machines, results obtained from an experiment to measure the effectiveness of the new technology, and finally, a description of how the attitude study was designed and launched within the single manufacturing plant. The study of the multinational organisation as detailed in chapter 5, is supported by appendices M to Q. This material covers four specific features concerned with the research namely, the research design for the multinational plants, the tripartite questionnaire used as a research vehicle, a basic history of the multinational, and the overall results obtained from the questionnaire.

Chapter 6 is concerned with the major field survey of firms using and not using measuring machine technology, the appendices R to U cover the questionnaire used in the survey, the overall results obtained and the detailed tables on manpower ratios on firms shown by various business activities and by employee size of firm. Copies of 18 specific organisation charts are also contained in these appendices, as supportive evidence to the details shown in the text of chapter 6.

1.6 - PRIOR RESEARCH AND LITERATURE REVIEW.

As previously stated in this introductory chapter, there has been limited prior research on the introduction of new technology into manufacturing industry. There has almost certainly been no prior research on the specific impact or problem of new measuring machine technology into manufacturing industry hence one of the needs for this research project. However, on the known research on other new technologies, N. Swords Isherwood and P. Senker of the University of Sussex (13) showed in a study conducted in 1978 of the Social Implications of Automated Small Batch Production on behalf of the Department of Industry, that the increase in new technology, such as numerical controlled (N. C.) machine tools in machine shops in Britain, had resulted in substantial increases in production over the last 7 to 8 years with no corresponding increase in employment, but they argue in their report that there was little or no resistance to the new N. C., machine, due to no redundancy pledges and early consultation with trade union officials.

This research, while agreeing with the shift in employment findings, refutes the above arguments and shows that two separate issues control the degree of resistance to the introduction of the new N. C., machine tools: 1. The recognition by plant level trade union officials that the continuous investment in new technologies such as N. C., machine tools is paramount to the long term survival of the plant, despite the short term effects of employee displacement, and 2. The self interest of the individual shop floor blue collar employee coupled with the evolutionary nature of N. C., machine tool introduction results in minimum resistance.

Abbot (14) in a study of 9 engineering firms published in 1978, showed that in relationship to technological change, professional and white collar staff employees had considerably increased as a proportion of the total labour force. This research would argue that, while professional and white collar staff employees are undoubtedly

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increasing in their power and influence due to the introduction of new technologies, these unions are not necessarily increasing in numbers, as a relationship to total employees. If anything their numbers are reducing with the increasing effectiveness and efficiencies of new technologies in both factory and office functions.

One of the subordinate objectives of this research is concerned with how new technologies start in a firm. Langrish and associates (15) made a study of 84 firms who gained a Queen's Award for technological innovation and concluded that new technology came mainly from other existing technologies within the organisation and identified some of the major causes for delay in getting the new technology underway, such as, waiting on other yet to be discovered technologies, insufficient market demand, shortage of capital or manpower skills, lack of recognition by management and poor co-operation or communication. This research shows that management's reluctance to accept the responsibilities of new technology had a large degree of relationship to the speed and success to which new technology could be implemented into the firm. Myers (16) in a study in America suggested that personal experience and personal contacts were one of the principal sources of information for successful change in technology. This research disagrees with Myers and shows that from a very large field study, the individual manager most favourable towards the new technology tended to have long company service and was not moving from one plant to another in short term assignments.

Organisation structures are discussed in several chapters of this research project. Burns and Stalker (17) in their study of the management of innovation distinguish two broad polar types of industrial organisation, mechanistic and organic, and that one was much more adaptable to new technology or innovation than the other. While this particular theme is beyond the specific terms of reference, it is shown in this research that in a multinational or indeed a multiplant enterprise, the concept of organic and mechanistic structures

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become complex and difficult to discern, in that centralised services often conceal the apparent omission of particular styles of hierarchies, divisions of labour and spans of control. Jasinski (18) makes an interesting observation in his paper "Adapting Organisations to New Technology" suggesting some alternative methods for integration between technology and organisation. This research tends to agree with his third alternative, that firms will set up mechanisms to reduce or minimise disruption, rather than attempt to change the organisation or the new technology itself within the firm. A mechanism in this research is identified for example as a staff co-ordinator such as a N. C., programmer who would be assigned as a type of liaison between the planners and the users of the technology within the firm.

On the subject of technology and the structure of management, the late Joan Woodward of Imperial College, London (19), is probably the best known and most influencial proponent of the thesis that contrary to much of classical organisation theory, the management structure most appropriate to a firm's requirements largely depends on its technology. While much of Woodward's work was concerned with technology within the firm and not with new technology entering the firm, some of her work will be used as a comparative datum to the nature of the new technology researched in this study.

Contrary to observations made by Anderman (20) in his study entitled "Trade Unions and Technological Change", the operators assigned to new technologies studied and observed in this research, did not suffer decreased job satisfaction nor lower status within the firm. However one distinct aspect of this research, which may make it unique from other findings, is the fact that the blue collar workers under study are craft or time-served engineers. All of the case studies related to this thesis where job satisfaction and/or status was being researched, showed quite conclusively that, while the former did not increase, that is more satisfaction, it certainly did not decrease. Status among the N. C., machine tool machinists was observed to increase at the

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early stages of using the equipment but it was considered that this may have been a temporary phenomenon due to the amount of attention which was given to the equipment by all levels of employees and by visitors who were purposely shown the machines as part of their tour of the plant. Further to this, and as will be shown in chapter 4, the craft inspectors assigned to the new measuring machines claimed that their status had improved. One particular group of employees being affected by changing technology is that of the first line supervisor. Among the problems associated with this group are, 1. The increasing demand on their technical skills from new technology which they were never trained to understand and 2. The administrative and work scheduling duties now being handled by the computer. Lundgren (21) observed in a study of 7 American companies, that the foreman appeared to have lost status in terms of fewer responsible duties performed and to have gained status only in the sense of being associated with a dramatically new manufacturing technique, a gain in status that would last only as long as the novelty of the equipment. The findings in this research thesis agree with Lundgren and further observes that the role of the foreman or first line supervisor is slowly being reduced to one of man management.

Bhattacharyya (22) in his study of the Penetration and Utilisation of N.C., machine tools in British Industry 1976, found that trade union members at plant level were often misled about the whole implications of N.C., technology before it arrived. These misconceptions were often created by over zealous sales literature from N.C., equipment suppliers with statements related to reducing operator costs and no more problems with the shop floor. It is perhaps for this reason that this research argues a case for minimum communication to trade unions and blue collar shop floor employees on the future plans for acquiring new technologies of any type. This study demonstrates by reporting several case studies where advanced communications have resulted in disruption often prior to the arrival of the technology, while other case studies indicate that minimum communication resulted in minimum disruption. Contrasting this was the findings of

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Ettlie (23) in a study of 10 firms in the mid west states of America, suggested that there was a correlation between early involvement with trade unions on the new technology and the later success with utilisation of the equipment. This research would refute this above finding by Ettlie and shows that there are many other factors which determine successful utilisation of new technology to name manning, wage and grade systems, training, maintenance and others, which would be of higher priority than early involvement of trade unions. However there is one other important factor of difference and this is related to the difference between the attitudes and needs of British and American trade unions. Perline and Tull (24) observed in another American study that unions were facing a major dilemma with the increasing degree of shop floor advanced technology due to the loss of skilled and unskilled membership, which in turn weakened the union bargaining power and reduced its financial support. This study suggests that the dilemma in Britain is even more complex with the number of different unions and the possible shift in employment resulting in members of blue collar unions moving to white collar tasks as a direct result of new technology.

The first trade union in Britain to make some constructive recognition of the consequences of new technology is the Association of Professional Executive, Clerical and Computer Staffs (APEX). They published a very detailed guide entitled "Office Technology - The Trade Union Response" for the benefit of their officers at plant level, in order that they obtain the best negotiating strategies possible with respect to any new office technology, which could directly affect the employment of their members. The clear instruction given in this guide is for negotiation to encourage the progress of advanced technologies and this is the policy to which the APEX trade union would encourage all other unions to adopt. This research argues a case for the involvement of trade unions on the whole question of new technology, evidence from this and other prior research would show that little progress will be made without involvement of trade unions. Where this research will differ from other research is in the timing and manner which is best

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used for this involvement. The work of Leonard Sayles (27) is interesting as it finds some correlation with the results of this study. Sayles identified 4 behavioural patterns observed in working groups namely, apathetic, strategic, erratic and conservative. Two of these groups namely, strategic and conservative, are as defined by Sayles applicable to this research and can be identified in the case studies discussed.

On the subject of organisation structure Lundgren (21) found in his study of 7 companies in the mid west of America, that changes had been necessary due to the impact of numerical control machine tool technology. These changes showed that a modular type structure as a means to assure an efficient operation had been incorporated as a component of a larger manufacturing system. Chapple and Sayles (28) also advocated the design of a structure from the bottom up, basing the organisation on the actual work flow and superimposing structure on a known technology. This research argues a different approach to organisationstructure as interrelated to new technology. Previous research indicates that specific structures should be set up to accommodate the technology but these prior research findings do not appear to recognise that in the majority of manufacturing firms, new technologies tend to be integrated into existing technology within the given machine shop or factory. The existing structure and control systems absorb it, there is no need for a special management or indeed operator structure. Williams and Williams (29) in a research paper on the possible consequences of new N. C., technology on the organisation structure perceived 2 major implications for the work force. These were: 1. Horizontal effects resulting from pressures which require greater and more effective interpersonnel relationships and 2. Vertical effects which would result in the need to appoint individuals possessing high levels of technical knowledge to specific duties and responsibilities within the structure.

On the key question of obtaining a return on investment (ROI) for new technologies acquired by the manufacturing firm, several of the aforementioned researchers have made contributions. Bhattacharyya (22)

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in his study on the penetration of N. C., machine tools showed that only 5 percent of the firms were obtaining 60 percent or more utilisation rates. Huggins (31) in another British study found that specific reasons were given for the failure to realise ROI these ranged from inaccurate calculations of overheads to lack of teamwork in the firm. Ettlie (23) in his American study identified specific factors which indicated successful utilisation of N. C., technology in a firm and thus maximised on ROI. All of these studies and findings will be challenged and compared against the results of this research with respect to return on investment.

One of the most recently publicised conflicts concerning new technology has been the dilemma concerning the Times Newspaper where revolutionary changes in printing mainly through word processing technologies would displace a substantial number of blue collar printers (32). This conflict is only referred to in this research due to its relationship with the less dramatic but inevitable integration of certain tasks in manufacturing industry. This research will investigate the attitudes of employees who have been or will be subjected to this consquences of new technology. Walker and Guest (33) investigated almost 30 years ago, the problems associated with men working on car assembly lines and helped to lay the foundations for further research on the subject of job satisfaction and job enlargement. Chinoy (34) researched similar work activities and the effects on the worker. Probably the best known related prior research to this thesis is that of Trist and the work of the Tavistock Institute (36). His study was very specific and directly concerned with the effect of a completely new form of applied technology. Blauner (37) distinguishes main types of technology on the basis of degree of mechanisation and standardisation of the product. He discusses the problem of alienation as it applies to these types and suggests that it will be highest for assembly type fragmented skills and lowest for craft type skills. This research which is deeply concerned with the craft element identified by Blauner centers on particular engineering skills and not on any broad front workgroup or assembly line. It therefore argues a

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special case for the introduction of new technology into manufacturing industry which makes this research unique and unparalleled in any previous studies.

From the limited prior research on the subject of de-skilling of craftsmen and the reaction of these employees to the new technologies causing the change, it is implied that the employees will have a negative attitude to the new technology and seek to resist. See Abbot (14), Bright (38), Sayles (27), Scott (39) and Mumford (40). The last two researchers were mainly concerned with office equipment and computers but the reported effects were of a similar view. One further study which correlates with this research is that of Hall and Miller who noted that skilled craftsmen were afraid of losing intrinsic job satisfaction and job status as a result of dilution of skills (41).

The multinational organisations have received much criticism over the last decade and more so recently with the apparent withdrawal of many American-owned groups from Britain back to America. Schumpeter (44) and others have placed more emphasis on the role of these giant corporations in stimulating technical advances. Jenkins (45) in his recent book suggests that there are 2 major reasons for this and these are the availability of finance and the resources to be devoted entirely to research and development. In a report by the United Nations Department of Economic and Social Affairs in 1974, it was observed that while multinationals are an important source of certain types of technology, these corporations do not always want to transfer this technology to their affiliates either because it is not suitable for use or they just do not wish to make it available (46). While this research does not enquire into the special problems of multinationals as related to new technology, it will be shown that special problems do exist with the multinationals and their decisions to move technology from one plant to another. Bass and Barrett also observed in their writings that the multinationals have an important role to play in the advancement of new technology but question, as this research will do,the effectiveness of this activity (47). Further research and reports have been highlighted by Servan - Schreiber (48), Boner (49) and Perlmutter (50), on the whole question of integration of the American multinationals into Britain and Europe but this research will differ in some respect with these above findings suggesting that many of the problems or integration of new technologies were not only associated with the attitudes, traditions and practives of the residents but many of the problems were brought over by the American multinational managers.

This research again argues a case that there are differences in the organisation structures of firms using and not using new measuring machine technology. To establish a datum for the analysis of 100 organisation structures, the principles of hierarchical levels derived by Weber and Fayol are applied (52). The evolution of the quality control function as a separate organisation from that of manufacturing was first reported by Juran (53). The definitions for specific position titles as identified by Juran are also applied to this research, in order to show differences between those firms using and not using new measuring machine technology.

It is observed in this research that the larger the size of an organisation then the lower is the ratio of monthly paid or senior staff to total personnel in the firm. This result tends to replicate the findings of Starbuck in terms of organisations of less than 100 employees (54). This study examines different business activities in relation to new technology and observes that the firms in the British machine tool industry do not reflect well in terms of good organisational structure or manpower ratios compared to other business activities, but these findings are somewhat paralleled with a recent Machine Tool Industry Business Ratio Report, which reflects a very erratic performance (55).

CHAPTER 2 - THE MEASURING MACHINE

2.1 - THE OBJECTIVE OF THIS CHAPTER.

The objective of this chapter is to describe the new technology which is central to this research project. In order to make this description fully comprehensive, the following stages of development of measuring machines will be discussed -

- History and development of the early measuring machines.
- Industrial metrology today.
- Types of measuring machines in use.
- The co-ordinate measuring machine.
- The measuring machine technology available to industry.

The text in the chapter will be supported by photographic plates, figures and appendices material as follows -

- Significant dates in the history of development of measuring machines. See Appendix B.
- Moire fringe principle of optical scales. See Appendix C.
- A worldwide review of manufacturers and their systems of co-ordinate measuring machines. See Appendix D.

Highlights of Chapter.

Chapter 2 traces the history of the measuring machine concept from the initial invention by Joseph Whitworth in 1855 to the mid 1960s, when there was a tremendous expansion of measuring technology and equipment. The early engineers and scientists were concerned essentially with creating some form of standard gauging from which they could obtain good interchangeability of manufactured components. They wanted to improve their crude machine tool accuracy so the first measuring machines were therefore created to be a form of comparator to meet the aforementioned objectives.

Marc Thury of the Societe Genevoise D'Instruments de Physique in Geneva, invented a linear dividing machine in 1863, not for any

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commercial or industrial purpose, but essentially as a means of improving the accuracy of the wide variety of scientific instruments being made by his organisation. Indeed over the years Societe Genevoise tended to be biased towards scientific work as opposed to industrial manufacturing. They developed, manufactured and marketed a 3 co-ordinate measuring machine almost 30 years ahead of most other manufacturers, yet they appeared to have failed to exploit this market during these years, or even today.

Richard Moore, who founded his company in 1924, set out on a commercial basis from the beginning, supplying gauges and dies to manufacturing industry in America. He built a jig boring machine tool and invented a jig grinder to assist him in making more accurate gauges. Moore soon found himself manufacturing and selling jig borers in addition to his gauges and dies, and indeed, the jig borer was so accurate, that he and his customers began to use it for measuring purposes, thus the Moore Universal Measuring Machine was conceived and evolved from the original jig borer machine tool.

Other high precision instrument manufacturers found themselves in the measuring machine business by a need to develop a piece of equipment to measure their products. Carl Zeiss of West Germany is a good example, as they developed very high precision optical measuring devices in order to manufacture their binoculars and precision photographic equipment. Today their line of products is headed by a range of co-ordinate measuring machines.

It was not until the 1960s that certain companies were founded purely for the business of manufacturing measuring machines and this event came about primarily due to the development of many other technologies; the use of light waves as a natural standard for measuring length, the development of the computer and the microcomputer, together with a whole host of other related electronic inventions. The creation of today's advanced measuring machine from all the

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various beginnings, scientific, industrial, by-product or other, would not have happened in the final analysis, but for the establishment of a ready market of users. This market was created in manufacturing industry with the increasing complexity of numerical controlled machine tools generating components of much higher volumes and degrees of accuracy and, consequently, a higher standard of inspection, which could not tolerate the slow methods of measurement utilised in previous years within that industry.

Chapter 2 then examines the width of industrial metrology today, to show where the measuring machine fits into the general spectrum of methods adopted by manufacturing industry, illustrating in particular the basic concept of interferometry and laser technology which will be referred to later in this research as it is an integral part of the 3 co-ordinate measuring machine. The various types of measuring machines are discussed together with the complete range of co-ordinate measuring machines being used today in industry.

2.2 - HISTORY AND DEVELOPMENT OF THE MEASURING MACHINE.

The first known measuring machine was constructed by Joseph Whitworth (1803-1887) in England about 1855. This was a linear type machine based on end measurement which, it was said, could detect differences as small as one millionth of an inch - probably this machine did not measure sizes, but simply compared minute differences. The practical use of the machine was in the production of standard gauges and Whitworth in 1841, advocated before the Institution of Civil Engineers, the general use of standard gauges graduated to a fixed scale as a constant measure of size. - He pointed out that these would enable standard machine parts to be produced instead of the existing "indefinite multiplication of sizes". In a letter to "The Times" in 1855, Whitworth stated "that the engines of 90 gunboats for the Crimean War were completed in 90 days, only as a result of the adoption of standard gauges so that intermatching parts could be produced in quantity by different firms." These arguments proved convincing and in 1880 his standards were officially adopted by the Board of Trade. Whitworth is best known for his standardisation of screw threads, which was universally adopted by 1858. (3).

There are 2 organisations in the world which could lay claim to being pioneers with the introduction of modern 2 and 3 co-ordinate measuring machines. These organisations are - Societe Genevoise D'Instruments de Physique of Switzerland, and Moore Special Tool Company, America. The following brief description shows how each of these firms evolved their respective types of measuring machines.

The Societe Genevoise D'Instruments de Physique (4) which means in English - Genevese Company for Physical Instruments, known the world over as S.I.P., was founded in 1858 by a few professors of the University of Geneva, who wanted to have near the university, a work shop where they could build the instruments they used in their laboratories. Many of the instruments available at that time were

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rather primitive and inadequate for their purpose. It was therefore felt that much advance could be achieved in several branches of science, if better and, in particular, more accurate instruments, could be made, hence the desire to start a workshop with the highest quality of workmanship. SIP was established in 1862 as a corporation for the manufacture of scientific instruments, particularly for physical research work. It was actually engaged for a number of years with the manufacture of a very wide range of instruments such as - mathematical and geodetic instruments, comparators, microscopes, meridian telescopes, equatorial mountings, spectrometers, compasses, experimental machines, electrical instruments and others. Circumstances were soon to lead SIP to handle other manufacturing problems, the first one was that of graduating machines, called dividing machines. It was found that most of the instruments made entailed precision divisions, either linear or circular and there was at that time no automatic machine to graduate them with the required accuracy, so it was decided to build special machines for this purpose. The first dividing machine (linear) was made in 1863 and this was the first machine ever to be equipped with an automatic correcting device. It took 2 years to be completed and had finally an accuracy of $\pm$ .01" over its entire travel of 20". Once this machine was in service, SIP was soon engaged on making precision scales, which led to the manufacture of instruments for checking these scales or comparing them between each other. From this stage SIP were able to progress with the manufacture of more accurate measuring instruments.

As time went on industrial firms started showing interest in precision measuring instruments. The development of mass production, which called for interchangeability of the manufactured parts, made it necessary to dispose in every industrial machine shop an accurate and permanent basis of measurement on which all the tools and gauges used for the production could be checked. SIP's measuring instruments, which had at first been used principally for

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scientific purposes, had to be adapted to the growing requirement of the industry, for the control of gauges of all kind, threaded parts, etc. One of the forerunners to the modern co-ordinate measuring machine was the jig borer machine tool. The first jig borers were made by SIP for Swiss watchmakers at the time of World War I; they were used only for spotting but were not very different from today's 2 co-ordinates measuring machine. Eventually the idea was conceived of extending their application to all mechanical industry and in 1921 the first industrial jig borer, MP-4, was completed. With these machines, settings were made by means of lead screws with correcting devices, but later in 1934, SIP developed the first jig borer with optical settings, called the Hydroptic, and this machine greatly increased the field of application of jig borers. Thus it is seen that by a continuous and logical evolution, SIP has gone over from a purely scientifical to an industrial production. If the products have changed, the tradition, the methods used have not, nor the approach to any manufacturing problems, as all the machines or instruments made by SIP continued to entail some scientific elements.

The world's first known 3 co-ordinates measuring machine was developed and marketed by SIP in the early 1930s, it was called the MU-214B, and had a range of 6" x 16" x 4" for the z, x and y axes respectively. The main features of this machine were its high precision for absolute measurement of lengths, diameters, external and internal threads, profile gauges, plates and jigs, etc. It had steel standards built into the longitudinal carriage supporting the parts to be measured and into the transverse carriage receiving the locating microscopes and various auxiliary measuring attachments. An improved and updated version of this machine is still marketed by SIP today. By 1960 SIP had sold over 900 of their MU-214B measuring machines around the world, having almost 30 years of no serious competition, which may account for the surprising lack of development in the measuring machine business up to this point in time, apart from the need to await other technologies being invented

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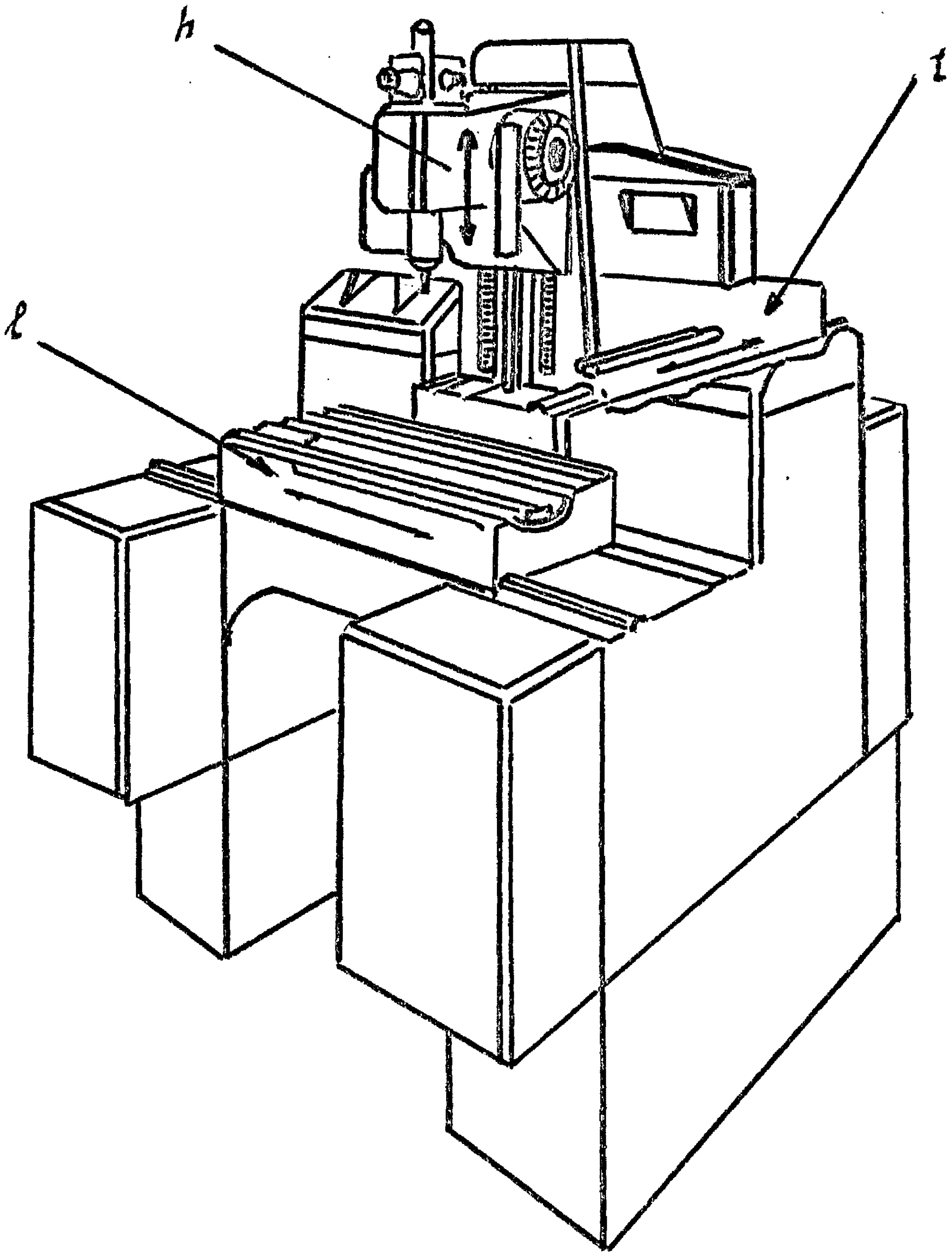
Figure No: 2.1.

TRIOPTIC CO-ORDINATE MEASURING MACHINE

(Source - Societe Genevoise D'Instruments De Physique, Geneva).



especially related to the field of electronics.

In 1961, SIP marketed the Trioptic measuring machine which in many respects was the world's first true 3 co-ordinates measuring machine and it was at that time described as follows:- (4).

Trioptic Description.

The majority of universal machines which are available on the world market are only intended for measuring small, light parts and those rare machines which are capable of measuring heavier parts are not sufficiently accurate to meet the requirements of modern industry. SIP with its Trioptic universal measuring machine, places at the industry's disposal an instrument of high precision, and particularly well adapted to the needs of the day. The work load permissible on the table is 330-lbs (150 kg). Accurately measuring parts as heavy and as cumbersome as these means that the machine has to be in the first place, both rigid and stable, the bed and the 3 mobile elements, longitudinal, transversal and vertical carriages, are made of stabilised cast iron. Rigidity is obtained by very strong ribbing and a well balanced bed resting on 3 points.

General Functioning Principle.

The displacement axes of the 3 mobile elements defined the 3 measuring co-ordinates, 1, t and h. (Figure 1).

a. The longitudinal carriage '1' which supports the part to be measured.

b. The transversal carriage 't' which is displaced perpendicularly to '1' and which supports the vertical carriage.

c. The vertical carriage 'h', perpendicular to the plane formed by the displacement of the longitudinal and transversal carriages, which takes the locating instruments.

A standard scale is mounted inside each mobile element - the divisions of these scales are projected onto 3 micrometer screens which give the position of the scale and consequently that of the mobile element. It can therefore be seen that the machine transforms the length to be measured into a measurable displacement -

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that of the standard scale mounted on the mobile element in relation to a fixed point, the micrometer screen. It can be seen how it is possible to measure the displacements of the mobile elements in relation to the machine, but the position of the mobile elements has still to be determined in relation to the part to be measured. This locating operation is carried out by means of optical or mechanical instruments which are mounted on the vertical carriage. (Later, and on the current models of the Trioptic, electronic instruments were added).

During the period that SIP had marketed their first measuring machine, the MU-214B in the early 1930s, a new firm had been founded in America which was to firstly use the SIP equipment and latterly to emerge as an important competitor. This firm was the Moore Special Tool Company (4), founded in Bridgeport, Connecticut in 1924, specialising in highly accurate gauges and dies. Much of its early work was for the clock and brass shops of the Naugatuck Valley, but by 1932, Richard F. Moore had designed and built a jig borer for his firm's own use and then for sale to adapt to toolrooms and jobbing shops making tools and dies for clocks, locks, small electric devices, typewriters, adding machines, toys, instruments and many other small and moderate sized parts. He had set for himself the requirement that the price should be low, so that the machine will pay for itself in a short time. The No: 1 Moore jig borer was small, accurate and fast, its great innovation was the use of hardened, thread-ground and lapped lead screws, which gave greater security to measurement than the soft, compensated ones. In a small machine the lead screw provided many advantages over either a scale or end measure, most notably in faster setting and the simplicity of design enabled the machine to be offered at a reasonable price, so it soon achieved acceptance - this led to the jig borer becoming a basic machine tool. In 1940, Moore invented the jig grinder - this machine tool overcame the problem of having to jig bore parts in a soft state and somehow trying to compensate for the resultant hardening

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distortion. With the jig grinder, holes could be ground to location after hardening, a capability especially needed for such accurate work as progressive motor-lamination dies, watch and clock dies, hardened jigs, fixtures and gauges.

By 1946 the National Cash Register Company had specified that all dies, where accurate hole location was involved, had to be jig-ground. From today's perspective, this would seem a logical requirement, but considering the then recent introduction of the jig grinder, such a specification required great perception by management. At this time, the jig borer was also enlarged and improved, without doubt, the basic locating features of the jig grinder evolved from and are identical with the jig borer. However, the jig grinder is considered by some to be more accurate or more sophisticated than the jig borer, and may possibly be attributed to the higher finish achieved with ground surfaces. It was at this time during the 1950s, that Moore, on the basis of his now wide experience with the jig borer and jig grinder, developed his first universal measuring machine. This new measuring machine was almost identical in appearance to the jig borer but its function was different and therefore its inner mechanisms, apart from the basic frame, were quite different from either the borer or grinder. Jig borer owners initially asked "Why is the universal measuring machine necessary at all, given the accuracy of today's jig borers? Aren't our jig borers sufficient for any measuring task?" The answer may be found in the nature of the jig borer itself, since it evolved towards a design which seeks the ultimate in positioning accuracy - certainly one can measure with the jig borer and, indeed, the very function of boring to accurate location involves the measuring process and the most accurate inspection which can be made of a jig-bored part, outside of a universal measuring machine, is on the jig borer after machining.

However the jig borer does have limitations, notably in its column, housing and spindle design, although the spindle must be accurate for

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measuring purposes, it must also be capable of taking a substantial machining cut, therefore included with the requirement for accuracy are the additional requirements of rigidity, reliability and serviceability. Another unavoidable factor to be taken into account in using a jig borer is the presence of heat producing elements, because of the high revolutions per minute involved. The spindle bearings have a tendency to warm up and heat from motors, gears, belts and pulleys, impose certain modifications in design. In contrast, the design of the measuring machine is concentrated around the singular functions of measuring and, as a result, it is more accurate and more efficient. It is natural that the measuring machine should "borrow" those design principles that contribute to accuracy in a jig borer. However, just as the jig grinder is a distinct type of machine, though it "borrows" from the jig borer, so too is the universal measuring machine. It is quite understandable thus that Dr. Farago would describe this machine as a "Jig borer-type measuring machine". (6)

Another reason for the emergence of the universal measuring machine is the fact that the jig borer came to be increasingly used in inspection processes. Some were used totally for that purpose and it was inevitable that demand would arise for a machine which would just measure, and with all the controls and capabilities built in, do the measuring job more efficiently without unnecessarily tieing up an expensive material cutting jig borer. A further reason for increased use of the measuring machine relates to the need to remove special ultra accurate parts from a machining environment into an environment devoted exclusively to inspection. Here an inspection could be given to the part in a clean, temperature-controlled environment by a machine designed strictly for measuring and used by personnel with a strong bent for inspection.

Today neither Moore nor SIP are the front runners in the field of coordinate measuring machines although they both continue to produce updated versions of their original models with improved accuracies and additional peripheral equipment in keeping with the rapidly advancing computer technology. Despite the undisputed high accuracy of both the Trioptic model from SIP and the Universal measuring machine by Moore, these measuring machines have the disadvantage of small table size, less speed of measurement and less overall flexibility than the competitive CMMs offered by other firms in today's co-ordinate measuring machine marketplace. The so called "co-ordinate measuring machines" are of a different evolution from that of the Universal or Trioptic measuring machine. They have emerged out of the need for checking parts made in production to thousands of an inch tolerance (several hundredths of a mm). Prior to their introduction, it was often the case that it took longer to measure a part than to produce it. This was an intolerable condition with high volume production parts.

During the late 1950s, Ferranti Ltd., in Edinburgh, Scotland designed a system known as the moire fringe system (Appendix C) which was to give a technological breakthrough to the problem of accurately recording precise measurement of travel and about 1959, Ferranti Ltd., launched their first co-ordinate measuring machine known as the F1-22. This early machine was of a different construction from both SIP's Trioptic and Moore's Universal measuring machines. Indeed its cantilever open throat design was to be the forerunner for many more organisations who entered the CMM market in the mid and late 1960s. The Ferranti F1-22 was designed for very quick measuring of distances between holes with an accuracy of $\pm$ .001 in. ($\pm$ .02mm). A locating tool is displaced transversally along an arm which can itself be displaced longitudinally. The position of the locating taper in relation to the co-ordinate axes x and y, are read directly on a display panel. The measuring reference is a glass grating bearing 500 lines per inch. Measurements to the nearest .0005" are made by a photoelectric sensing unit which senses both the amount and the direction of the probe movement (7). Leitz of West Germany introduced their

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Leitz-Strasmann universal measuring machine about 1963. This was described as a good workshop machine especially designed for measuring screws and hobs. (See plate No: 2.1, page 55). As the market for 3 co-ordinates measuring machines expanded very rapidly in the mid 1960s, many well-known measuring equipment manufacturers such as C.E. Johannson of Sweden and Carl Zeiss of West Germany got into the business. They were joined by many new names who were to specialise in the CMM field (9). For example, Digital Electronic Automation (DEA) Italy, are today one of the largest producers of CMM and certainly they are the manufacturers of the largest types of CMM in the world. As an example of quantity, a detailed account of the DEA sales is given below. Considering that DEA is only one of 24 different companies manufacturing around the world in 9 different countries, it gives some indication of the new magnitude of this total market.

TABLE No: 2.1

DEA SALES OF CO-ORDINATE MEASURING MACHINES AS AT 13TH JUNE, 1977

	MODEL						
Country:	Beta:	Iota:	Gamma:	Alpha:	Delta:	Sigma:	TOTAL:
Italy	112	46	32	5	9	6	210
United King.	29	2	4	1	1	0	37
Benelux	4	3	5	0	2	0	14
France	32	24	17	4	4	1	82
Germany	24	32	30	5	5	11	107
Spain	7	4	2	0	0	0	13
E. Eur.block	45	27	37	17	19	10	155
Scandinavia	11	7	6	1	1	0	26
America	65	33	3	2	0	3	106
Total M/cs:	329	178	136	35	41	31	750

Source of above data - letter to the author from Sandro Del Sarto, North European Sales Manager, Digital Electronic Automation, Corso, Turino, Italy dated 13th June, 1977. Apart from the sales to their home country Italy, it is interesting to note the sales achieved to the East European block countries in comparison to the West, especially Britain, despite its high degree of industrial development. (See Appendix B for a chronological breakdown of the history and development of measuring machines).

2.3. INDUSTRIAL METROLOGY TODAY

To correctly describe the relationship of the measuring machine to other systems within the overall field of metrology, it becomes important to briefly describe these systems as a backcloth to the more detailed research on the use of measuring machines. Industrial Metrology today has eight basic methods - these are listed below:

1. Inspection with plain or limit gauges.
2. Measurements with sliding caliper or micrometer.
3. Measurements by means of block gauges.
4. Measurements by comparison with a reference piece.
5. Pure optical measurements.
6. Measurements on measuring machines.
7. Interferometric measurements.
8. Laser.

1. Inspection with plain or limit gauges:

This method is often the most adequate for mass production so long as the prescribed tolerances are not too close, it can be used by non qualified manpower. In the case of the usual tolerances, there is no hesitation. The "Go" and "Not Go" gauges determine whether the part is accepted or rejected, but up to what degree of accuracy is this procedure valid? One of its weak points is that it is subjective - it depends on the "feel" of the operator and it is known this leads to rather important dispersion errors. Another weakness of the procedure lies in the relatively rapid wear of the gauges which necessitates a constant check and therefore in the machine shop every working gauge should undergo inspection each fortnight.

2. Measurements with sliding caliper and micrometer:

There is not much to be said about the sliding caliper which is part of the set of the machinist, its measuring accuracy varies from 0.005 in. (0.1 mm) to 0.001 in. (0.02 mm) according to its quality. A good screw micrometer will allow dimensions up to 2 inches (50 mm) to be gauged to 0.00005 or 0.0001 inch (1 or 2 μ m)*. Above this size, the uncertainty rapidly increases for the following reasons:

/.... (* μ = abbreviation representing a millionth of a meter).

/....(*μ

A. Overheating of the gauge held in the hand or simply through the corporal heat radiated by the operator.

B. Heavy components are difficult to be correctly placed between the anvils and have a tendency to jam.

C. Lack of rigidity of the large micrometers.

D. Uncertainty of the initial setting increasing with the size of the micrometer.

3. Measurements by means of sets of gauge blocks:

Gauge blocks are these plane parallel gauges which can be assembled together by mere adherence - it was Johansson, a Swedish manufacturer who, in 1865, first developed these measuring media which brought about a new advance in industrial metrology. (7). Today, gauge blocks are available all over the world and they are manufactured with a very high degree of accuracy (one millionth of an inch or a few hundredths of μ m. for the best makes). Block gauges in good condition can be wrung together to obtain the nominal size of the dimension to be tested. The latter is then compared as an assembly by means of dial indicators or mechanical, optical, electronic or pneumatic comparators, on some of which, a precision of 4 millionths of an inch (or 0.1 μm) can be attained. The method is excellent, rapid and precise, providing the dimensions to be tested do not require the use of too many blocks. That is why it is universally used. Unfortunately the blocks are subject to wear and tear, the edges are rapidly impaired by slight knocks resulting in burrs which make assembly difficult and less accurate.

4. Comparison with a reference piece:

In this case the gauge blocks mentioned above are replaced by a reference piece. This method can be recommended for the inspection of parts which are periodically produced in large batches. It proves to be economical, for instance, when manufacturing gauges, where one or two sets of reference gauges allow the whole production to be compared by means of relatively inexpensive micro-indicators and supports.

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Inaccuracies to be accounted for are the following:

A. Uncertainty regarding the exact dimension of the reference piece itself, as the latter is generally neither machined nor measured with the same degree of precision as a block gauge.

B. The reference piece is most often made of hardened steel, the stability of which is doubtful.

C. Risk of wear which, nevertheless, is less than in the case of gauge blocks or other gauges. The major trouble lies in the obligation of keeping in stock a number of reference pieces equal to the different parts machined.

5. Pure optical measurements:

This is measuring and gauging work as performed on profile projectors. Inspecting contour of parts of complicated form can only be carried out satisfactorily on a profile projector, the classical method consists in projecting the magnified image of the object onto a screen and comparing the image with a master chart traced on transparent paper, the contour must be outlined at the exact magnifying ratio of the projection. Discrepancies between the image and the reference drawing are ascertained by taking readings on a glass scale or tracing the prescribed tolerances directly on the graph. Silhouette or surface projection can be obtained as required on most projectors but what is the accuracy to be expected with this method? The measuring accuracy achieved on the screen by means of glass scales is in the range of 0.005 inch (0.1 mm). The magnifying powers generally available are 10X, 20X, 50X and 100X, which should correspond to measuring accuracies of 5, $2\frac{1}{2}$, 1 and $\frac{1}{2}$ tenths (10, 5, 2 and 1 μm.) respectively. In practice however the 50X and 100X magnifications do not provide a sufficient sharpness of the image to allow readings to 0.005 inch (0.1 mm) and actual measuring accuracies of respectively 5, $2\frac{1}{2}$, $1\frac{1}{2}$ and 1 tenths (10, 5, 3 and 2 μm.) must be accepted. This lack of image sharpness is not to be ascribed to the projector itself, but to the fact that, in most cases, the contour of the object is not sharp. Only sharp edges can provide well defined images. The main inconvenience of projectors is the following:

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The greater the prescribed accuracy, the higher the magnifying power to be used, but the size of the screen being unchangeable, the dimensions to be gauged are restricted to its limits.

6. Measuring Machines:

In a modern factory the measuring machine constitutes the permanent metrological basis of the inspection department. It is of course not used for checking the whole production and does not replace the usual gauges and comparators, but it is consulted in any dubious cases. Furthermore it serves for:

A. Periodical inspection of the whole set of gauges and reference pieces of the plant.

B. Measurements for which the use of gauges does not ensure enough accuracy.

C. Measuring prototype components or small batches of workpieces for which the making or purchasing of gauges would not be justified.

There are two main types of measuring machines:

1. Linear or axial machines.
2. Two or three co-ordinates machines.

The fundamental measuring element of a measuring machine can be, for each co-ordinate, a micrometer screw or, in the more advanced machines which will be discussed later, the Moire fringe optical scale technique, a set of gauge blocks or end gauges, or even a standard scale. It seems however that the standard scale offers the greatest advantages: the standard scale is read by means of a microscope. It is fully protected against shocks, dust and wear. It does not need to be made of hard metal. Material of greatest stability can be chosen. An accuracy of $\pm$ 0.00002 in. (0.5 μ m.) can be obtained with a good dividing machine on a length of 40 in (1 metre). This corresponds to a measuring error of 0.00004 in (1 μ m.) in the most unfavourable case. In a well designed machine certain fundamental principles must be adhered to: in axial machines, the measuring anvils must be in true alignment with the measuring element, screw

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or scale. On a two or three co-ordinates machine this principle cannot be observed but the parallax between the object and the measuring element has to be reduced to a minimum. The bed has to be rigid enough to avoid flexure, whatever the position of the measuring carriage, and must be supported on three points so as to be free from any uneveness or deformation of the floor or the table on which it rests.

The measuring pressure has to be judiciously chosen, sufficient so that small parts automatically take up a correct position between the anvils, yet small enough to reduce to a minimum the possibility of deforming the part to be measured. Lastly, it is most important to eliminate as far as possible any detrimental source of heat or, if this cannot be done, to provide for an appropriate ventilation. As measuring machines are the central technology studied in this research then the above brief introduction will suffice at this time and a more detailed discussion will follow in this chapter.

7. Interferometric Measurements

There is some hesitation to classify interferometry as an industrial measuring method for the simple reason that, up to now, apart from its use in testing gauges, it has rarely been applied to ordinary measurements. The interferometer is used for laboratory experiments rather than as an industrial means of measuring, but, as nowadays, the wall between laboratory and workshop is becoming more and more fragile, inferometers are finding applications on the machine shop floor. The major disadvantages lie in the slowness of the procedure with the common types of interferometer mainly owing to the drastic precautions that have to be taken in order to ensure the constancy of the wave length from the light source, because wave length varies by way of ambient air temperature, carbon dioxide content, humidity and barometric pressure.

8. Laser - Principle of the Laser Interferometer:

In order to measure length or displacement in terms of the wave-

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length of a particular monochromatic source, it is necessary to use an optical system whereby interference fringes can be formed and counted electronically. For such measurements the earlier laser instruments used a system based upon the Michelson interferometer. The principle of this is shown schematically in (Figure 2. 2). The beam from the monochromatic source is split at 'A' by a semi-reflector and part of this travels along path AEFD while the other part travels along path ABCD. The two beams re-combine at D and are received by the photo diode. If now the reflector moves by a distance equivalent to half the wavelength of light (λ 2) then the path ABCD will change by λ and hence the variation in the intensity at D due to the interference of the two beams will pass through a complete cycle. This means that a cyclic change in the intensity at D is caused by the movement of the reflector, and this is detected by the photo diode and converted into the equivalent distance travelled by the reflector. The use of reflectors in the form of corner cubes rather than plane mirrors makes the set-up easier and less sensitive to small tilts of the reflector. A problem encountered with this system when used for testing machine tools or measuring machines may be spurious counting of the fringes due to intensity changes which are caused by small misalignments and turbulence.

Most of such problems have now been overcome by the system adopted by Hewlett Packard. The principle of this is shown in (Figure 2. 3) The laser source emits two coherent red light beams of frequencies F_1 and F_2 which differ in frequency by 2 MH_z and are of opposite polarisation. After collimating and expanding the beam, a portion is split into a fixed reflector and directed onto a photodetector. Since the two frequencies are polarised they can easily be filtered and such a filter passes only F_2 along this path. The transmitted beam is reflected from the movable corner cube reflector and filtered to contain only the polarised F_1 beam. Any movement of the reflector along the axis of the beam F_1 Doppler shifts the signal frequency about F_1. This Doppler shifted signal combines with F_2 at the photodetector to generate fringes at the beat frequency between these two

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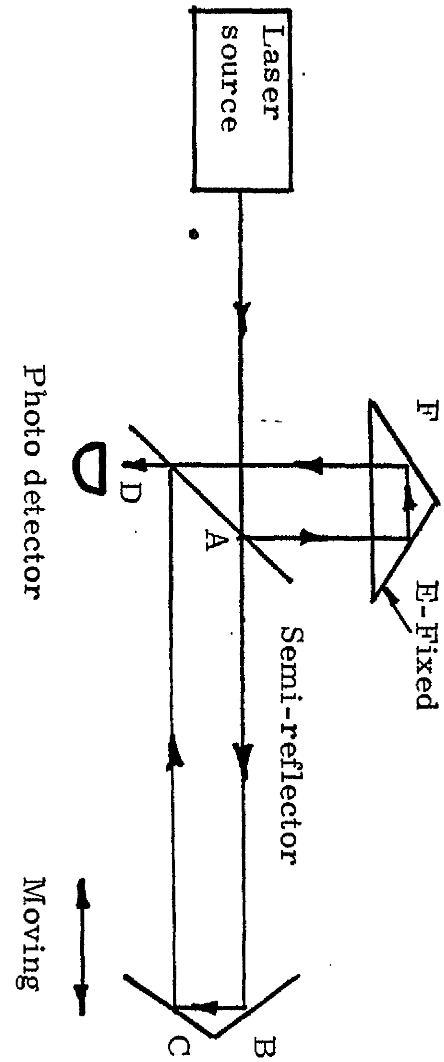
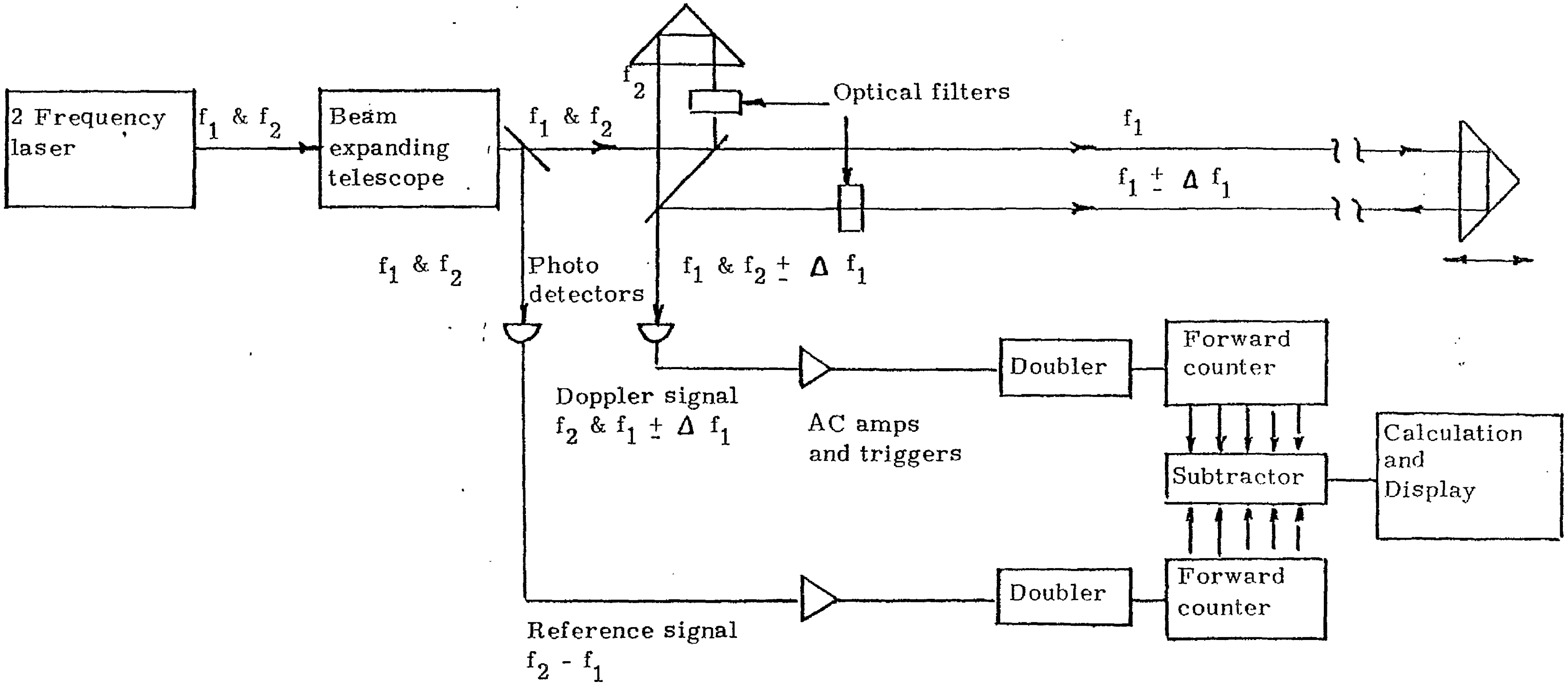
FIGURE No: 2.2



PRINCIPLE OF MICHELSON INTERFEROMETER

FIGURE NO: 2.3



PRINCIPLE OF HEWLETT PACKARD LASER INTERFEROMETER signals. The reference frequency is obtained at the second photodetector by the beat frequency between F_1 and F_2. The reference and Doppler shifted signals are then amplified, doubled and transmitted to two counters where the difference in fringe counts is determined. A calculator converts this measure into units of length. Hewlett Packard laser interferometers are used extensively for the calibration of most co-ordinate measuring machines.

2.4 TYPES OF MEASURING MACHINES IN USE

Although this study is concerned with co-ordinated measuring machines in particular it would be useful to examine, if only briefly, the complete spectrum of four types of measuring machines before developing the various options specifically within the co-ordinated measuring machine field.

1. Single-Axis Measuring Machine (Plate No. 2.1)

Three general types of single-axis measuring machines are considered, representing distinctive systems and different ranges of measuring capabilities. These types differ primarily in two basic respects; namely, the staging of the specimen and the system of length measurement. The first group comprises instruments which utilise a master scale attached to the axially movable vertical measuring spindle, the vertical arrangement permits locating the specimen on a staging table which also serves as the datum plane for the length measurement. Typical of the group is the Leitz optical length measuring machine. Incidentally, instruments of this group resemble closely the measuring machine designed in 1890 by Ernst Abbe, the originator of a measuring principle, still frequently quoted and of unchallenged correctness, which calls for the aligned arrangement of the specimen and of the master scale. The second group comprises the horizontally arranged mechanical length measuring machines. These machines having a threaded measuring spindle for master element, resemble in the basic principles of their operation a stationary micrometer, although in a highly refined variety with substantially upgraded discriminating properties. Important features include the integral staging table and the variable referencing position of the tailstock which incorporates the measuring anvil. The third group combines the characteristics of purely optical distance measurement with the advantages of a horizontal staging and independent datum member. This system of measuring machines originates from Carl Zeiss and strictly adheres in its design to the above mentioned length measuring principles. The Zeiss plants in both parts of Germany are currently manufacturing improved versions of this type of measuring machine.

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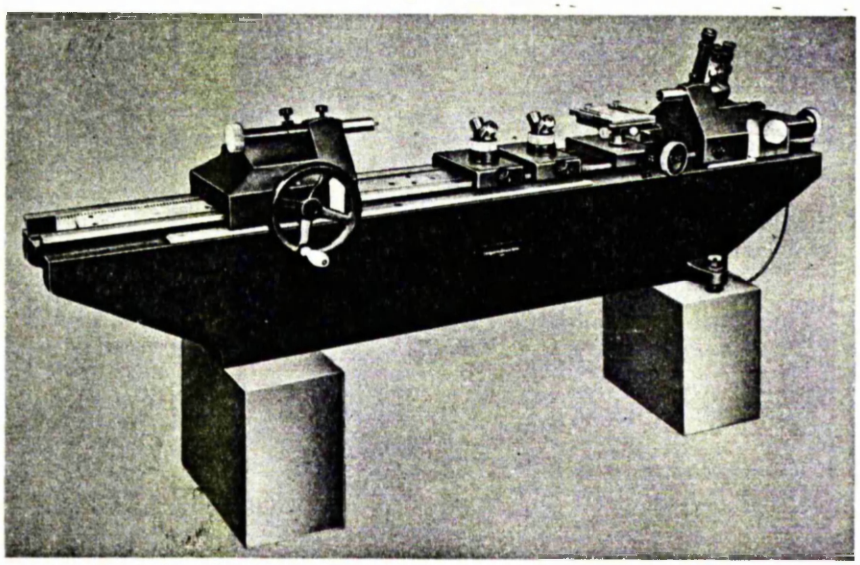
THE SINGLE-AXIS MEASURING MACHINE

Measures outside and inside length on precision scales, gear racks, lead screws, threaded spindles.



DATA

Coarse scale reads to	100 mm
Fine scale reads to	0.1 mm
Precision dial gauge scale reads to	1 micron
Apparent width of fine scale's divisions	7.5 mm
Apparent width of dial gauge divisions	1 mm
Measuring Ranges	
1-Metre Length Measuring Machine	0–1000 mm
3-Metre Length Measuring Machine	0–3000 mm
Precision dial gauge	± 100 microns
Approx. measuring pressure	200 g

From the user's point of view, one of the essential aspects in selecting measuring equipment is the scope of its applicability, that is, the array of basic measuring processes which can be carried out with any specific category of instrument.

2. Co-ordinate Measuring Machines (Plate 2. 2)

The development, in recent years of displacement measuring devices which provide digital readout for the distance travelled by a movable machine member, brought into being a new concept of measuring machines. In these instruments, the travelling member of gauge head with the mounted sensing probe, is guided along two straight line paths which are contained in a common plane and are mutually perpendicular, representing the x and y axes of a rectangular system of co-ordinates. Optionally, a third (z) axis, in a direction normal to the plane of the x and y axes, can also be provided in several models of these machines. The guideways of the travelling head are, depending on the particular model, either of a cantilever or of a bridge-type design and permit a nearly frictionless displacement of the head by applying a very small force. For the function of referencing, that is, locating on the part of the boundary points of the distances being measured, contact probes of a tapered plug form are the most commonly used elements. These probes are supplied in an extensive range of sizes and taper angles, to accommodate holes of different diameters. Jig plates with bores located in a network of rectangular co-ordinates represent typical examples of parts whose meaningful dimensions can very effectively be measured by using tapered probes for locating the individual positions. It is interesting to note that the tapered probe, by seating itself in the best fitting centre with respect to the maximum material condition of the bore, automatically locates the individual reference points in agreement with the concept of true position dimensioning. The essential design characteristic of these instruments is the application of a non-contacting type displacement measuring device which senses in discrete increments of an inch the separation between the individual points of referencing. The length of the sensed displacement is displayed in

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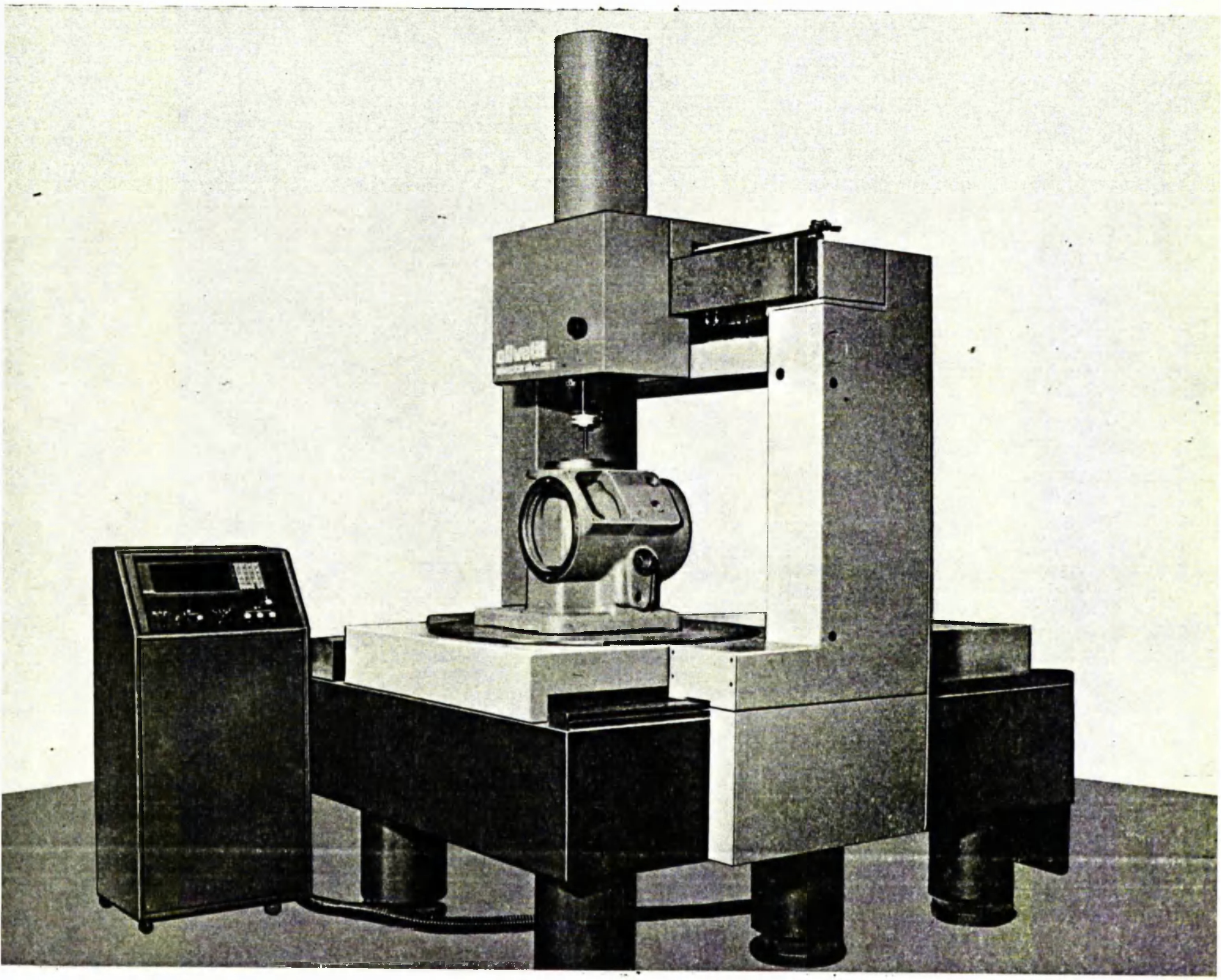
CO-ORDINATE MEASURING MACHINE

THE OLIVETTI INSPECTOR VERTICAL MAXI.

Positioning Accuracy $\pm$ 8 microns.

Repeatability Accuracy $\pm$ 2 microns.

2 models with measuring travels of 1140 x 900 x 405 mm and 1640 x 900 x 405 mm.



digital form representing integer and decimal fractional inches.

3. Jig Borer type Measuring Machines (Plate 2.3)

This type of machine which was described earlier in the text under the history of measuring machines was one of the original models designed by Moore (5) and which latterly gave birth to the co-ordinate measuring concept. The accuracy of jig borer type machining operations has greatly advanced in the past decade mainly as the result of improvements in integral measuring devices, supported by developments in the materials and in the manufacturing processes of the mechanical machine elements. Jig borers are designed to position the object in the plane of a system of rectangular co-ordinates, and possess complementary controls in directions normal to that plane, as well as for rotation around different axes, with all these movements being carried out in relation to common datum elements. The positioning flexibility of jig borers, combined with the use of very accurate measuring devices for setting the object and for controlling the tool advance, brought about a situation where the conventional measuring instruments which were available to inspectors proved to be inadequate dimensionally for checking complex parts machined on a modern jig borer. These conditions led to the practice of inspecting the part while still on the jig borer. However such procedures often caused costly tie-ups of the jig borers required for machining operations and were still poor expedients considering the temporarily mounted sensing devices which replaced the cutting tools. Another shortcoming of this practice, not only in principle but also affecting the results, is attributable to the use of the same measuring device in the inspection operation which controlled the original production process. Furthermore, no recourse could be made to such methods in the receiving inspection of parts which were machined by an outside supplier, or on complex and critical components which were manufactured by means of special fixturing without the use of jig borers.

In view of the described conditions, it would have seemed an obvious

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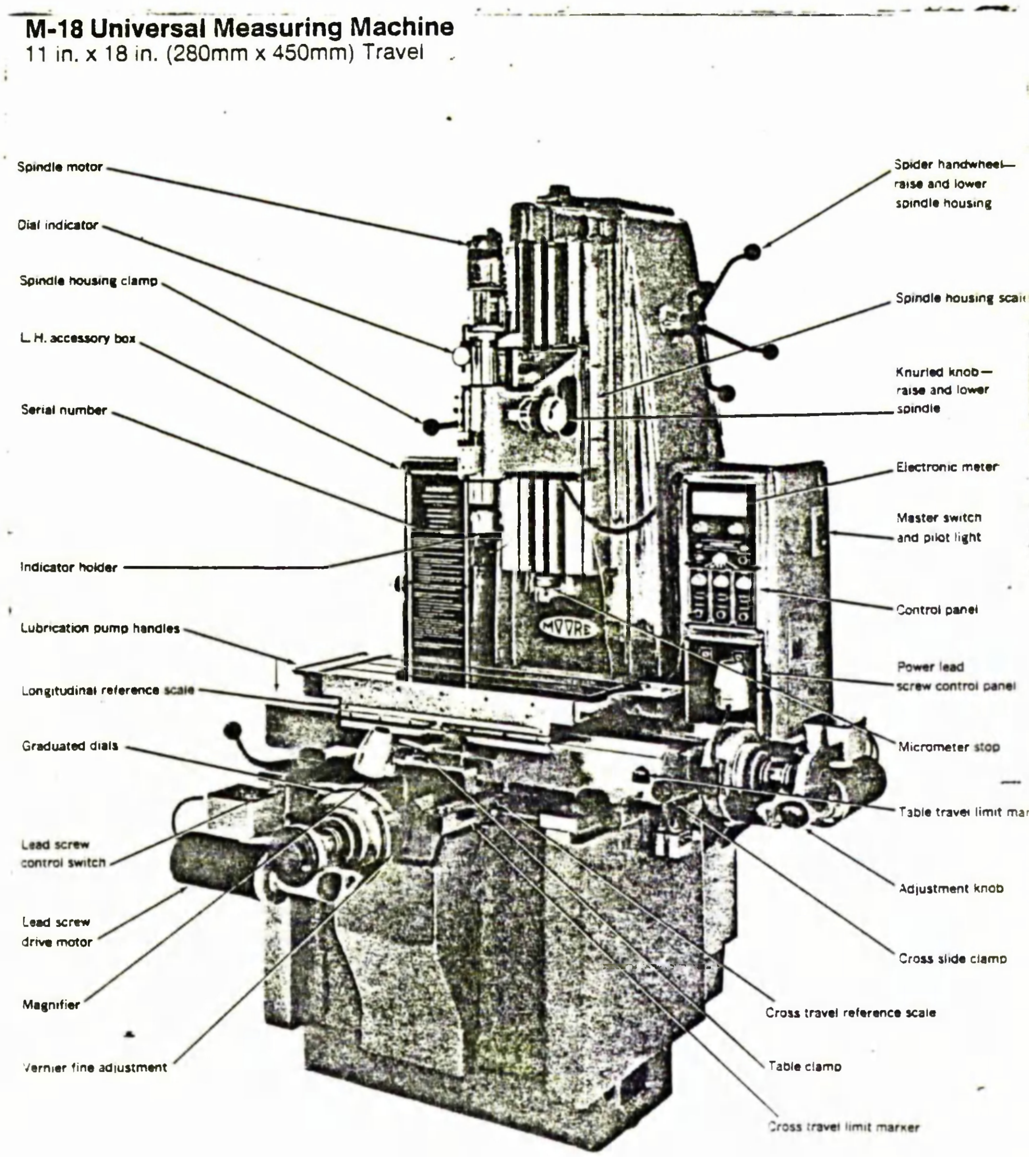
PLATE No: 2. 3



Location of essential controls used in operating the Universal Measuring Machine solution to the problem to create measuring machines which, by incorporating the jig borer's characteristic flexibility of adaption, would possess the essential properties of a measuring instrument as well. In this latter respect, important additions would include excellent tracking and orientational accuracy of the traverse and rotational movements, very sensitive and accurate displacement measuring devices as well as sensitive locating instruments, preferably with indicating capabilities. In retrospect, it may appear surprising that, although the practice of using jig borers as a means for checking the accuracy of complex parts dates back to the pre-war period (late thirties), it was only in recent years that jig borer measuring machines were created, primarily as an American contribution. The practice of using jig borers for making measurements has probably not been generally discontinued. However, the advantages of single-purpose measuring machines for operations involving no chip removal, but requiring the highest attainable level of accuracy, are becoming more widely recognised.

In contrast to jig borers, measuring machines are not required to resist the forces applied to, and the dynamic effects resulting from, heavy chip removal. However, the concept of inspection implies measuring and positioning accuracies which represent a higher grade than those available for the production phases.

4. Optical Measuring Machines (Plate 2.4)

The basic design of these machines goes back to the original Societe Genevoise MU214B which this research identifies as being the world's first measuring machine of this type introduced in the early 1930s. The optical measuring machines are distinguishable from other types of multiple-axes instruments discussed by the exclusive use of line graduated master scales and optical scale reading devices, as means for measuring linear distances and angular spacings. The distinguishing characterstic in relation to engineering microscopes is the method of targeting, mechanical contact being primarily used for this function in the measuring machines. Mechanical contact is the preferable

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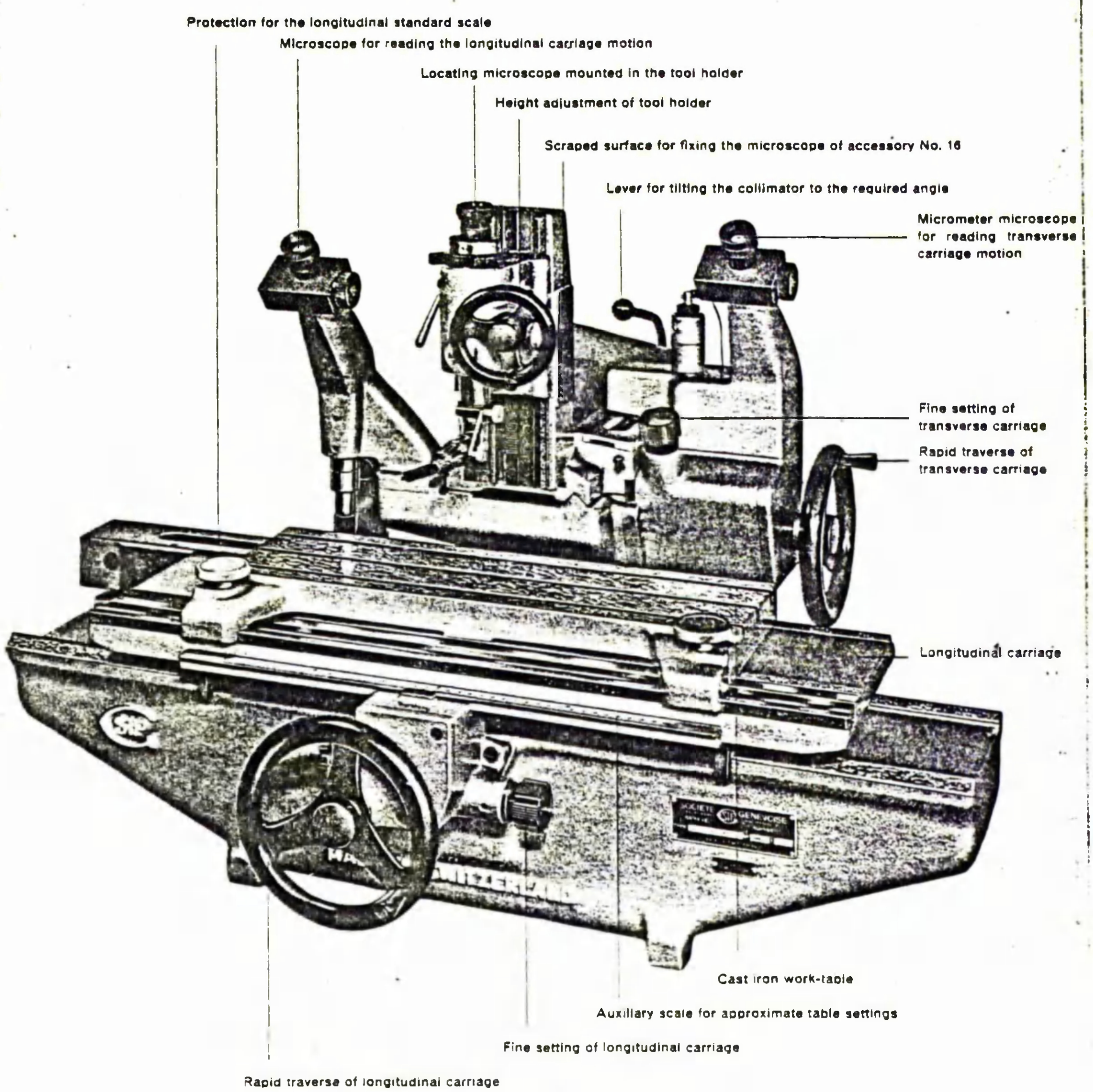
PLATE No:2.4

Universal Measuring Machine MU-214 B



method of targeting when clearly defined boundary surfaces of regular form are present on the part, and the only practicable means when the boundary points of the dimensions being measured are not accessible to optical observation. With the greater depth control and reach of mechanical contact members, optical measuring machines are capable of making measurement over an extended vertical range. This condition makes them adaptable to measurements on much bulkier parts than are manageable on a microscope. For that reason, the optical measuring machines are usually built with large staging surfaces which are dimensioned to carry relatively heavy objects without affecting the positioning and tracking accuracy of the translational movement. Most of the optical measuring machines are designed for measurements along three axes, including the vertical.

The described characteristics of the optical measuring machines, as compared to those of engineering microscopes, involve higher cost which must be justified by the need for these additional capabilities. It should also be realised that there is a great variety of part configurations, geometric features, dimensional categories and bounding elements for which optical targeting by the highly adaptable means of modern measuring microscopes offer the best means of inspection. Optical targeting by visual observation of the part surface may be used optionally on measuring machines also, and is recommended when the overall size or weight of the part requires powerful staging members, yet the feature to be measured calls for microscope viewing.

2.5 THE Co-ORDINATE MEASURING MACHINE (CMM)

There are several definitions given to the co-ordinate measuring machine, 4 of which are given as follows:-

1. Measuring machines are stationary instruments which employ their own standards for obtaining dimensional measurements, and are designed for work of a high degree of accuracy. Reliance on standards which are integral elements of the machine implies the assurance of precisely controlled displacement paths for the moveable sensing members. In these instruments, the travelling member or gauge head with the mounted sensing probe is guided along two straight line paths which are contained in a common plane and are mutually perpendicular, representing the x and y axes of a rectangular system of co-ordinates. Optionally, a third z axis, in a direction normal to a plane of the x and y axes can also be provided in several models of these machines (7).

2. Co-ordinate Measuring Machines were designed as a universal technique of inspection to measure relative dimensional positions and display them in a convenient form. The technique involves the establishment of a datum and the measurement of the positions of features relative to that datum in the form x, y and z dimensions. The features are positionally detected by probes of different types, for example, cylindrical tapered rigid probes or electronic (pivoted) probes. (10).

3. The Portal Type CMM can be loosely defined as "A surface plate with mechanised measurement". Its co-ordinate axes are square in their own relationship, square and parallel with the surface plate, and its measurement is independent of any fixed reference point within the measuring envelope or to any master. (11).

4. The concept of a CMM is to have either two or three measuring systems placed square to each other and operating simultaneously giving length, width and depth. A CMM is more efficient because it

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is both faster and more reliable. Speed is accomplished both by reducing set-up time, from three to one, and through the use of tapered probes which self-align on the centre of a hole, allowing two dimensional location of holes with only one positioning of the measuring system, a reduction of four to one. An electronic digital readout for each axis gives greater reliability with tenth of thousandths (.0001) resolutions by the numbers rather than interpretive readings from multiple reading devices such as micrometers, verniers and dials. CMMs are rated generally to be 8 to 10 times faster than conventional layout type inspection methods. (12).

This study identifies fifteen different types of co-ordinate measuring machines although some are only slight design changes from a bank of seven namely, GANTRY, CANTILEVER, BRIDGE, UNIVERSAL, PORTAL, BENCH and HORIZONTAL SPINDLE. The fifteen types as illustrated in Figures 4 to 7 are described briefly as follows:

Type 1 - BRIDGE TYPE (Figure 2.4) Probably one of the most popular designs due to its speed and flexibility. The table which can either be granite or cast iron is mounted on a floor supporter stand with the bridge structure carrying the probe head moving on air bearings at either side of the table travelling the length of the table. Major advantage of this design is the ability to locate the work piece without interference from the probe head or overhead structures. Most common suppliers are L.K. Tools in Britain, Brown and Sharpe in America.

Type 2 - GANTRY (Figure 2.4) This model belongs to the giant type CMM with dimensions reaching 10 meters wide by 20 meters in length manufactured mainly by Digital Electronic Automation (DEA) in Italy and used generally by builders of very large components such as turbines for atomic reactors and large boilers. The model has a series of floor mounted pillars connected by overhead rails on which the moving gantry carrying the probe head is supported. The number of pillars is governed by the length required to be measured, there is

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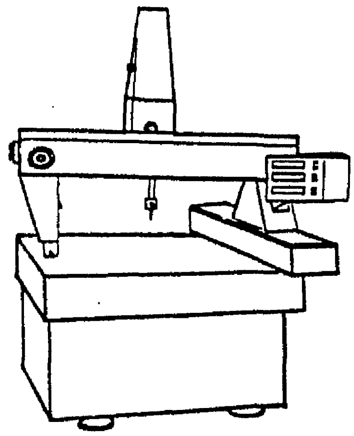
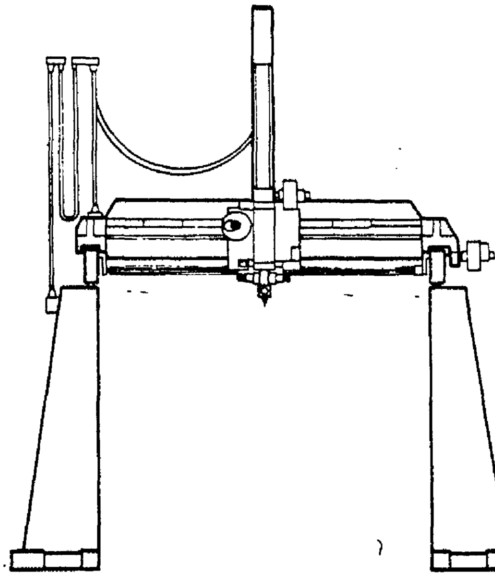
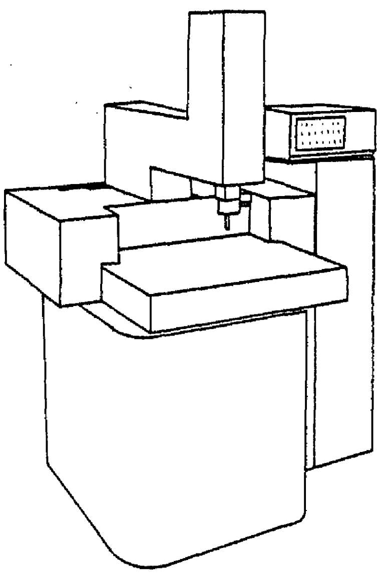
Type 1.



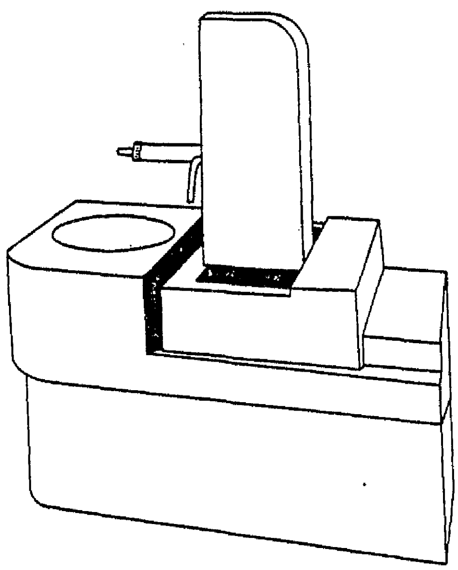
Type 2.



Type 3.



Type 4.



no detrimental effect on the given accuracy of the machine by its size.

Type 3 - CANTILEVER (Figure 2. 4)Normally this design is limited to small work pieces mainly due to the extent of the probe range. It is however highly accurate and can incorporate additional features such as rotary tables (giving a fourth axis) and angular orientation devices to accommodate special work pieces. Olivetti of Italy are the major manufacturers.

Type 4 - HORIZONTAL SPINDLE: (Figure 2. 4). Again somewhat similar to the Cantilever except that the probe head projects directly from the rear support column and provides the facility for measuring in the horizontal plane. (Many Cantilever and other models now have special probes which can either be used in any vector or adapted to the horizontal plane by an adaptor head). The horizontal spindle with the rotary table makes for quick and accurate measurements of small to medium sized components. The major supplier of this type is Olivetti of Italy.

Type 5 - CANTILEVER WITH ELEVATED TABLE: (Figure 2. 5).This model is different from Type 3 in that the x, y and z axes movement is controlled from the head and not the table. The machine has a cast iron slotted table mounted on a robust floor supported base. The table can be elevated thus extending the z axis capabilities. The size of the machine can be extended simply by lengthening the table and rear support column. This is one of the most popular CMMs and is offered by Ferranti Ltd., of Scotland.

Type 6 - PILLAR: (Figure 2. 5). A combination of Types 1 and 2 but with fixed dimension and less flexibility. This machine as illustrated can incorporate the rotary table and measure fairly large work pieces between its four pillars. The measuring head again is supported on a bridge type gantry. DEA of Italy are the major suppliers of this model.

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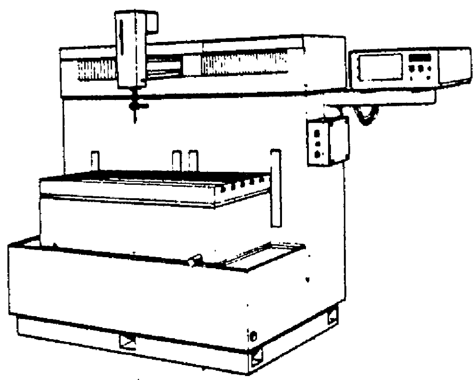
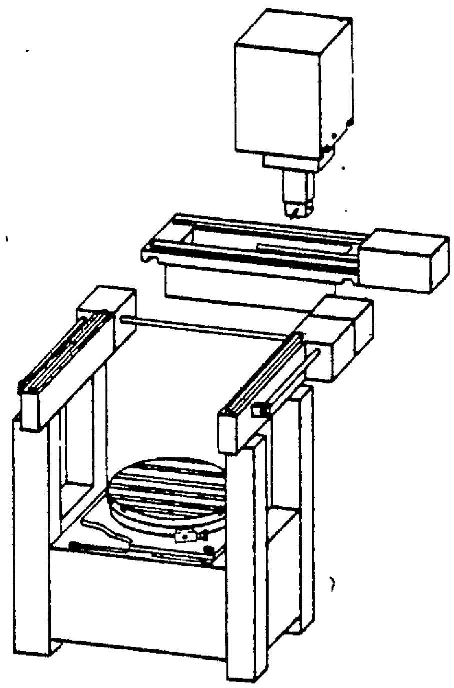
Figure No: 2.5

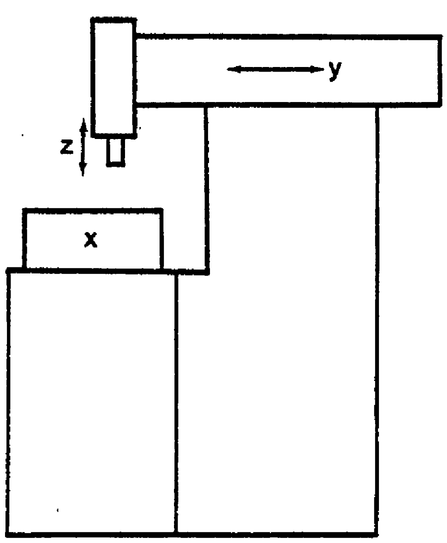
Type 5.



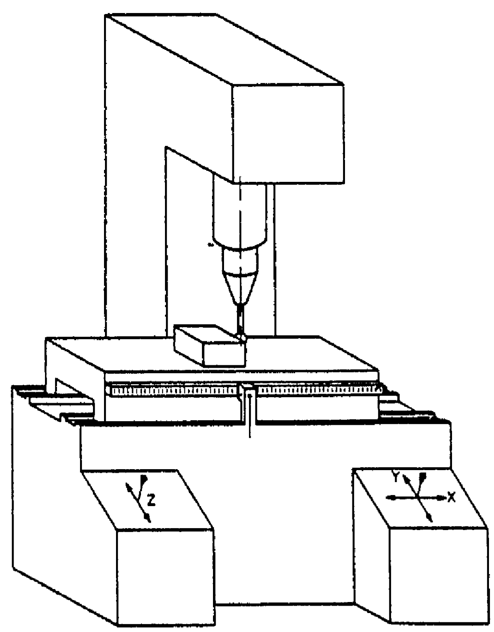
Type 6.



Type 7.



Type 8.



Type 7 - CANTILEVER - BENCH (Figure 2.5)

The major difference between this and the type 3 Cantilever is in the movement of the y-axis which is gained from the probe head and not the table. The nature of this machine calls for a seated operator working with small components. C.E. Johannson of Sweden are the main suppliers.

Type 8 - UNIVERSAL. (Figure 2.5)

One of the most accurate measuring machines on the market, designed after the original Moore Universal No: 3 but incorporating special electronic features and generally supported by the most advanced peripheral equipment available. It is also one of the most expensive machines for its range on the market, and users would have to clearly justify specific usage in order to show effective return on investment. Main suppliers are Carl Zeiss of Germany and Moore of America

Type 9 - BENCH-MARKER OFF. (Figure 2.6)

Very cheap manually operated CMM generally controlled with the hand gripping the probe head, which is not electronic but generally mechanical steel probe conical, ball, or cylindrical in shape. This machine is often duplicated for marking off plates, by fitting a scribe probe. Each axis can be located by a simple locking nut. Numerex and Quality Inc. of America manufacture these machines.

Type 10 - CANTILEVER (Figure 2.6)

Similar in design to Type 5 with the exception of the y-axis supporting a mobile probe head along its whole length also the table controls the movement of the x-axis somewhat similar to Type 7. This is at the cheaper end of the range and normally has pure manual operation. Ferranti of Scotland supply a model of this basic design.

Type 11 - UNIVERSAL - PORTAL. (Figure 2.6)

A development of the type 8 - Universal machine which incorporates a mobile table in the y-axis through a portal type support structure. This facility greatly extends the scope of the Universal machine by

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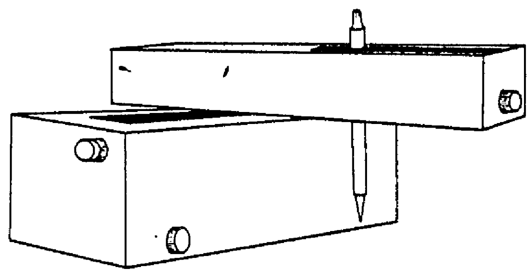
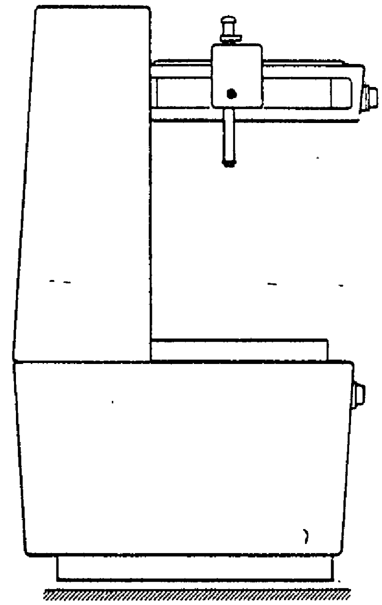
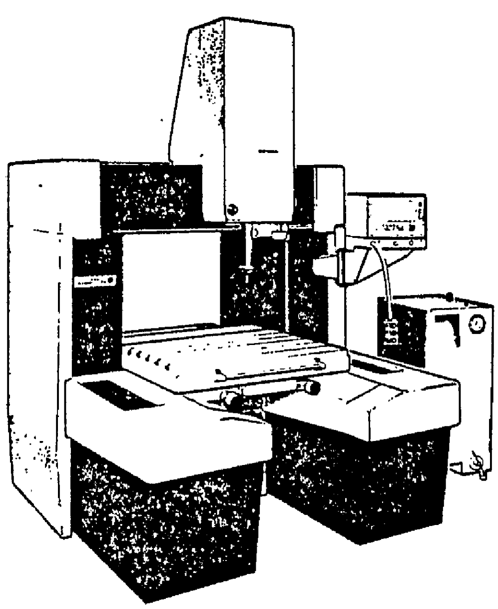
Type 9.



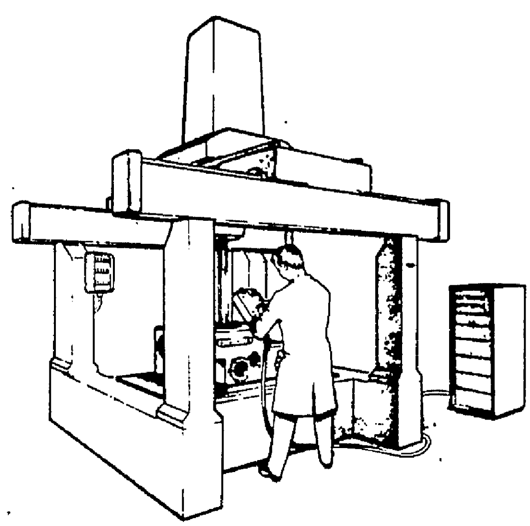
Type 10.



Type 11.



Type 12.



permitting much larger components yet continuing to obtain the high degree of accuracy demanded of type 8. Carl Zeiss of Germany have only recently marketed this machine.

Type 12 - PORTAL. (Figure 2. 6)

This machine comes in a whole variety of sizes simply by pushing out the support pillars and extending the bridge or by lowering the working table to suit specific components. This design is offered almost exclusively by DEA of Italy.

Type 13 - TRIOPTIC. (Figure 2. 7)

Described early in the study as the oldest designed CMM in the world but still being marketed by Societe Genevoise in Switzerland. A highly accurate although special purpose machine utilising optical reading devices as opposed to the more common digital systems.

Type 14 - CANTILEVER - MOBILE BASE. (Figure 2. 7)

This is a special purpose machine with limited use in a universal sense and has questionable accuracy due to the nature of the mobile table. However it can be used for quick probes with conical shapes to check hole patterns or scribe out holes on plates.

Type 15 - JIG BORER (Figure 2. 7)

Obviously adapted from the machine tool and converted specifically for the purpose of measuring exclusively. Both x and y axes are controlled from a mobile table while the z axis comes from the main head. This machine is offered by Moore of America, Zeiss of Germany, and SIP of Switzerland.

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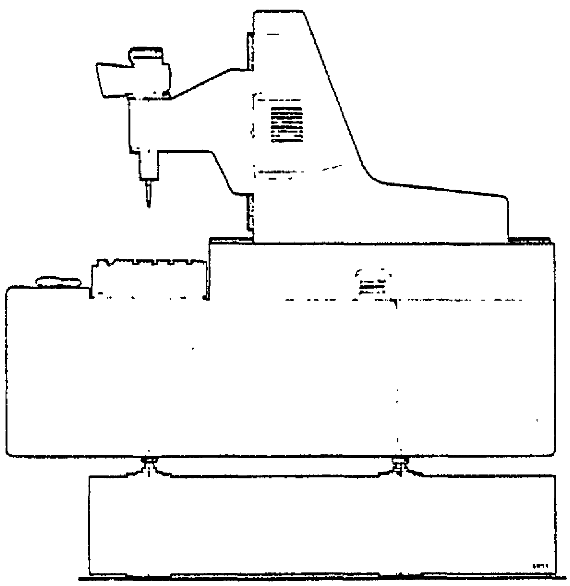
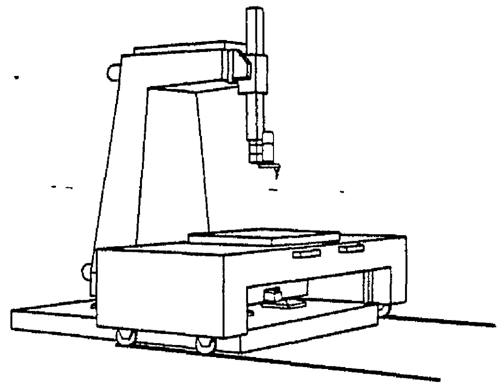
Figure No: 2.7

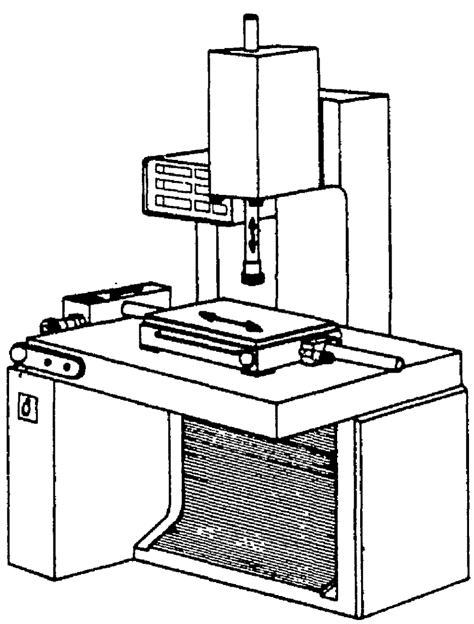
Type 13.



Type 14.



Type 15.



2.6 - THE MEASURING MACHINE TECHNOLOGY CURRENTLY AVAILABLE TO INDUSTRY.

In forthcoming chapters of this research, detailed analysis will be made of the impact of measuring machines on management structure, strategies, machine shop environment, control systems and people. References will be made to a wide variety of measuring machine technology now available to industry and, although this technology as such is not the central theme to be investigated, more so the effect of the technology, it will be necessary to embellish on the detail of the measuring machine technology as previously given in sections 2.4 and 2.5 , if, for no other reason, but to ensure some understanding of what this technology can do within the industrial environment.

Co-ordinate measuring machines as described in 2.5 , not only come in a variety of different types, but also are available in 3 general levels of design namely, manual operation, computer-assisted and full computer control. These machines are generally designated as follows:-

C. M. M.	Manual operation co-ordinate measuring machine.
C. C. M. M.	Computer-assisted co-ordinate measuring machine.
D. C. C. M. M. (DCC)	Direct computer co-ordinate measuring machine.

For a detailed review of world sources and types of co-ordinate measuring machines now available, see "Co-ordinate Measuring Machines - A Worldwide Review of Manufacturers and Their Systems" by Sam Black, Metrology and Inspection, November 1977. (Appendix D - Ref. 8).

The prospective owner of a co-ordinate measuring machine obviously has to determine his particular requirements in order that he can accurately draw up a specification and choose the most suitable price of equipment which will be within his capital budget.

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Currently production type "off the shelf" measuring machines range in price from approximately £10,000 at the lower end of the market to approximately £500,000 at the top end. The investment is therefore one that requires considerable forethought and analysis prior to any decision being made. To clearly illustrate the nature of this technology, 3 different models are discussed and displayed pictorially. These measuring machines cover the previously mentioned levels of design from manual to full computer control.

1. <u>Manually Operated Co-ordinate Measuring Machine.</u>
   The Hansford Rapid Check co-ordinate measuring machine (Plate 6) manufactured by the Hansford Manufacturing Corporation of Rochester, New York, U.S.A., is a good example of a basic manually operated co-ordinate measuring machine. It is of the bridge-type variety as previously illustrated in Figure No: 2.4. The base of this machine is a non magnetic granite surface plate. Granite has been used for many years as a suitable material for surface plate work mainly due to its inherent qualities of stability and a very low co-efficient of thermal expansion. It is also hardwearing, rustproof and of reasonable cost. The bridge and superstructure is supported by a heavy adjustable saddle which rides along a fixed runway at the rear of the granite table. The bridge is a modified tubular weldment ensuring both rigidity and light weight. The outboard end of the bridge is supported by a self aligning ball bearing to assist in a very sensitive and low friction operation. This machine uses a standard type of rack and pinion to move the bridge piece along the table. This in turn activates a rotary encoder and the electronic digital display readout system.

   Each axis has a floating zero in that when a reference point or datum position is reached, the button for that axis, shown on the outboard leg of the bridge, is activated and the digital display readout returns to zero. The probe head is then manually moved

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THE HANSFORD RAPID CHECK CO-ORDINATE MEASURING MACHINE

Example of a manually operated CMM with solid probes and a 3-axes digital readout display.

through the inspection pattern comparing co-ordinate dimensions with those on the print.

Most digital readout displays have a polarity indicator feature which can display positive or negative directions of movement from zero, others have the added facility of reading in both imperial/inch or in metric sizes. The probe holder, like the tool holder in a machine tool, is supported within the bridge compartment and is counterbalanced to permit vertical movement for the z axis travel. A wide variety of probes is available depending upon the component to be measured. However, the taper probe is the most popular, as it is ideal for checking hole patterns in random positions within a workpiece. Probes can be changed during the course of a measurement check as each axis is lockable and this does not upset the zero point.

Several advantages are available with this low cost unit, in that it can be retro-fitted to an existing surface table thus minimising initial capital cost and the whole unit can be pushed to one end of the surface table to permit other uses to be made of the surface area.

2. Computer-Assisted Co-ordinate Measuring Machines.

The second generation of design on measuring machines introduced a computer-assist facility. This development came about with the need for further reduced time on the analysis of recorded inspection results and the simultaneous fall in the cost of small computers. Measuring machines of this second generation needed motorised drives in each axis of movement, thus enabling the machine to communicate its position to a computer. A good example of a computer assisted measuring machine is that produced by L. K. Tool Co., Ltd., of Derby in England. Their Metre Four measuring machine is of the type 4 horizontal spindle

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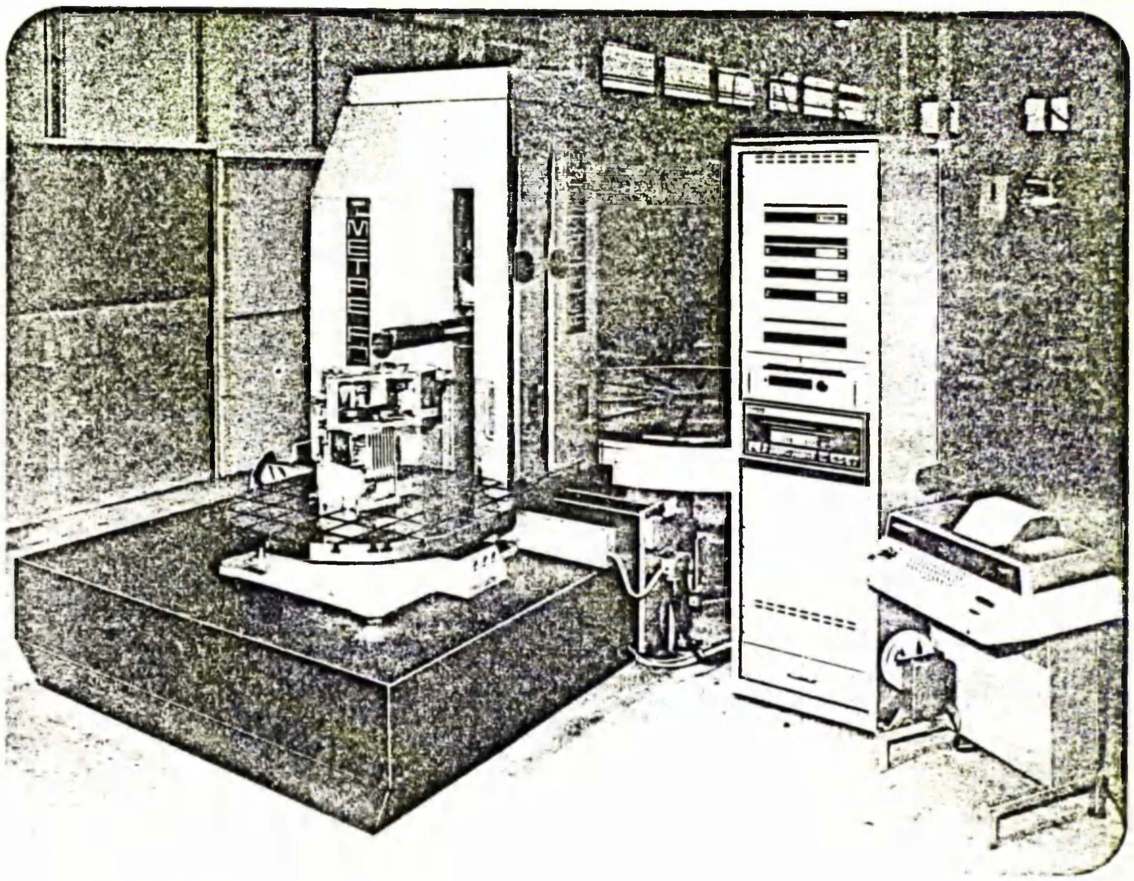
PLATE No: 2.6

L. K. TOOL CO. LTD. METRE FOUR MEASURING MACHINE

Horizontal probe with optional rotary table. CMM is computer assisted to record measurements against master programme and printout results on high speed printer.



Metre four

as illustrated in Figure No: 2.4 and shown in Plate No: 2.6. This machine is one of many where computer-assist facilities have been added, but this particular machine presents a fairly radical approach to inspection techniques in both machine construction and configuration. It is constructed from geometric blocks of granite in conjunction with air bearings. This results in extreme accuracy and precision of travel, thus eliminating the stick-slip tendency that can have a detrimental effect on fast accurate measurement. The horizontal design permits the probe to be presented to the workface in the same manner as a cutting tool within a machine tool, which would be used to generate the workpiece in the first instance. This measuring machine therefore lends itself to easy integration in a group technology machining centre or cell.

The key difference between the manual and computer-assist measuring machine is directly related to the software programming fed into the dedicated mini-computer linked to the machine. The concept is identical to the numerical control tape programmes, which were written in a basic computer programme and committed to tape, such that the machine could be instructed to move in any prescribed direction with the selected tool cutting the workpiece accordingly.

The measuring machine system is similar except that the computer-assist systems are of a comparative nature in that, as the inspector checks a particular dimension on a workpiece set up in the measuring machine, the computer interprets and calculates the actual dimension measured and compares it to the print dimension, which is already contained in its master tape. Both results are then simultaneously printed out on a teletype high speed printer, very often the differences, positive or negative, are also printed out. The inspector can continue through a routine of dimensional inspection of a workpiece without

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need to record any results. When the full check is completed, he then examines the printed sheet to confirm whether this component is correct or not to the dimensions given in the blueprint.

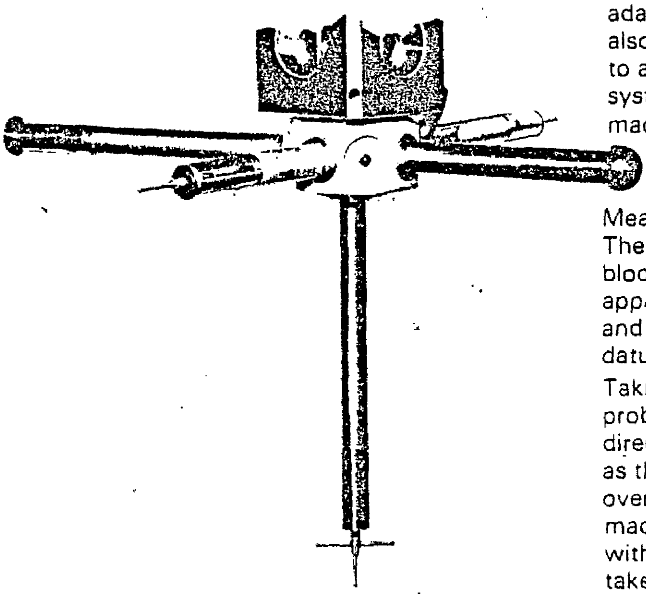
All of these actions can be carried out with the same basic solid type probes as were mentioned in the discussion concerning manually operated inspection machines, but in keeping with the advance of the measuring machine technology, the design of the probes has also been advanced. (Plate No: 2.7). One of the most successful has been the 3-axes electronic probe, which has an ultra sensitive 3-axes switch, which, when used with the teletype printer, automatically records dimensional data in each axis. When contact is made between the probe and a surface, an instant signal to the printer records x, y, z, co-ordinates, which are also displayed on the axis digital readout units.

The actual operating procedures for a computer-assisted inspection machine are fairly simple. The appropriate input tape is first run through the reader to programme the system, then the inspector simply follows the instructions as they are printed out during the subsequent runs. As the stylus is moved to each stated "read" point, he operates a control that conveniently may take the form of a footswitch and the computer indicates when it has assimilated the information relating to the point by clearing the switch ready for further operation, and, simultaneously, illuminating a lamp. At this stage the printer may not necessarily have completed the corresponding block of results, but the operator can proceed to the next point immediately the clearance signal has been obtained, taking advantage of the buffer memory facility in the computer.

3. <u>Direct Computer Controlled Co-ordinate Measuring Machines.</u>

In a similar pattern of development to that of the measuring machine and probes, the computer assistance to the machine /....

3 Dimensional Touch Trigger Probes for Measuring Machines



The latest range of probes provide a complete range of systems that can be used to suit the requirements of any size machine and complexity of components. Probes can be readily retrofitted to existing machines with shanks available to suit most manufacturers.

Probes are supplied in precision mahogany cases either individually or kit form. Electrical interfaces adapted to suit most measuring machines can also be supplied. (These convert the probe signal to a form suitable for the machine control system. They are already incorporated in some machines.)

Measurement with the probe is extremely simple. The probe stylus is first calibrated on a gauge block, ring gauge or sphere to determine its apparent stylus tip diameter. It is then datumed and dimensions are recorded relative to the datum.

Taking readings is simply a matter of driving the probe stylus into the workpiece in the required direction. The reading is then automatically taken as the stylus contacts the workpiece. Generous overtravel built into the probes permits the machine to travel beyond the contact point without damaging the probe. Readings are thus taken **while the machine is in motion**, giving fast checking of even complex components. The workpiece can be contacted in any direction due to the omni-directional feature of the probe. Hole diameters, depths, step heights widths etc, can all be measured with one ball stylus. For difficult undercuts, grooves deep holes etc, special styli and extension bars are available to'ensure these can be speedily checked.

Source from L. K. Tools Ltd., Derby, England. Sales Literature has changed from assisting measurement results to full automation. The changing pattern is shown in Plate No: 2.8, showing options A to D for C.M.M. inspection, moving from the above discussed computer assist option to one of full automation, where a more powerful computer not only receives the information but also instructs machine movement, and the machine can be operated in either a manual or automatic mode. In the automatic mode the measuring machine's positioning servo drives are controlled entirely by the computer systems. The control is provided by instructions and data obtained from a previously prepared part description tape. Included on the tapes are parameters such as inspection sequence, operator instructions, nominal data and the method the inspection data is to be processed. From this information the computer determines the direction, distance and velocity, and commands the probe to move the x, y, z axes to the point requested. Upon reaching this point, the probe will move at a slower rate until the part is contacted. Probe contact will initiate automatic data collection by the computer. The data may then be processed by the desired mathematical routines (e.g. diameter calculation), printed on the output device and/or stored for analysis at a later date. Data storage is a function of the computer's memory capacity and may be increased if necessary by the addition of a mass storage device (e.g. cartridge or floppy disc).

The completely automatic co-ordinate measuring machine represents significant 'state-of-the-art' advances in measuring machine technology. The key advantages are derived from the software programming in the computer, which through its mathematical capability gives immediate total evaluation without the need for operator presence during long or repetitive runs. Such examples indicate a 5-minute period to inspect and report on an aero engine component that took 70 minutes on the surface table plus calculation time and a 26-hour unsupervised

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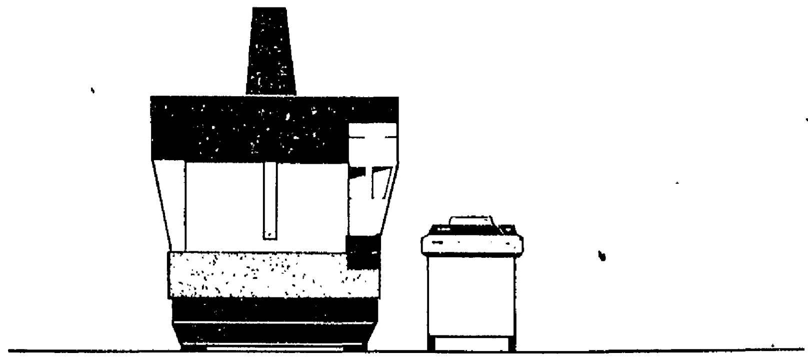
Option A:
Data recording

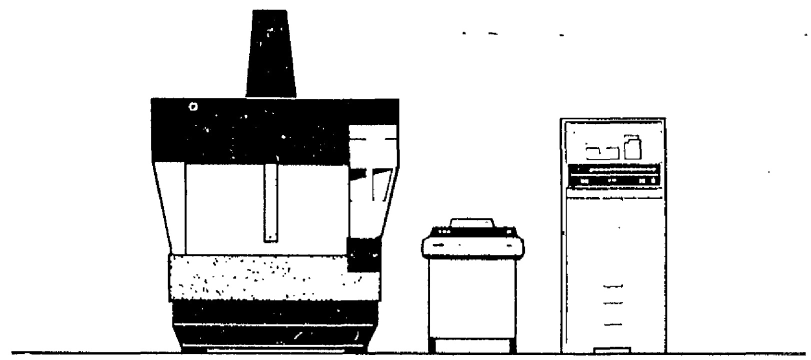
Basic machine
Teletype



Teletype gives paper tape, read-out and punch facilities to record and schedule inspection routines

Option B:
Computer-assisted inspection

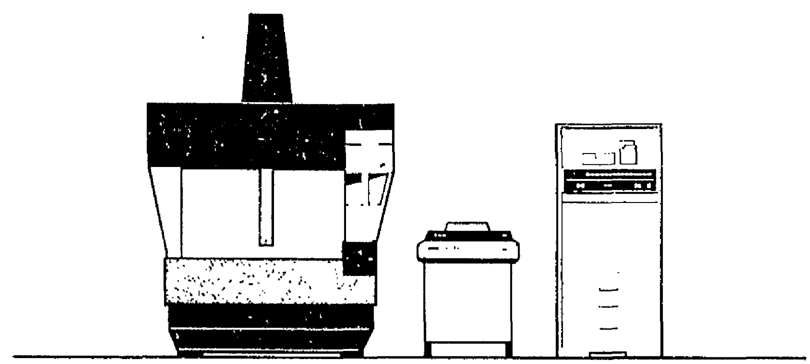
Basic machine
8 K computer
Teletype
High-speed paper tape reader (in cabinet)
Electronic probe



The 8 K computer gives facilities identified in standard 8 K software system

Option C:
CNC inspection

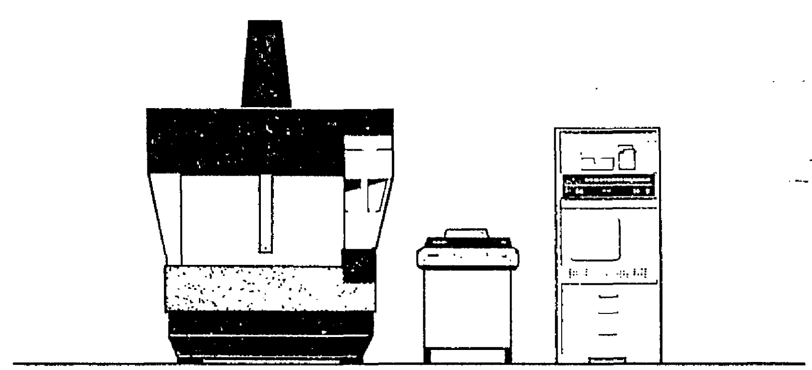
Basic machine 16 K computer Teletype
High-speed paper tape reader (in cabinet)
Electronic probe



The 16 K computer gives facilities as identified in standard 16 K software system, including CNC control

Option D:
CNC inspection with display

Basic machine
16 K computer
Terminal with visual display and twin magnetic cassettes
High-speed printer
Electronic probe



This 16 K (optional 24 K) system gives the ultimate in speed and flexibility

Figure 5. Computer options

continuous run on a complex component.

Option D, as displayed in Plate No: 2.8 includes a visual display units which permits full programme editing. Moreover, the final results can be edited and only features in error need be printed. Programmes can be stored in cassette tapes and be recalled from file by keyboard selection.

Plate No: 2.9 displays the Ferranti Cordax Co-ordinate Measuring Machine, which is offered in the full automatic computer control, as well as the computer assist system. The Cordax was one of the early machines in the market and therefore is probably the most common measuring machine to be found throughout industry in both Britain and American.

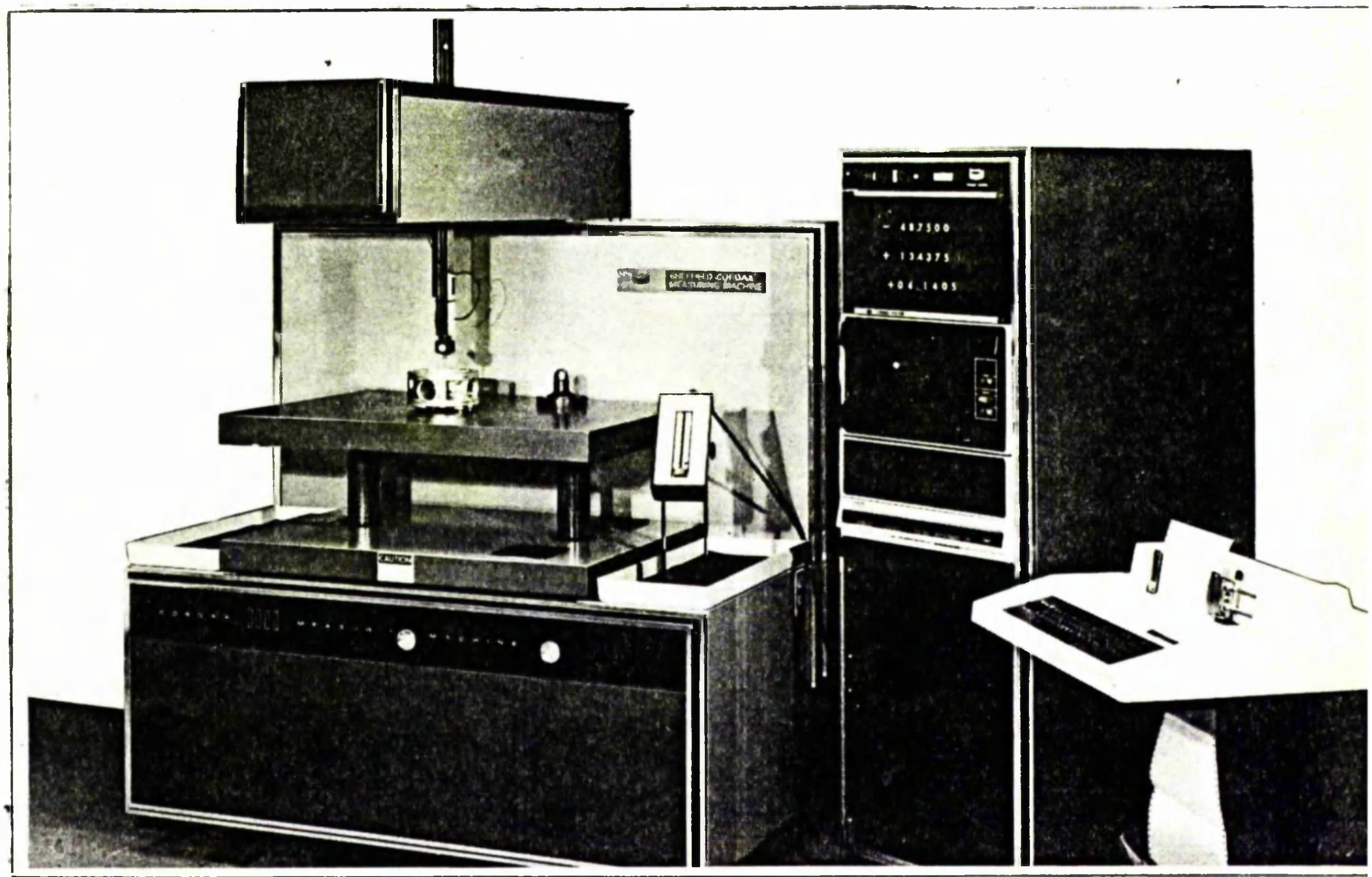
Plate No: 2.10 displays a D.E.A. of Turin, Italy, Sigma DZ-Auto 3, which is a fully automatic measuring machine which incorporates an automatic tool magazine, which allows for a probe change and a change from a horizontal to vertical position and vice versa, making it unnecessary for the inspector to intervene at all during the measuring operation.

Plate No: 2.11 displays another D.E.A., measuring machine called the Alpha BE - DEAC1001. This machine is designed for measurement of very large components such as nuclear power plants, large electrical machines and diesel motors, bodies of turbines, etc.

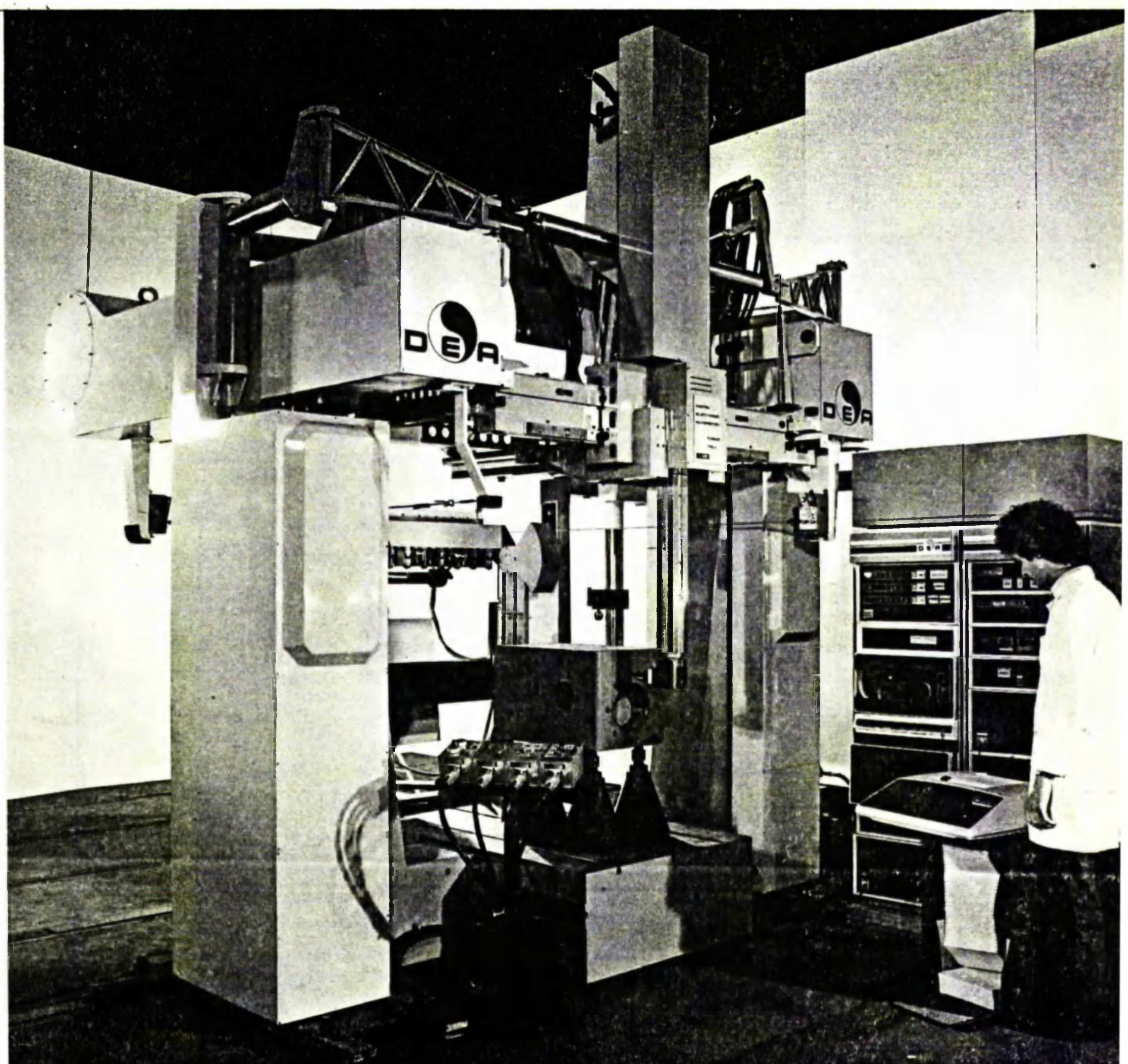
(See also Plate No: 2. at facing page for this thesis. This is the Mauser Co-ordinate Measuring Machine which has several options available within the system, from manual to complete computer control).

FERRANTI CORDAX CO-ORDINATE MEASURING MACHINE

Full automatic direct computer control co-ordinate measuring machine with power drive on all axes, PDP-11 computer, Decwriter Input-Output Terminal and a high speed reader. An operator's remote button box is also available which permits the operator to direct the probe to the desired location and initiates the data collection routines by contacting the part with the probe.



D.E.A. SIGMA Co-ordinate Measuring Machine which is fully automatic and incorporates an automatic probe changer.



D. E. A., actually manufacture measuring machines much larger than the Alpha, as illustrated, but these generally are custom built.

It is evident that measuring technology will advance in step with advances in machine tool technology. The development of low cost computers has provided equipment which can measure anything which is manufactured. Peripheral equipment is now available which will reproduce the results of measurement in either 2D or 3D graphics. From the original drawings the designed form and the dimensions can be digitised and stored in the computer. The measured form can be digitised and stored in a similar manner and transmitted to the same store. From the store, the actual and designed shape can be recalled and simultaneously displayed in graphic form on the screen.

Future systems will have the ability to manipulate both shapes into 'best-fit' condition. Communication is greatly improved by these systems, particularly with multiplant organisations, components can be designed at one location and produced at another, with a direct 'human error free' link between both locations.

In a planned complex of production C. N. C., machines, the co-ordinate measuring machine can be the inspection satellite servicing a number of machines. Information for production and inspection can be fed from a large central computer to local data banks, and all the information resulting from manufacture can be returned from the co-ordinate measuring machine and stored.

Thus, from the store, all the statistical quality information of production trends, process capabilities, variability, can be

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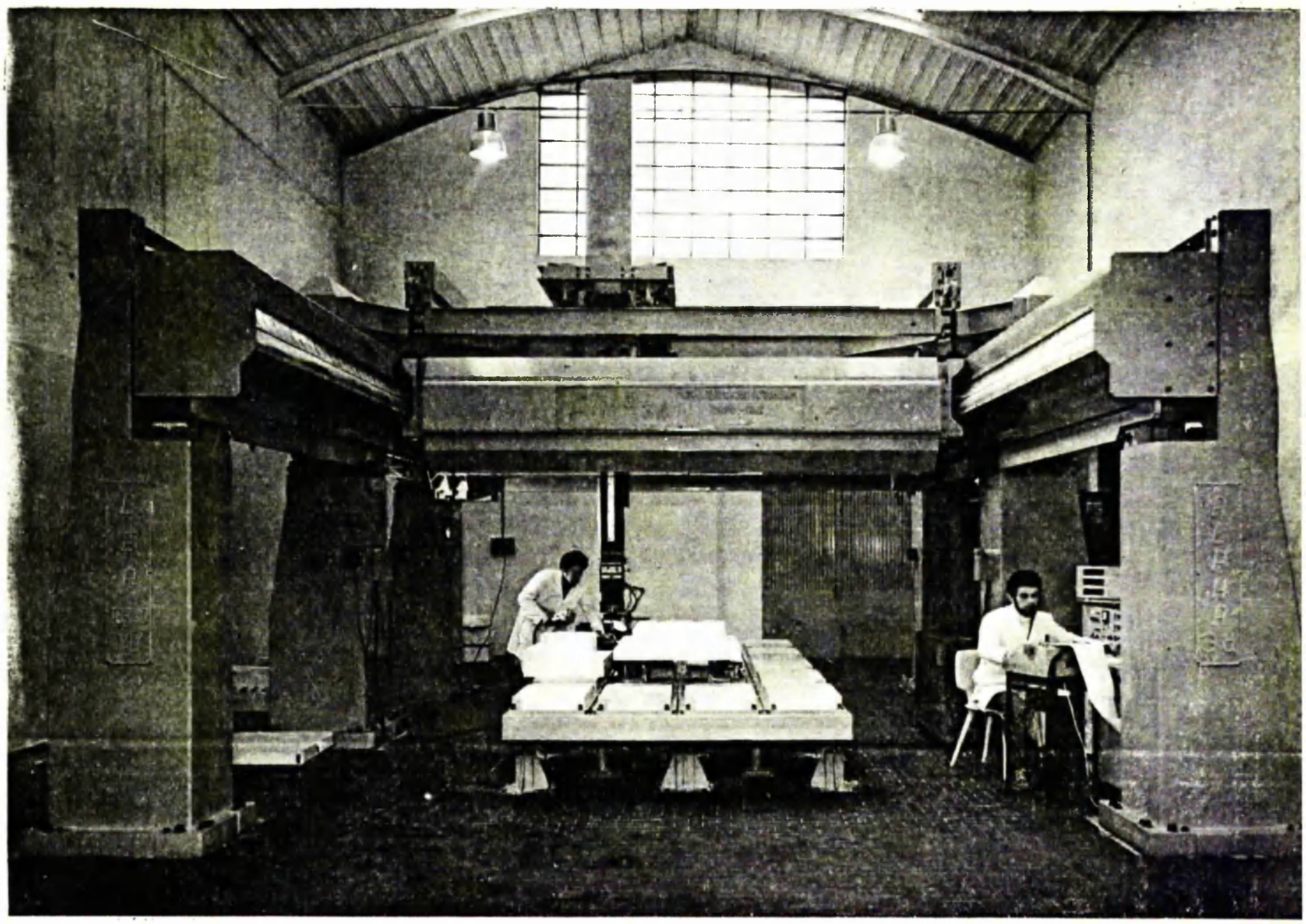
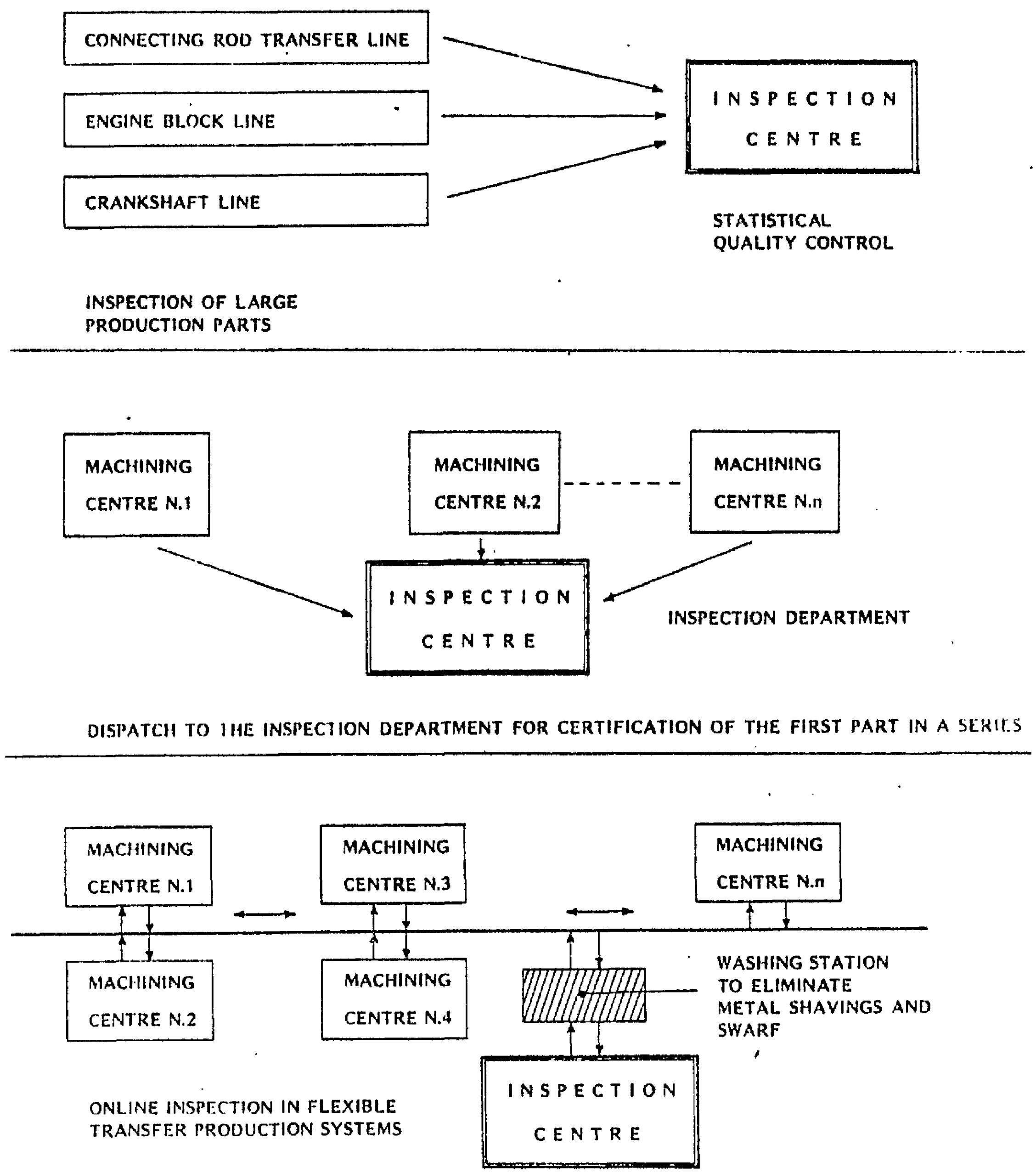
D.E.A's ALPHA Co-ordinate Measuring Machine - can be fully automatic or computer assisted. One of the largest models made in the world.



readily available to production, design and quality. A closed loop has therefore been obtained, holding information and knowledge of total quality assurance. The concept of the Inspection Centre is shown diagramatically in Figure No: 2.8. This depicts the development of the production and inspection from an individual system to a complete integrated on - line system.

FIGURE No:2.8


CONNECTING ROD TRANSFER LINE
ENGINE BLOCK LINE
CRANKSHAFT LINE
INSPECTION CENTRE
STATISTICAL QUALITY CONTROL
INSPECTION OF LARGE PRODUCTION PARTS
MACHINING CENTRE N.1
MACHINING CENTRE N.2
MACHINING CENTRE N.n
INSPECTION CENTRE
INSPECTION DEPARTMENT
DISPATCH TO THE INSPECTION DEPARTMENT FOR CERTIFICATION OF THE FIRST PART IN A SERIES
MACHINING CENTRE N.1
MACHINING CENTRE N.3
MACHINING CENTRE N.n
MACHINING CENTRE N.2
MACHINING CENTRE N.4
WASHING STATION TO ELIMINATE METAL SHAVINGS AND SWARF
INSPECTION CENTRE
ONLINE INSPECTION IN FLEXIBLE TRANSFER PRODUCTION SYSTEMS

CONNECTING SUMMARY

- Chapter 2 presented a history of measuring machine development enumerating the stages starting with Joseph Whitworth's display of his new measuring device in 1855 and tracing the improvements by refinement on that first machine up to the design of the co-ordinate measuring machine in the late 1950s. The measuring machine was discussed in relationship to its place in the overall field of industrial metrology and an attempt was made to compare its importance to that of conventional measuring equipment while recognising that the latter will continue to play a key role in the day to day measurement of accuracy in the manufacturing industries.

- The current 'state of the art' co-ordinate measuring machine which represents a revolutionary leap in measuring technology was discussed at length, giving details of all types available today and the measuring capabilities of each type. The advance in parallel to measuring machine development of microcomputers and other cheap electronics has lead to the addition of new peripheral equipment added to the basic measuring machine, which now provides manufacturing industry with a total system. These systems have the capabilities of being totally integrated into a machine tool complex thus achieving a closed loop of feedback data to obtain and maintain consistent measurements within pre-determined tolerance bands. Equally this measurement hardware can be used as a stand-alone system to carry out after the fact measuring activities on semi or completely machined components.

- The objective of chapter 3 is to open the central argument of this research project by close investigation into real practical situations of technical organisational development at the single manufacturing plant or enterprise level. The new technology to be investigated in this chapter is that of the numerical control (N. C.) machine tool and the anticipated outcome of this study will be findings which establish the impact and problems of N. C., machine tools on the enterprise.

CHAPTER 3 - New Technology in a Single Manufacturing Plant.

3.1 - THE OBJECTIVE OF THIS CHAPTER.

The objective of this chapter is to report the findings of a pilot study made on a single manufacturing plant. The specific aims of this pilot study will be to analyse -

1. Background and strategy behind setting up the plant.
2. Results of operations related to new technology.
3. Shifts in employment.
4. Technological developments.
5. Trade Unions' reactions to new technology.
6. Management attitude to new technology.
7. Return on investment related to new technology.
8. Advance communications on new technology.
9. Influence of new technology on the plant.

Highlights of Aims and Findings.

The strategy behind setting up Caterpillar Tractor Company's Glasgow plant is discussed by initially developing 7 major reasons for the selection of this particular location. These reasons argue a case for positive marketing, financial and technical benefits directly related to the proposed site at Glasgow. Initially the Glasgow operation of Caterpillar was not successful and some of the problems associated with this failure are identified. Among other factors a weakness in process technology is discussed as a factor for failure. To contrast the doubt concerning the decision to select Glasgow, a listing of 10 proven benefits is given. This is followed by a summary of the challenges which lay before the new manufacturing facility in the early 1960s. The reactive changes made to the plant in 1964 and onwards are detailed in the discussion.

In order that an accurate measure be made of the effect of technology and the progress of the Glasgow Plant, the results of operations are

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detailed and discussed over a 10-year period. These measures are broken down as follows -

- o Factory performance.
- o Cost of operations.
- o Sales profits and return on assets.

Each of the above statistics is supported by tables of information which appear to indicate a correlation between the results of operations and the contribution made by new technology.

Prior research indicates that new technology often results in some form of employment shift either a reduction or a movement from one redundant job to a newly created assignment. Shifts in employment are measured for the single plant operation at Caterpillar Glasgow by examination and discussion of employment statistics for all levels of manpower over a 10-year spread. The broad results of this examination would indicate only marginal changes in employment levels within the plant.

The next section of this pilot study examines in detail the technological developments at Caterpillar commencing with a theoretical base and a brief examination of prior research. Some positive correlation is noted between the prior research findings and the situation at Glasgow. Initial technology transfer of equipment from American facilities to Glasgow is discussed, followed again by a summary of the status at Glasgow of technology of production processes as it was between 1958 and 1966. The lead up to the initial introduction of numerical control equipment is explained through the phases of planning, product and process standardisation, installation of N. C. equipment and finally maintenance policy, the last item is supported by a short case study.

Having discussed the physical hardware of the new technology, the pilot study opens the research to these areas which are affected by the consequences of the new technology. The first to be discussed is the reaction of trade unions to new technology. This discussion is broken

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down by each trade union involved with supportive case studies of real situations which arose due to new technology introduced at Glasgow Plant. The recent policy by the Trade Union Congress with respect to new technology is discussed in this section together with the basic findings of prior research of this aspect of new technology and trade unions.

The next section investigates the attitudes of various levels of management to the introduction of new technology. Senior management were seen to support the investment of new technology while middle management initially resisted this change. The reasons for these differences are discussed at length again with a backcloth of prior research findings. The important relationship between new technology and the possible changes in organisation structures are investigated. Caterpillar appeared to have minimum formal change to the organisation structure but had much informal organisational activities resulting from the new technology. These informal activities now seem to be evolving into a more fixed structure modulated within the main overall organisation structure. The question of how new technology actually gets into manufacturing industry has stimulated some recent research. This pilot study includes two short case studies on how certain managers were motivated towards innovating new technology within the plant.

The whole aspect of ensuring a return on investment (ROI) as related to new technology is examined in this section of the research project. The system operating at Caterpillar is used as a datum from which a discussion is developed on why the anticipated returns are not achieved. Some interesting recent research findings are compared to the Caterpillar experience and various observations and recommendations are provided.

Advance communications within the organisation as related to new technology and in particular with trade unions is the subject of the penultimate section of this chapter. The formal systems operating at Caterpillar are shown followed by three case studies on how

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communications related to different types of new technology affected the operation at Glasgow. This subject is again supported by prior research into the new technology and other changes which affected people at work.

The final section of the pilot study summarises the influence and effects which new technology, and in particular numerical controlled machine tools, have had on Glasgow Plant. An attempt is made to correlate the introduction of N. C. technology with shifts in employment and improvements on the return on assets. A table of effects has been developed from this pilot research to bring together all of the key components within the organisation, which have been identified as having been affected in some way by the introduction of new technology. It is the intention of this research to replicate this table at each point in the overall study where new evidence is discovered to support the general hypothesis that new technology has an effect on the whole enterprise.

<u>How This Pilot Study was Conducted.</u>

Information was gathered from several sources within the Glasgow Plant of Caterpillar Tractor Company Limited. These sources consisted of the following:-

- o Accounting - financial and other measured results of operations as documented statistically from 1962 to 1977. Specific information provided a detailed measure of the Glasgow Plant's performance year by year, sales generated, profits gained and the resultant return on the investment.

- o Personnel - a complete history of the founding of the Glasgow Plant together with the details of employment changes at all levels in the organisation over a 10 year span.

- o Industrial Relations - a review of minutes of meetings concerning disputes and terms of references agreed to resolving these disputes on the introduction of new technology.

- o Planning and plant engineering - an examination of all projects raised for new N. C., technology, the return on investment anticipated and gained. The associated problems of installation and uptime on this equipment.

The above information mainly obtained from company official

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documentation was supported by interviews with personnel at all levels of employment at the plant. These people consisted of senior managers middle managers especially at factory line operations, planning and other service support managers, supervisors, staff engineers and hourly paid blue collar employees operating new N. C. machine tools.

The information was developed mainly from these 2 types of approach es namely documents and interviews, and was aimed at deriving deeper understanding of the interplay of organisational, social and technological factors on the question of how new technology affected those factors within a single manufacturing plant.

Why Numerical Control Machine Tools are of particular interest to this Research Project.

Numerical Control Machine Tools or N. C., as they are now commonly known,were chosen as the central feature of this first pilot study for the following basic reasons:

- N. C. machine tools were a major change of manufacturing technology at the Glasgow Plant.
- The introduction of N. C. at Glasgow appears to have been accompanied with an improvement in the plant's operational results.
- There has been some prior research on the impact of N. C. equipment into industry.
- The N. C. technology is the apparent cause of a need for a new measuring technology, the effects of which on manufacturing industry will be discussed elsewhere.
- N. C. technology has such a broad front that it has had some degree of contact with almost every function in the Glasgow plant.

It is therefore of particular interest that N. C. be chosen as the first pilot study to develop information on the impact of technological change. Information derived will be used as a comparative datum for further phases of this research project.

3.2 - BACKGROUND TO CATERPILLAR TRACTOR COMPANY, GLASGOW PLANT.

Caterpillar Tractor Co. Ltd., is a subsidiary of the Caterpillar Tractor Co., Peoria, Illinois, the world's leading manufacturer of earthmoving and materials handling equipment. The British subsidiary was originally formed in 1950 to provide a source for Caterpillar parts within the sterling area. Its operation started near Accrington in Lancashire and moved to Coalville near Leicester in 1951. In 1953 these temporary premises were vacated and the Parts Operation moved to the present site at Desford near Leicester. In 1956 the assets of the Birtley Company were acquired; this Company, located near Newcastle-on-Tyne, had held a manufacuring licence from Caterpillar Tractor Co., since 1947 and made bulldozers and scrapers; the Newcastle Plant has subsequently been entirely rebuilt and rippers and truck bodies have been added to the product line.

The Glasgow area, famous for its steel mills, with labour experienced in the skills of shipbuilding and other engineering activities, and offering excellent port facilities, had the best combination of the essential requirements for Caterpillar's third and largest British facility. A 65 acre site was purchased at Tannochside, near Uddingston, Lanarkshire formerly an old mining village. The site was cleared and construction work began in 1956. This was to become one of the most modern and best equipped plants in Europe. The original floor area of 680,000 sq. ft., was increased in 1964 by 84,000 sq. ft., and again in 1969 by a £3.9 million expansion programme, to a total of 1,060,000 sq. ft., site area at present is 145 acres. The design of the factory both in layout and appearance had been given careful attention and has been acclaimed as an "outstanding contribution to the appearance of the local scene" by the Civic Trust. The employment figure at Glasgow Plant has grown from 1,250 in 1958 to a current figure of 2,500. To provide skilled personnel for future requirements, the Company is currently training 75 apprentices and has already trained many people in shorter machine shop courses in addition to the formal apprentice training programme. Nor is the training of management personnel neglected,

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a Management Development Division has been established which organises and co-ordinates short in-plant courses together with business conferences and courses at Universities in Britain and America.

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3.3 - STRATEGY ON FOUNDING OF THE GLASGOW PLANT.

In 1954 it was decided by the Board of Directors of Caterpillar Tractor Company to set up a manufacturing plant outside the United States of America. The major reasons for selecting the location at Glasgow were as follows:-

* Creation of a manufacturing base in an already established British market for Caterpillar products.
* Avoidance of tariff barriers when Britain became a member of the European Economic Community (E.E.C.).
* Benefit from generous British Government subsidies for buying capital equipment such as machine tools.
* Allow dollar scarce countries to pay for product built in Britain rather than America.
* Benefit from British Government development schemes attracting industry to low cost land purchasing areas.
* Sources locally for good quality steel in quantity.
* Available skilled engineering labour and good technical educational facilities.

The machine shop cut its first piece of metal in early 1958 and the first Glasgow built tractor was shipped to the customer in the autumn of that year. It took a further seven years before the Glasgow plant declared a profit and for this reason some observers thought that the original decision to locate the plant at Glasgow to be unsound. Some of the major problems which were considered to be the cause of this initial failure were -

1. The product mix and range assigned to the plant to manufacture and assemble was much too diverse to permit economies of scale or standardisation. This resulted in very small production batch runs and constant re-training of employees.
2. The management at senior, middle and even some supervisory levels were almost all American nationals brought over to the new plant for three to four year assignments. Their principal objectives were to get the new plant running efficiently on Caterpillar methods and procedures, train local managers to replace them, then return to America. These objectives were not met and it was reported unofficially that these American managers had come from relatively low levels of management in American plants and did not have adequate experience to take on senior assignments in the new plant. There were many production problems and not many good solutions. The objective of replacement training was not attained and instead of local managers gradually taking over, more American managers

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were brought in to try and resolve the continuing inefficiences. In a nutshell the management organisation and decision-making left a lot to be desired.

3. A good deal of the first machine tools and other capital equipment was second-hand imported from American plants where it had apparently been successfully used for a number of years. Errors were made by American planning managers at Glasgow on the acquisition of new machine tools and related equipment. These mistakes were made due to lack of knowledge of the British and European machine tool market. Cheap low horsepower equipment was bought to perform heavy demanding iron cutting. Equipment broke down frequently, production was interrupted and prime product schedules were not achieved.

4. Some of the aforementioned American nationals on the manufacturing side tried so called tough management approaches to force through production schedules. The result of this was a very poor quality prime product, which in turn reached a customer who had only experienced American built equipment. Poor results came back from the user in terms of early hour failures to the extent Glasgow Plant quickly gained an adverse reputation for poor quality and some customers insisted on American built equipment.

5. Initially when Caterpillar set up at Uddingston, there was no trade union recognition at all, the original concept was similar to IBM, in that Caterpillar believed that wage rates and conditions were far in excess of the area market value and therefore no trade unions would be necessary. Secondly, early experience in American plants of Caterpillar had shown that the company could get along with its employees without trade union interference but, unfortunately in America, some of the big Auto Workers' Unions had eventually moved in from Detroit to Caterpillar in the midwest and latterly got employees organised. Caterpillar senior executives did not wish the same mistake to happen with their first overseas manufacturing operation. Regretfully the lack of sound advice, together with inexperienced American nationals, did not consider the basic factor, that the new plant had been located in an area of extremely strong and deeply traditional trade union activity, emanating on one hand from the mining industry and on the other, from the shipbuilding and heavy engineering industries. Like it or not, workers in the west of Scotland had bitter memories of bad times in the past, related to redundancies and oppresssive management and owner tactics, so whether this new American company had the world's best working conditions or the top wages for the district, the majority of the employees felt they needed the protection of a trade union around them and, unlike IBM, no formal grievance system had been considered to give the workers a voice of protest. Subsequently the Glasgow Plant took a 10-week strike, at the end of which, the management conceded to trade union recognition. The memory of this management-union battle remains today despite the fact that all of the leaders on both union and management sides are no /....

longer at Glasgow Plant. (10 week strike Nov. 1960 to Jany. 1961).

In contrast to the above there was a degree of success which supported another school of thought who considered the choice of Glasgow for a site to be a good decision. The basis for this reasoning was as follows:-

1. The Government Monetary and Fiscal Policy at that time had made it very attractive for Caterpillar to choose Glasgow, probably to the degree that no other site in Britain could have come close to this low cost of set up, even with Tyneside and South Wales considered.

2. Effective market price systems of general commercial type had allowed Caterpillar to manufacture equipment at low-labour costs (vis-a-vis American labour costs) and sell at American prices within European arena of the E. E. C., initially as a non member but eventually as a member.

3. The transporting of goods was facilitated with ready made road networks and efficient ports for shipping.

4. The people had good engineering skills and a long tradition of entrepreneurial drive and there were good technical education and training systems available.

5. There was a ready supply of the basic raw material, namely steel.

6. The West of Scotland area had already a long list of famous companies, some new, some long established, some British and American owned. It was therefore anticipated that local management expertise could be recruited.

7. The Caterpillar management organisation structures were reasonably simple and flexible, more organic than bureaucratic or mechanistic.

8. The mother language was common to America and Britain.

9. It permitted a better opportunity to meet competition from both American manufacturers and non American manufacturers by offering better priced products with the same technological base.

10. The President of the Company, a former Glaswegian, was very much in favour of Glasgow and would obviously use his power and influence to make it work.

<u>Challenges for the Early 1960s</u>

In the early to mid 1960s, seven specific challenges were identified by Caterpillar managers at the Glasgow Plant. These challenges are

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summarised as follows:

1. A less than acceptable prime product which had a poor reputation amongst customers for reliability, durability and performance.

2. A poor level of factory performance in terms of efficient use of labour hours in the production of components.

3. A wage/effort drift dilemma was beginning to have an effect on previously good cost comparisons to American plants.

4. A high level of scrap, waste and rework again affecting cost of manufacture.

5. A strong trade union organisation not entirely encouraged by the management group by communication, co-operation or any form of participation. In fact the two groups remained hostile since the early days of the 10-week strike, the work force was inflexible and resistant.

6. A product mix which was much too diverse for a plant of this size - the early decisions to manufacture had not been properly studied from the aspect of overall manufacturing efficiency.

7. A less than acceptable technological base of production equipment.

Changes made to the Plant in 1964 and Onwards.

To meet the challenges listed above the following major changes were made to the Glasgow Plant:-

* In 1964 the physical size of the main building was expanded by 84,000 square feet.

* This additional space was filled with new machine tools, heat treat equipment and more assembly space was created.

* In 1966 the first Numerical Controlled (N.C.) machine tools were installed.

* The first of the two major rationalisations of prime products was instrumented in 1967. Two years later the second phase reduced the number of models from 5 down to 3. Almost immediately the machine shop was able to increase batch sizes and gain economies of scale.

* In 1969 the main building was again expanded to a total area of one million square feet and more new equipment was acquired with particular emphasis on N.C. machine tools.

* By 1973 all of the management posts were filled by British nationals. The plant management team had moved from an ethnocentric (American nationals) to a geocentric (British nationals) base.

3.4 - RESULTS OF OPERATIONS AT GLASGOW PLANT BETWEEN 1968 AND 1977 HIGHLIGHTING SOME EFFECTS OF NEW TECHNOLOGY ON THE RESULTS.

With the above changes, Glasgow Plant began to show improved results in the following measures:

A. Factory performance.

B. Cost of operations.

C. Sales, profits and return on assets.

These results have been extracted from Company statistics and are shown over a period of 10 years from 1968 to 1977, on three tables. The analysis of each table is given below.

A. Factory Performance. Table No: 3.1

Caterpillar place great importance on the utilisation of direct labour, and measure on a daily basis, the effectiveness of the plant by comparing the saleable hours spent by each direct operator to the actual hours spent in the plant. (Saleable hours are those measured by works standards, making parts or assembling product - Caterpillar term these hours as base hours). When the base hours are divided by the actual hours, a ratio of performance figure is achieved. The greater the number of base hours generated against the actual hours spent, then the better will be the performance of, firstly, the individual operator and ultimately the whole plant. Constraints on achieving good performance are related to material availability, machine tool uptime or the operator, in terms of competence and/or effort. As a further measure of effectiveness, the reported performance has to be analysed in terms of how much time was spent by the operator running scrap components, and how much time was spent on reworking parts, which were incorrect but not scrap. This measure is termed Direct Labour Yield (DLY) and provides a truer assessment of the plant's effectiveness. The difference between the performance and the DLY percentages is therefore the loss in relationship to the combined effects of scrap and rework hours.

Table No: 3.1.

FACTORY PERFORMANCE

1968 TO 1977
(Hours in 000'S)

Year	Actual Hours	Rework Hours	Base Hours	Scrap Hours	Performance	D.L.Y.	D.L.Y. Loss
1968	1498	122	1091	38	72.93	65.00	7.93
1969	1465	28	1061	36	72.47	64.35	8.12
1970	1407	57	1057	28	75.96	70.26	5.70
1971	900	35	712	18	80.37	74.30	4.80*
1972	642	17	553	11	86.78	82.34	3.90*
1973	1094	31	959	17	87.69	83.73	3.77*
1974	1095	30	982	18	89.65	85.70	3.38*
1975	1290	29	1161	21	90.01	86.48	3.51*
1976	1150	31	1045	16	90.77	87.08	3.36*
1977	1171	34	1073	16	91.48	87.72	3.36*
Change	21%-	32K AVERAGE		42%-	18.55%+	22.72%+	4.57%-

FORMULA D.L.Y. = DIRECT LABOUR YIELD = $\frac{\text{BASE HOURS - SCRAP HOURS}}{\text{ACTUAL HOURS + REWORK HOURS}}$

With the above brief explanation of the system of measurement, one can observe from Table No: 3.1, that the Glasgow plant improved the performance percentage by 18.55%, DLY by 22.72%, and reduced the loss by 4.57% over the 10-year period. Actual hours dropped by the order of 21%, yet the number of base hours, while not increasing did not decrease, in effect more "saleable" hours were generated for fewer man hours, therefore the overall labour yield improved. Ignoring the unexplainable drop in rework hours between 1968 and 1969, the amount of hours spent on rework has not changed, averaging 32,000 hours per annum. Scrap has reduced substantially and is the major cause of the improvement in DLY loss percentage. Glasgow Plant has rarely suffered from long term shortages of material and it is unlikely that changes in material availability had any contribution to the above improvements. The 2 major contributions have come from improved labour competence and the effect of new and improved equipment.

B. Cost of Operations - Table No: 3.2

The cost of operations at Caterpillar is summarised under departmental costs (expressed in period or fixed costs, then as total costs), unallocated costs and the cost of holding direct inventory.

Departmental period and total costs both increased by 29 percent over the 10-year period against a 20 percent improvement in sales value. One should observe that the ratio of period and total costs to the sales value improved by 4.03 and 7.66 percent respectively. This indicates that, as sales volume increased, costs were controlled almost equally between the period and variable accounts. The plant succeeded in achieving more output for less cost over this period with the trend apparently continuing in this general direction.

Unallocated costs are those costs which are kept in a general account and cover the following:-

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TABLE NO. 3.2

COST OF OPERATIONS

Standard Cost (£'000's)

Year	Sales	Period	%	Total	%	Unallocated
1968	19716	2545	12.91	5107	25.90	1483
1969	20504	2909	14.19	5678	27.69	1426
1970	22384	3458	15.45	6349	28.36	1694
1971	20897	3385	16.20	5734	27.45	1707
1972	18686	3261	17.45	5302	28.37	1789
1973	27048	4391	16.23	7278	26.91	2229
1974	36984	5879	15.89	9440	25.52	2702
1975	60160	7593	12.62	13154	21.86	4308
1976	67275	7392	10.99	14515	21.58	4348
1977	97092	8623	8.88	17706	18.24	5591
Change		RATIO 4.9+	4.03% +		7.66% +	26% +

DIRECT INVENTORY STATISTICS

Standard Cost (£'000's)

Year	December Inventory	Average of Following 3 Mths' Usage	Months' Supply
1968	3978	1268	3.14
1969	3873	1469	2.64
1970	4629	1261	3.67
1971	2982	1011	2.95
1972	3021	1279	2.36
1973	5259	1844	2.85
1974	5351	1848	2.90
1975	4657	1780	2.62
1976	4910	1960	2.51
1977	12565	5008	2.51
Change			

+ 80% Improvement

Major Costs	Ratio Factor Increase 1968 - 1977
o Depreciation	5.6
o Freight	1.7
o Insurance	4.2
o Power and Gas	1.7
o Taxes	2.6

The total unallocated costs increased by a factor of 3.8 over this 10-year period but it should be noted that the major contribution to this increase was depreciation,which indicates the increasing amount of capital equipment which has to be depreciated. One should equally observe that the cost of power and gas, despite a 17 percent increase over the 10-year period, is not substantial considering the general increases in the cost of energy. The indication here is that new technology in terms of one N.C. machine tool replacing several conventional machine tools with less horsepower required for much greater productivity.

Direct inventory over the 10-year period has been held very steady, indeed with only an increase in value of approximately £1 million (1977 figures are ignored as this was a year when standard costs were revised). The number of months supply of material dropped by 0.63 of a month showing an improved control on capital tied up in direct inventory.

C. Sales Profits and Return on Assets - Table No: 3.3

In order to show the actual point of changing from a loss to a profit making facility, Table No: 3.3 has been extended to reflect 17 years of operation at Glasgow plant. From this data one can see on Table No: 3.3 that a negative return on assets was reflected since 1962, similar losses were reflected prior to 1962. It should be noted that assets were increased by over £1 million between 1964 and 1965 due to the plant expansion and new equipment as previously reported. Sales increased by over £3 million in 1965 over 1964 and for the first time in its history Glasgow plant reflected a small profit and a return on assets of 2.76

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percent.

Analysis of these tables will now continue as of 1968 in keeping with Tables Nos: 3.1 and 3.2 as previously discussed.

Sales were shown to have improved by a factor of 4.9 in Table No: 3.2. When these values are reflected per head of employee as shown in Table No: 3.4 one notes an increased factor of 5.42. Similarly when profit after tax is expressed in the same manner, it shows that profit per employee improved by a factor of 8.2. The number of employees has actually reduced over the 10-year period and these changes in manpower will be discussed later.

The average value of total assets more than doubled over the 10-year period notably with a sizeable increase of almost £2 million between 1969 and 1970, when more new technology was acquired to occupy the then recently expanded plant. Return on assets, (profit after tax over average value of assets) had increased quite substantially over the 10-year period with only slight decreases in 1969 and 1970. This measure reflects the primary performance of profitability of the Glasgow plant to be healthy. When related with sales value to average assets value, one has a measure of how intensively these assets are being employed, or in other words, how efficiently plant and equipment is being utilised. With a return on assets moving from 14.18 to 52.75 percent and a sales to assets ratio changing from 1.72 to 3.76 over 1968 to 1977, this would indicate coupled with the decrease in manpower, that these results are emanating from the capital equipment employed and not the effect of labour intensification.

Table No: 3.3.

RETURN ON ASSETS

Year	Average Assets	Sales	Profit or Loss( )	Return on Assets	Ratio Sales to Assets.
1962	7492	6664	324( )	4.32( )	.89
1963	7776	6056	415( )	5.34( )	.79
1964	9307	8427	180( )	1.93( )	.91
1965	10742	11695	276	2.76	1.08
1966	11077	14997	783	3.45	1.35
1967	11392	17065	883	7.74	1.5
1968	11468	15716	1555	13.56	1.72
1969	11816	20504	1272	10.77	1.74
1970	13256	22384	1371	10.34	1.69
1971	13333	20897	1610	12.09	1.57
1972	12183	18686	1445	11.83	1.53
1973	13457	27048	2448	18.19	2.01
1974	16218	36984	2709	16.69	2.28
1975	18560	60160	5428	29.22	3.24
1976	21765	67275	6541	30.03	3.09
1977	25816	97092	13618	52.75	3.76

Table No: 3.4

SALES & PROFITS PER EMPLOYEE

Year	Average Employees	Sales	Per employee or Loss ( ) Profit after tax
1962	1520	4384	388( )
1963	1481	4090	509( )
1964	1715	4914	191( )
1965	2117	5525	254
1966	2420	6197	288
1967	2547	6700	631
1968	2590	7620	916
1969	2716	7549	468
1970	2678	8359	512
1971	2356	8870	683
1972	2098	8907	767
1973	2338	11569	1047
1974	2353	15718	1151
1975	2350	25600	2310
1976	2312	29098	2829
1977	2349	41333	5187

SINCE 1968 - RATIO 5.4 RATIO 8.2

3.5 - SHIFTS IN EMPLOYMENT FOR ALL LEVELS OF EMPLOYEES BETWEEN 1968 AND 1977.

An interesting feature of the Glasgow plant's history is related to the shifts in employment over the 10-year period of 1968 to 1977. Table No: 3.5 shows that there has been a drop in total employees of approx. 10 percent, however this figure is misleading and has to be further explained. Due to a fall in orders for the prime product in 1972, a redundancy was declared and 547 employees left the Company between that year and the next. The breakdown of the 547 employees by payroll was as follows:-

Employees made redundant:	Employees No:	% of Total:
Direct labour hourly payroll	235	43
Indirect labour hourly payroll	204	37.3
Staff employees - weekly payroll	95	17.4
Staff employees - monthly payroll	13	2.4
TOTAL	547	100%

The first shifts in employment is concerned mainly with hourly paid employees and since 1972 the total manpower has increased by 219 employees, 164 direct plus 74 indirect hourly payroll less 15 fewer weekly and 4 fewer monthly staff personnel. In percentage terms to total manpower the direct hourly payroll has increased by 4 percent, indirect no change,and the weekly and monthly staffs have both dropped by 2 percent respectively over the six years since the redundancy and up to 1977.

The significance of these changes in manpower related to the previously discussed statistics on plant performance would indicate a negative relationship between increases in manpower and increases in profit, productivity and sales. In a recently published research by Swords Isherwood and Senker of University of Sussex on behalf of the Engineering Industry Training Board, it was observed that in N.C. machine shops in Great Britain, there had been substantial increases in production over the last seven to eight years with no corresponding increase in

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TABLE NO.:3.5

SHIFTS IN EMPLOYMENT 1968 TO 1977

ALL LEVELS OF MANPOWER

AVERAGE EMPLOYMENT

( ) PERCENTAGE OF TOTAL EMPLOYEES

Year	Hourly Direct	Hourly Indirect	Weekly	Monthly	Total
1968	1001 (38)	859 (33)	452 (17)	276 (11)	2590 (100)
1969	1009	937	466	304	2716
1970	1029 (38)	865 (32)	471 (18)	312 (11)	2677
1971	855	759	431	311	2356
1972	794 (37)	661 (31)	376 (17)	299 (14)	2130
1973	984	683	378	293	2338
1974	979 (41)	699 (30)	381 (16)	294 (12)	2353
1975	990	700	368	292	2350
1976	945	709	366	292	2312
1977	958 (41)	735 (31)	361 (15)	295 (12)	2349
+68.77	-43 (5%)	-124 (15%)	-91 (25%)	+19 (7%)	-241 (10%)
CHANGES SINCE 1972.	+164	+74	-15	-4	+219

employment (13). The Glasgow plant seems to correlate exactly with the above longitudinal study and suggests that the increase is coming primarily from the effect of new technology.

The second shift in employment concerns the weekly and monthly payrolls and is of particular interest to this research project. Increasingly the literature is indicating that advanced technology and automation is causing a shift in manpower from blue collar manual tasks to white collar staff assignments. Abbot in a study of nine engineering firms published in 1978, showed that in relationship to technological change, professional and white collar staff employees had considerably increased as a proportion of the total labour force. These increases were observed in the computer staff, technical services concerned with design and quality control and other matters which caused the size and importance of the white collar sections of the firms to increase. Abbot's report did not include any financial data on these firms, it is therefore not possible to correlate the change in manpower levels, increase in technology and success in terms of financial measures.(14). The Glasgow plant results on shifts in employment on weekly and monthly staff would indicate that rather than add more staff to the payroll to meet the increasing sophistication of technology, which may come to the plant, people's job classifications and assignments are being enlarged and reclassified to meet this need. Added to this as will be covered later, hourly payroll employees are getting a share of handling the new technology from an aspect of programming and control There is, it would seem, a reverse tide of control moving back to the shop floor.

3.6 - TECHNOLOGICAL DEVELOPMENTS AT GLASGOW PLANT.

The previous section described the strategy behind the establishment of Caterpillar at Glasgow and related some of the early problems and successes achieved by this subsidiary of an American parent organisation. This section now deals with some of the motives for technological development and change during the twenty years of operation at the Glasgow site.

Caterpillar in America in 1958 would have been considered to be a modern organisation technologically. It produced the most advanced earthmoving products in the world and used the best known technical production system and equipment to achieve this product supremacy. With these facts in consideration a review of some theories and research will permit some understanding of how the Glasgow plant was developed technologically.

Theory Related to Technological Development.

Engineering firms have different motives for improving their state of technological development, some of these motives are given as follows, not necessarily by order of importance:

1. Elimination of human error, thus improving quality.
2. Reduction of cost in terms of production.
3. Transfer of the primary responsibility for the rate of production from the shop floor to the offices.
4. Development of the prime product to new and higher capability standards (in the Caterpillar case, as an example, more power to move earth and rip rocks), forced firms to make significant technical changes in their plant and equipment to facilitate a means of producing these prime products.
5. The activity of competitors in both products and the means of producing these products.
6. The pressure exerted by customers in their demand for more reliable and durable products at a competitive price.
7. A secondary factor but one of real significance on the shop floor is the question of eliminating repetitive work.

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Related Research to Technological Development.

In a study by Langrish and associates of Queens Award winning innovations in Britain in 1966 and 1967 the authors found -

1. Technological development came mainly from earlier technology.
2. The industrial contribution of natural sciences (supply of trained manpower) was important generally.
3. The major cause of delay in innovating was lack of development in other technological fields (e. g. the long established machine tool awaited the development of the cheap micro computers) or insufficient market demand or need, shortage of manpower and capital, resistance to change, lack of management recognition and poor co-operation or communication. (15).

Somewhat parallel to the above findings was the result of a study by Myers in America where it was found that -

1. Technological change was, to a significant extent, based on the cumulative effect of small, incremental changes or innovations.
2. Recognition of demand was a frequent factor in innovation than recognition of technical potential.
3. Personal experience and personal contacts were the principal sources of information for successful change. (16).

In their study of the management of innovation in Scottish firms, Burns and Stalker, distinguish 2 broad polar-types of industrial organisation: mechanistic and organic. The typical mechanistic organisation is inflexible, hierarchic and characterised by intensive division of labour on a task or sub-role basis. Organic organisations, on the other hand, are characterised by broad role division of labour which cuts across specific sub-role skills, tasks or jobs. In practice it is these latter organisations, function - or performance - rather than status based, and flexible, that have the greatest capacity to adapt to technical and other kinds of change and conditions of market uncertainty and competition, (17).

Jasinski in his paper "Adapting Organisations to New Technology" suggested that there were three main alternative methods for achieving

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integration between technology and organisation. They are as follows:

- o Changing the technology to conform with organisational structures.
- o Changing the organisation so as to define and formalise the relationships required by the technology.
- o Maintaining both the existing organisations and existing technology but introducing mechanisms to reduce or minimise the discrepancies between the two. (18).

Caterpillar Glasgow plant's experience in relationship to these four findings was in the main positively correlated. The process technology was of an evolutionary rather than a revolutionary nature. The organisation structure, despite its similar lines to other Caterpillar plants in America, was not hierarchic but tended towards being performance based and very flexible. However the small quantity of technological change at any one time tended to be such that mechanisms, as suggested by Jasinski, were set up to cope with it rather than any attempt to change either the technology or the organisation.

Initial Technology Transfer from America to Glasgow.

The initial technology of production machine tools and equipment as established in early 1957 to inaugurate the Glasgow Plant of Caterpillar Tractor Company was directly related to the manufacturing requirements for the product line to be produced at that time, indeed, as was previously mentioned, there was if anything a slight degree of obsolence with some of the equipment, as it had been transported second hand from some American plants of Caterpillar. This was not necessarily a bad decision as some of this equipment was specially designed for production of Caterpillar components and had been proved in other plants over several years of production. It was not however the current "state-of-the-art" machine shop technology and in essence was highly manual in its operation and required particular maintenance skills to keep it in a running condition. All of the technology in the plant was not of course in this class, much equipment had to be bought new and in particular heat treat furnaces, paint spray booths, assembly lines, conveyors, etc., were all constructed to the best known advanced methods of

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manufacture at that time in the late 1950s, and indeed, in comparison with many surrounding British owned companies, Caterpillar Glasgow was considered to be highly advanced in process technology.

In summary, the status of technology of production processes at Caterpillar, Glasgow Plant, between 1958 and 1966 was largely governed by the following:-

1. The nature and type of technology being used in American plants for the same prime product manufacture.

2. The engineering design restraint to ensure interchangeability made it again easier to use the same methods as in American plants that run the risks of innovating with new methods.

3. American nationals on temporary transfer assignments at that time were comfortable with technological processes that they were familiar with in the past.

4. The low volume high value production type made it economically difficult to consider automation, transfer lines of other high output methods and systems.

5. The low wage economy did not encourage capital intensive equipment from a return on investment aspect.

6. The Glasgow Plant could only increase its manufacturing capacity with the given approval of the parent company in America, in that each subsidiary plant, and indeed, each American domestic plant, were directed on what products and parts they would make and at what volumes. Each plant was not expected to produce more than their planned capacity.

<u>Early Approach to Planning of new N. C. Technology.</u>

Caterpillar, Glasgow plant planning group, had considered at the outset of the numerical control machine tool developments in 1965 not to put all their eggs in one basket, since the whole field of N. C., was growing rapidly with several machine tool manufacturers in the business, but with no particular best system. Planning division consequently tried various suppliers for a variety of metal cutting functions, the basic machine tools did not vary considerably one to another, but the electronic systems guiding the machine tool did vary in terms of basic language and before long Glasgow plant had a population of 12 N. C., machine tools with 6 quite different electronic controls.

(A list of all N. C., machine tools with the electronic controls identified is given in Table No: 3. 6, page 154).

Evolutionary Changes in Product and Process.

The nature of Caterpillar Tractor Company's production process with relatively low volume high value output puts it into the small batch production type as defined by Woodward (19). This factor, coupled with a low wage economy in direct comparison to American operations, makes for less capital intensified equipment and more manually operated and controlled methods. In addition to this, and despite its world leadership in the earthmoving business, Caterpillar Tractor Company has long been known for its rather conservative and slow development of many facets of its operation. The reason for this attitude has been suggested to be related to a mid west of America conservatism, commonly found among farming communities, from which Caterpillar has its basic roots. There has never been any great rush to be the first with this or that method or system, but rather allow others to get the innovation proven as a profit-making and viable proposition, then to seek ways of grafting it into the Caterpillar system. These remarks apply principally to the production process systems and not particularly to the product line, although even in this area and until very recently, Caterpillar's clear policy was to permit the product to be more evolutionary rather than revolutionary, making changes to design based on results from the customers' use in the field, and to a lesser degree, by the research finding in the R and D division, set up in Illinois, near the parent operation.

Technology Product Standardisation Versus Advanced in Process Technology.

Another control factor which is highly important to the continued success of Caterpillar worldwide is interchangeability (uniformity of products). The policy is that all products or parts are to be made the same wherever they are made and the parts in them to be replaceable one for another. While the benefits of such a policy on a worldwide basis has undoubted advantages to a customer, the same policy has drawbacks at the production process end, as it suggests that engineering who control all designs at Caterpillar, virtually dictate the method of manufacture and process treatment despite the fact that entirely separate divisions are employed to seek machine tools and equipment, to optimise productivity and lower costs. It is not that Caterpillar purposely restrains technology, indeed it is highly involved in most of the current forms of technology transfers. Caterpillar has wholly owned subsidiaries like Glasgow plant, and partially owned affiliates or even companies to whom they transmit technology for royalty payments without any equity share, but only rarely does the company transfer to foreign countries any technology which is not actively in use in America.

Current Policy on Planning of New N.C. Technology.

While it has been shown that the planning division has had some autonomy from the parent organisation in terms of what technology it uses to achieve the capacity of production authorised by the parent, changes are already taking place which are beginning to interfere with this autonomy. These changes are concerned with advanced technology in the electronic field concomitant with the aforementioned policy of product parts interchangeability. Despite the differences in volume output from one Caterpillar plant to another, it makes economic sense that if an identical process is used to produce these components, while previously the exchange of paper method cards was implemented, today when both processes are computer controlled, then the generation of two master control tapes is all that is necessary to ensure identical output, assuming tooling and raw materials are also assimulated. The

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delivery of master tapes thus reduces the programming efforts at the subsidiary plant and this is beginning to affect Glasgow plant's planning activities.

First Introduction of Numerical Control Technology.

During the latter part of the 1960s, Glasgow plant began to invest heavily in numerically controlled (N. C.) machine tools. Up until this time most machine tools were of single purpose stand-alone conventional types, such as radial drills, turning lathes, milling machines, borers and such. Even in the non machine tool areas such as welding, heat treat, painting, assembly, cleaning, etc., most units were operated on a one man situation, in fact in the case of two ended roller conveyor furnaces, often there was a manned loader and unloader at the other end, no great thought had been given to gravity shutes or simple non operator unloading.

The investment of N. C. in 1966 was a radical departure from previous systems and the first four special purpose tape control drills were to replace twelve conventional machine tools and operators, double output on a two-shift basis of eight hours each and for the first time have one man operating two machine tools at the same time. Regrettably this first step in the technological change did not go smoothly technically due to the following:-

- Machine tools had frequent mechanical breakdown.
- The machine tool supplier namely Cincinatti did not have adequate service/repairmen to support the new equipment.
- The previous conventional machine tools although much slower were more reliable.
- The new N. C. machine tools were found to be under-designed as related to the special index tables which were not robust enough to support the heavy components.
- Insufficient time and attention had been given by planning division at the machine tool trials to ensure that these N. C. machine tools could meet the required specifications for accuracy and repeatability of operation.

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After several redesigns these first N.C. machines settled down to produce good quality components but at a less than satisfactory level of productivity. Some of the original conventional machine tools continued to be used and remain in use today.

Maintenance Policy on New Technology.
Case Study No. 3.1 - Maintenance of New Technology.

One of the disadvantages with any new technology is that there is always inevitably a shortage of people at the outset capable of servicing, repairing and adjusting the equipment. To combat this, Caterpillar set off in 1970 with a formalised in-house training programme to give the necessary knowledge of the numerical control systems to their own maintenance employees in the electrical field. Two staff engineers on the monthly payroll were sent to the equipment suppliers for training on the N.C. systems, they returned to Caterpillar Glasgow and began to train all the electricians in the plant. The training was voluntary and held off normal working shifts but payment was made on a basic hourly rate. Initially all electricians, numbering 26, attended but gradually the numbers dropped until a regular group of 12 continued with the training periods which would last approximately 12 weeks at six hours per week making a total of 72 training hours.

Management negotiated normally with four hourly unions altogether in the plant and although the engineers and the boilermakers were numerically strong, the electricians' union was very powerful within its own sphere of interest and controlled important areas of factory work. The electricians did not make any claims upon the Company in terms of value of added knowledge required for the new N.C. electronics until they had completed the long training sessions on each system. The inevitable claim from the electricians' union covered only those electricians who had completed the training which numbered 12 from the total of 26. Management had to obtain some guarantees on shift manning with the group of 12 and other flexibilities which would give continued service to the N.C. equipment. After many weeks of debate, analysis, discussion with other local firms on this subject, a final

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settlement was agreed upon which created a higher grade electrician still on the hourly payroll but at a higher rate than all other craft groups in the plant at that time. The so called "electronic" electrician would also continue to do normal electrical repairs when not called upon to work on N. C. equipment. (It was observed at that time that other local firms namely Weirs, Singer, Hoover and Honeywell had created weekly payroll electrical technicians to perform this task but Caterpillar could not get agreement on this approach as the electrical trade union would not permit a staff man to handle tools, therefore the weekly man would have been merely advising another hourly man on what to do in each repair).

This agreement with the electricians was to set off a chain reaction among other craft unions to the extent that it took two years to settle and even at that, did not quite satisfy all parties. The maintenance mechanical engineers claimed that, as they also repaired these N. C. machines from a mechanical aspect, then they should enjoy the same increase in wage rate, they withdrew their labour for a period of 3 weeks after which management finally agreed that a specific number of engineers would be upgraded,but not to be outdone, even the humble plumber or pipefitter claimed the higher rate as they had to work on the hydraulics of these machines. (The hydraulic systems of course were no different than those found on a conventional non N. C. machine tool). Eventually the welders raised a similar claim as they did not wish to see themselves be left behind from the top skill grading. Management refused to even consider upgrading of the welder group and they in turn banned overtime and introduced non-procedural working practices which caused disruption within the plant for almost a year, to be eventually resolved by a major regrading of the complete hourly structure.

3.7 - TRADE UNION REACTION TO NEW TECHNOLOGY - BLUE COLLAR UNIONS.

From a trade union perspective, structural unemployment and the plant level obsolescence of jobs are probably the 2 major negative social consequences of technological development in most industries. 2 short case studies are detailed below to illustrate some of the problems and solutions obtained from early technological developments at Glasgow Plant.

<u>Case Study No: 3.2 - Manning the new N.C. Tape Drills.</u>

The trade union directly involved in 1966 in Caterpillar, Glasgow, namely the Amalgamated Union of Engineering workers (AUEW), appeared to be unsure how to handle this new venture of N.C., machine tools. Basically they had to welcome continued investment at Glasgow and they could see for themselves the non competitiveness of conventional type machine tools for the future well-being of the plant. The immediate concern was for the plight of 12 redundant machine operators but this was overcome by a management guarantee to provide other jobs within the plant at the same wage level. (There was a general expansion at that time and new employees were being hired). The next concern was the manning of 4 new machines which would come out of the 12 operators. This was finally agreed by the industrial relations division as a 3-man 4-machines condition, much to the dissatisfaction of the planning and work standards divisions who had shown that 2 men could have adequately operated the 4 machines. The question of wage rates was the next obstacle between the union and management groups, as originally the management saw this new equipment as a much easier operation than the conventional machine tools, where some degree of skill was required to set up and drill the numerous holes in the large components. The new N.C. drills, after the initial set up called only for a drill change at specific intervals, apart from that, the operator was mainly observing the process. The management consequently placed the evaluation of work for these machines at level 4 in a 5-grade unskilled to semi-skilled grading system. At that time

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there were a total of 8 grades on the hourly pay structure, these were all on measured day work with no incentive or bonus scheme at any level. The floor sweeper and janitor were at grade 1 and the highest semi-skilled operator, which generally meant a machinist on a complex machine tool, was at grade 5, grades 6, 7 and 8 were concerned entirely with time served or craft skills. The union fought this issue very strongly and succeeded in achieving two additional semi-skilled labour grades namely N. C. 1 and N. C. 2. These were added to the top end of the semi-skilled grades between the semi and craft gradings. Management conceded this grading on the basis that -

1. The new output from the four machine tools would more than compensate for the higher cost of labour and merely extend the payback period.

2. The new N. C. grades would eventually be absorbed in the next restructuring of grades.

3. They had succeeded in keeping a differential between the semi-skilled and the craft skill grades.

The union for their part were satisfied because they had demonstrated their considerable influence in an area that was almost certain to expand in the future, and an area in which they strongly considered that their members should enjoy benefits gained from new technology, as much as the Company would enjoy higher output and lower costs. The operators, contrary to observations made by Anderman,(20) did not appear to suffer decreased job satisfaction nor lower status within the firm, indeed the new N. C. machines seem to increase the operator's status and add to the satisfaction of the job. There were no other machine tools like this in the plant and at the beginning other operators came to observe these machines working, also management made them a focal point for plant tours for visitors. Despite the long periods of pure observation while the machine tool automatically indexed its way through the operation, the operators who were all carrying out their own machine tool setting, did not wish to participate in any additional tasks such as tool sharpening, etc., in order to avoid boredom or to gainfully (in management terms) employ their time in any other way.

Case Study No: 3.3 - Manning N.C. Machining Centers and Lathes.

In a group of highly advanced Milwaukeematic 200 series machines acquired in 1968, management wanted only three operators over 3-shifts whilst the union wanted six operators over three shifts. The union eventually agreed to the management proposal for 3 men only for a three month trial period. During this time constant downtime resulted with minor electronic and mechanical failures thus interrupting production schedules and eventually stopping prime product assembly. Management suspected that much of the downtime was contrived but could neither prove this nor take corrective action. After the three months trial, management again compromised with a group of 5 men covering the three shifts, the evening shift being covered by one man and by overtime from the day and night shift operators or with an understanding that the operator would run whichever one of the machines as required by management. The technical problems disappeared almost overnight and output increased dramatically with the added bonus of good quality components. Management did not concede all one man one machine conditions, as it was shown with N.C. turning lathes in particular, and despite continuous union objection, the first group of two N.C. lathes in 1970 were successfully manned and operated by one man and all similar groups since.

White Collar Unions.

The three white collar trade unions at Caterpillar, Glasgow plant are as follows:-

- o Association of Professional, Executive, Clerical and Computer Staffs. (APEX). Weekly paid.
- o Technical and Supervisory Section of the A.U.E.W. (T.A.S.S.) Weekly paid.
- o Association of Supervisory and Technical Managerial Staffs. (ASTMS). Monthly paid.

Despite the fact that the overall numbers of white collar union members had reduced over the 10-year period as shown in Table No:3.5, page 110, the influx of new technology had tended to give these unions greater

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power and influence within their own specific spheres, within the Glasgow organisation. The introduction of the new N.C., equipment was too spread out over time for the TASS union to make any issues over it, especially as the members involved were mainly concentrated in one area namely, planning, and therefore members in other areas such as metallurgical, engineering and others, were unconcerned. Any restrictive practices adopted by TASS in order to gain higher gradings or such within planning, did not have great support and tended to have little or no effect on the day to day operation of the plant. Recently, due to the now considerable volume of N.C., equipment and other advanced technology in the machine shop, a special group has been created in planning to handle this activity. In Jasinski's terms, this is a mechanism created to handle the new technology without changing the said technology or organisation.

The other weekly paid union namely, APEX, have also increased in influence if not in numerical strength of members. This influence is mainly due to the accelerating growth of computer activities. Interestingly the growth of these computer activities has not resulted in any conflict between the management and APEX until very recently, when visual display units (VDUs) were introduced into areas outwith the computer room. Case Study No: 3.4 discusses one of these problems.

Case Study No: 3.4 - The Use of Visual Display Units.

The first experience at Glasgow Plant related to the extension of computer services and led to an inter-union struggle on who would use visual display units (VDUs). On the shop floor, the AUEW blue collar engineers claimed in this case that work being absorbed by the VDU was a storeman's task and therefore an AUEW member ought to operate the VDU by inputing data and recalling data as he had previously done manually with paperwork. APEX claimed that as this was computer work then it must now belong to their white collar union. Management for their part knew that eventually these units would be widely used throughout the plant and that anyone ought to be able to utilise the service from senior management to hourly machine operator

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should he or she need the service, almost like a telephone, as only in this way would the benefits of increased efficiency be achieved. Currently the problem is resolved as both unions use the VDU but the blue collar storeman has access to data only, while the white collar staff union member inputs the new data. The nature and extent of the growth of the white collar unions, in terms of importance, if not in numbers at Caterpillar, is directly related to product development, changing methods of operations and other factors which call for more computer time, production control and planning efficiency, technical problem-solving staff and so on.

Supervisors -White Collar Union.

One other union group which has been affected by changing technology at Glasgow plant is the monthly paid supervisors' union of ASTMS - Association of Supervisory and Technical Managerial Staffs. The major effect on them has not been the de-skilling, fears of redundancies or exacerbated boredom among machine tool operatives, the major effect has been the increasing demand on their technical skills brought about by automation and N. C., systems that they were not originally trained to understand. The extension of the computer into production control has for some years taken away the basic decisions on what component to run, when, and in which machine, the effect has to lead to the reduction of the supervisor's role to one of man management, by -

- o An increasing demand on their technical skills from automation and N. C., systems that they were never trained to understand nor can keep up to date on.
- o The effect on the computer determining and issuing work schedules which used to be the supervisor's prerogative and responsibility.
- o The impact of industrial relations legislation and other Acts of Parliament making the supervisor more dependent on non-line management experts.

Indeed the technical staff are exerting greater influence over the line supervisor simply because the weekly paid technical staff man has the knowledge required to process the production. Lundgren observed in a study of 7 American companies that the foreman had appeared to have

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lost status in terms of fewer responsible duties performed and to have gained status only in the sense of being associated with a dramatically new manufacturing technique - a gain in status that would last only as long as the novelty of the equipment. Indeed in some of the American firms the foreman of the N. C., machine area had been displaced completely and replaced by the programmer (21). Despite these changes made, the handling of human relations will not likely be mechanised. It is most unlikely that a set of coded instructions will be developed to cope with the myriad of problems accompanying technological change in the shop floor, therefore the supervisor or foreman's man management responsibilities will remain.

Further observations on the new measuring machine technology which will be discussed later, is showing that the hourly blue collar inspector is also having increasing influence with the line supervisor, mainly brought about by the power of the advanced technology at the inspector's elbow. The effect of new technology at Caterpillar Glasgow is tending to reduce the role of the supervisor considerably. By contrast with both the hourly blue collar workers and the weekly white collar employees at Caterpillar, the supervisors have not yet been in conflict with the company on the possible effects of new technology on their members. This may have some relationship to the 1972/73 redundancy, when the company paid off hourly and weekly employees without touching the monthly paid supervisory group. This may have given confidence to the general security of this level of management despite the fact that increasing evidence of technological advances are being made on the shop floor.

Trade Union Congress Policy on New Technology.

In March 1979, the TUC published a list of demands that unions should consider when negotiating new technology agreements. The motivation for these demands is most related to the micro-electronic explosion and the consequent effect on employment. Some of the points raised in these demands include the need for automation to be accompanied by an increase not a decrease in numbers employed, that /....

unions be consulted before any new equipment is even bought and that unions should make vigorous use of status quo clauses in the short term to impress on employers the need for consultation. Unfortunately while some applaud can be given to the social merits of these demands, they tend not to work out in real practical shop floor level terms. To justify the investment and obtain some return on investment for automation, employers must shed people or find bigger markets for their products. As has been briefly described in the cases given in the text, discussion with unions about new equipment before it is even bought would result in no new equipment being bought except perhaps replacement equipment, and for unions to adopt status quo attitudes only pushes employers towards conservatism and not innovation of their plants in the long run. In conclusion therefore on the subject of the extent to which the work force are consulted and informed about changes in technology on the one hand, and the general acceptability/ non acceptability of the changes on the other, is in the experience of Caterpillar, dependent upon the nature of the change, the type of union involved with the change, and the timing of the change in relationship to other activities going on within the plant. (e.g. annual negotiation of contract). Basically experience has shown that the less said the better about the change until the last moment of installation, at which point discussions can be commenced if necessary, and only if raised by the union. (Note TUC Policy on this subject as shown in Appendix E).

Bhattacharyya in his study of the penetration and utilisation of N.C., equipment in British industry, found that trade union members at plant level were often misled about the whole implication of N.C., technology before it arrived. These misconceptions were often created by over zealous sales literature from N.C. equipment suppliers with statements related to reducing direct operator costs and no more problems with the shop floor (22). Swords Isherwood and Senker argue in their 1978 report on the Social Implications of Automated Small Batch Production for the Department of Industry (13) that there was little or no resistance to N.C., machine tools on the

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shop floor mainly due to no redundancy pledges and consultation with trade union officials at an early stage of the development to N. C., technology. On the question of manning, it was reported that unions took a money negotiating attitude to any problems. The report also observed that while some shop floor workers were afraid of redundancy in the future because of automation, it was interesting that the workers' councils were apparently not so against N. C., because they took a longer view and could see the implications of falling behind technically for aggravating unemployment.

Bhattacharyya also observed in his research of British firms using N. C., equipment, that in the majority of firms the operators had total responsibility for the machine tools. This it was claimed in some firms was at the insistence of the local trade union, in an attempt to keep some control of the operation in the hands of their own union members. Management learned to accept this situation because the skilled operator became an important member of the N. C., team informal as it may have been, but advising the programmer of optimum tooling systems and other factors.

Ettlie in his study of 10 firms in the mid west of America in 1972, found that in clustering 26 independent variables and the degree of utilisation, that each firm had attained (dependent variable), that there was an inter-correlation between union and employee relations varying directly with participation in decision-making and this being significantly correlated at the 0.05 level. In other words the success of utilisation had some relationship to how early and how involved the union group had been at the earliest stages of concept (23).

In another American study in 1970, Perline and Tull observed that unions were facing a major dilemma with the increasing degree of shop floor advanced technology. The loss of skilled and unskilled membership alike weakens the union's bargaining strength, as fewer employees are covered. It weakens the union's financial structure through loss of dues paying members. With less membership, less

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financial support and subsequently less coercive power, the existence of the union is actually threatened (24). The British situation is more complex than in America, because of its multitude of unions and the possible shifts in employment due to new technology causing members of blue collar unions to move to white collar unions. One alternative in Britain to the above problem is the creation of one industrial union representing all employees in the firm, similar to the German system.

The first major trade union in Britain to recognise and respond to the problem of advancing technology has been the Association of Professional, Executive, Clerical and Computer Staffs (APEX). They published a very detailed guide in 1979 to all their negotiating members on the aspects of Office Technology and in particular, the impact of the word processing equipment. The interesting implication spelled out in page 13 of this guide is that the APEX union are not advocating a policy of resisting technological change and improved productivity, but clearly stating that it should be a major priority for all trade unionists to encourage advanced technology. However APEX take cognisance of the real concern for job losses which will result from the new office technologies and thus are encouraging their negotiators to adopt specific strategies in trying to avoid unemployment when a firm plans to introduce such new technology into the office (25). Related to the above is Joan Woodward's observation in 1968 that trade union institutions are determined mainly outside an organisation but are modified to fit the circumstances of particular organisations, that is to say, if APEX or any other trade union develop a policy, it very often has to be interpreted to suit the situation inside the organisation (26).

Without doubt this research would argue for the involvement of trade unions in the whole question of new technology. Evidence of much related research and the experience at Caterpillar, Glasgow shows that little progress will be made without involvement of trade unions at all levels of the union hierarchy. Where this research may differ

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from the findings of other researchers is in the timing and manner which is best used for this involvement, a subject to be discussed later under "Communications", as the means by which new technology is implemented, is as important as the technological change itself.

In certain technical situations, as those related to N. C., machine tools, certain types of behaviour predominate. The work of Leonard Sayles is interesting in this connection. He identifies 4 behavioural patterns observed in working groups and he calls these apathetic, strategic, erratic and conservative. In the strategic work groups the norms and values of the work group itself are concentrated on developing a strategy in dealing with management. The people he puts in this group are people working on the fringe between skilled and semi-skilled employment, welders, machinists, cutters and the like. These groups, he says, pick the right issues on which to strike from the point of view of a favourable outcome. He also describes the conservative work groups; these are the craft work groups whose disputes are always related to what are viewed as attacks on the status of that particular work group or, for example, where the differential between skilled and semi-skilled gets too narrow. This research is not concerned directly with the other 2 work groups, apathetic and erratic, as described by Sayles (27).

The work and findings by Sayles can be identified in the case studies reported in this research as related to the craft electricians, maintenance engineers and the welders at Caterpillar, Glasgow.

3.8 - MANAGEMENT ATTITUDE TO NEW TECHNOLOGY.

Senior management at Caterpillar, Glasgow in 1964, were divided in their attitude to new N.C., machine tools. Manufacturing management were frustrated with the performance of the original American equipment which was in the main, conventional stand-alone machine tools. Production methods were labour intensive in small batch type productions, output was slow and haphazard. The planning and cost accountant managements were concerned about the size of the investment in N.C., equipment when the plant was still not profitable and they could not justify this equipment on a return on investment analysis, especially when British labour rates were compared to American. Other senior managers were concerned about the consequences of N.C., related to trade union demands and possible resistance.

Ettlie in his research of 10 American organisations who use N.C., equipment, concluded that top management support at the concept stage was an important factor in the successful utilisation of the N.C., machine tool when it was eventually installed (23). Swords Isherwood and Senker observed in their extensive study of British and German users of N.C., equipment, that some top management appeared to be resisting the introduction of N.C., equipment. Actually they were in fact demanding specific returns on investment, which without previous experience, their cost accountants and production engineers were unable to accurately quantify (13).

Despite the division of thinking in the senior management group, the decision was made to seek approval for the acquisition of the first group of N.C., machine tools which were eventually installed in the Glasgow Plant in 1966.

Changes in Organisation Structure.

On the subject of technology and the structure of management, the late Joan Woodward of Imperial College, London is probably the best known and most influencial proponent of the thesis that, contrary to

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much of classical theory - the management structure most appropriate to a firm's requirements largely depends on its technology (26).

Lundgren in a study of 7 companies in the mid west of America in 1969, observed that changes had been made in the organisation structure due to the impact of N. C., technology. These changes showed that a modular type structure as a means to assure an efficient operation had been incorporated as a component of a larger manufacturing system. Figures Nos: 3.1 and 3.2 illustrate the type of structures which Lundgren found in his study of 7 American companies (21). Chapple and Sayles also advocated interrelating the production and organisation structure with the decision-making process affecting the individual, designing the structure from the bottom up, basing the organisation on the actual work flow, and superimposing structure on a known technology (28).

Caterpillar, Glasgow in its evolutionary development of N. C., technology had not attempted to change the organisation at first line management level, but had set up a co-ordinator to programme all N. C., machine tools. This co-ordinator working out of the planning division had informal relations with both the plant engineering staff assigned to the electronics of N. C., and the computer staff for programming hardware and software assistance, but there is no formal structure responsible for N. C., technology. Lundgren in his findings did not appear to take cognisance of the fact that many organisations do not have an N. C., foreman or even an N. C., machine area, but more often it is a mixture of N. C., and conventional machine tools. The changing of the organisation structure to suit the N. C., technology could not be easily achieved with an established mixed technology. Williams and Williams in a research paper on the possible consequences of N. C., technology on organisation structure perceived 2 major implications for the work force, viz:-

- The Horizontal Effect. Pressures require greater and more effective interpersonal relationships between the individuals concerned with the numeric control process.

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Figure No:3.1

Representation existing structure for N.C. shows work flow, information flow and authority flow. Some of the customary formal vertical relationships are bypassed as indicated by the position of the programmer and his links of authority. (After Lundgren)

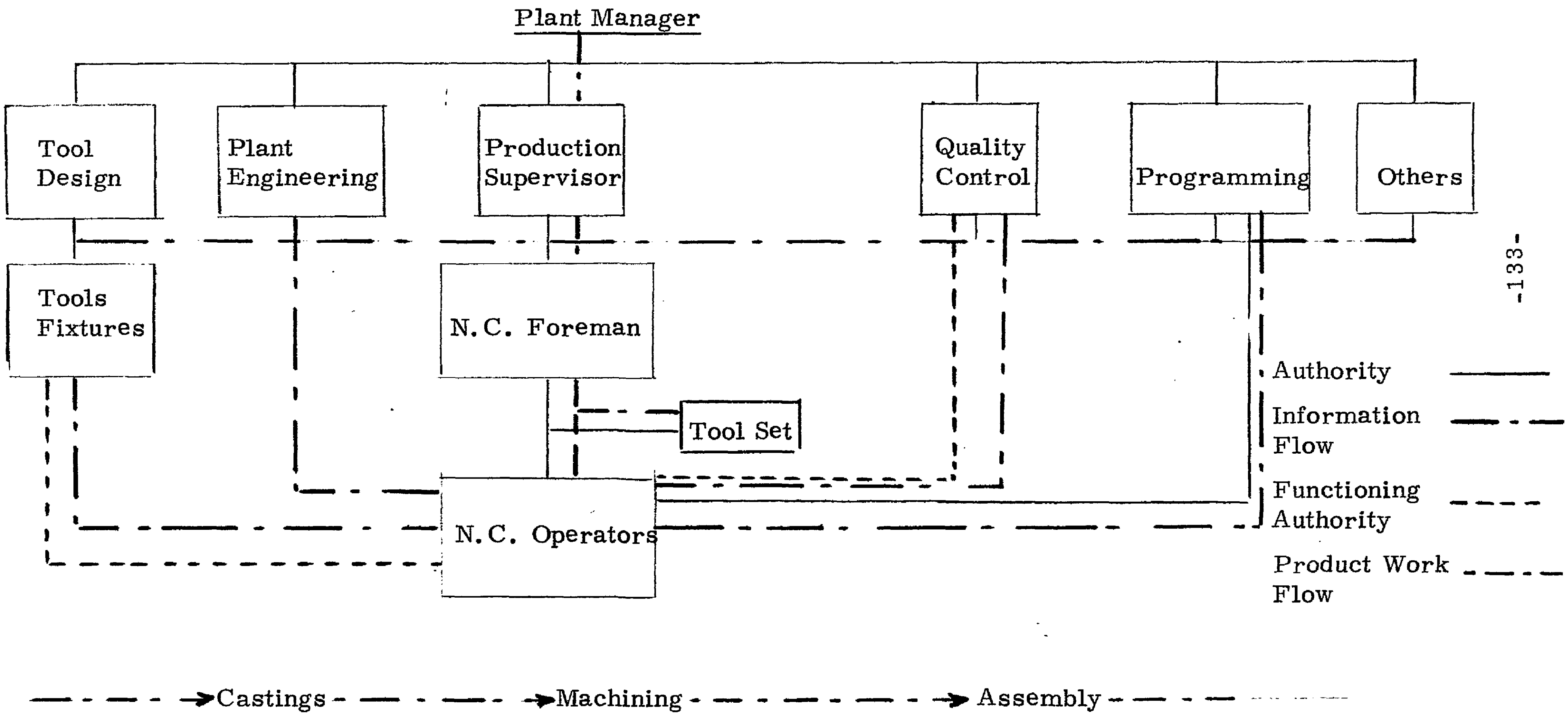
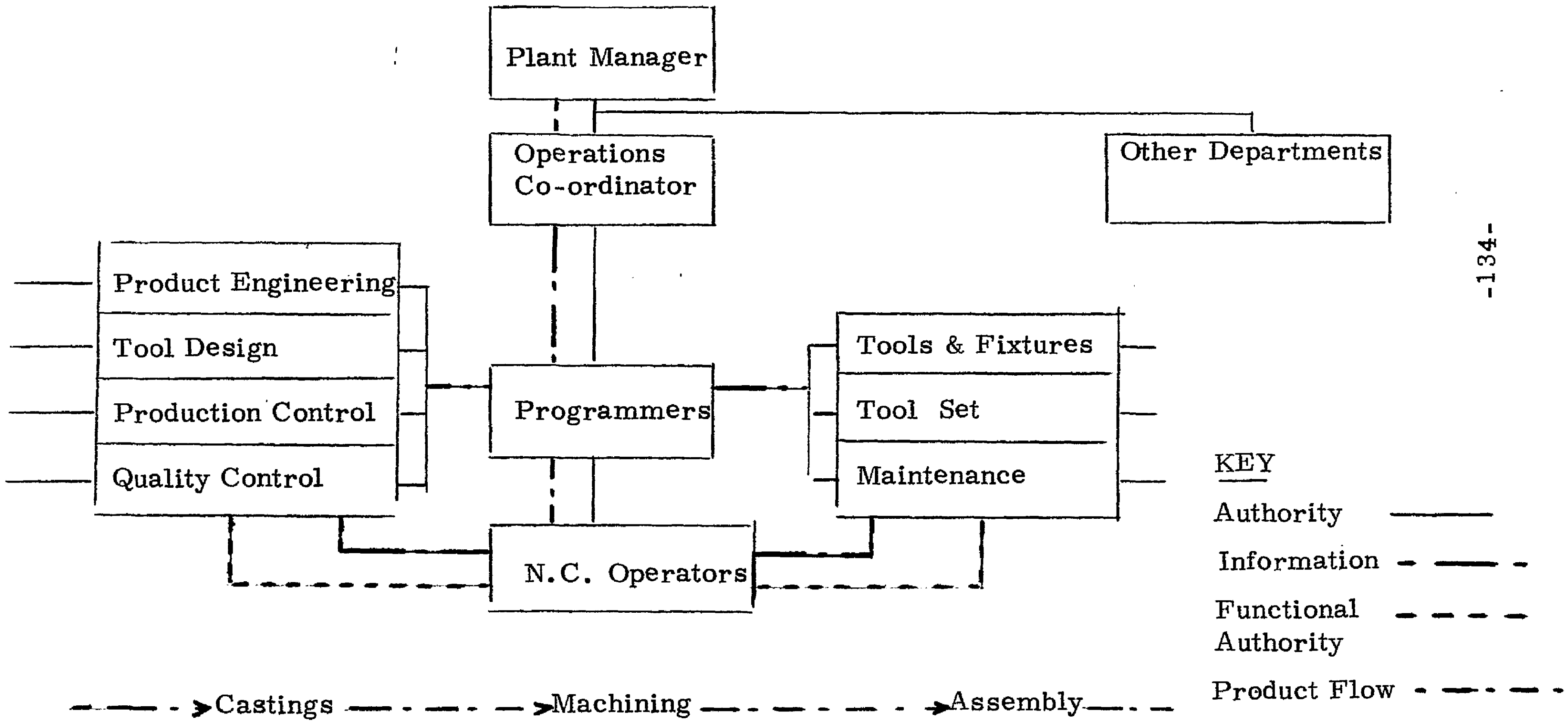


Figure No:3.2

N.C. Programmer is placed directly beneath the operations co-ordinator and in a focal position with respect to the N.C. Team since so much of the work and information flow must be co-ordinated through the programmer. The foreman has been displaced.

(After Lundgren)



- o The Vertical Effect. This arises from the necessity to assign job duties and responsibilities to individuals possessing a high level of technical knowledge (29). Their argument tends to agree with the findings of Lundgren and the changes made by certain companies in order that they effectively utilise the N. C. technology.

Management structure at the Glasgow plant has little relationship to the technology of manufacturing processes but it is closely related to the technology of the prime product produced. Indeed the whole of the Caterpillar worldwide organisation structure is almost identical plant by plant, with perhaps some minor exceptions; this is again almost related to the policy of interchangeable parts no matter in which plant they are produced, they will fit exactly. Equally so managers, supervisors and many of the weekly paid staff, could be exchanged in any number of Caterpillar plants worldwide, and accepting the language barriers, could within a few days carry out the same tasks as they performed in their original plant. However admirable this may appear and it has been effective for many years, the whole question of management structure is coming under question at Caterpillar, not due to changes in the technology of the prime products,but more so related to the use of manufacturing and other technologies which are central to this research. An example of this pressure to change is related to the senior manager responsible for manufacturing the product; up until recently he had control of not only the means to manufacture in terms of labour and equipment, the maintenance of this, the control of production and material flow and also the future technical planning for the plant. Today due to changes in technology and computer systems, production control has gone to another discipline and future planning of very advanced technology has been created into a separate entity. It is not to say that one manager is incapable of controlling the former structure, but more so that the differences in technological knowledge are becoming too varied for one person to competently organise and control on a day to day basis. A new function to be known as technical services has been created and it is anticipated in time that the function of developing and planning advanced technologies for Caterpillar will eventually be linked together with the business of managing the

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computer services, the latter which, as is found in most organisations due to the nature of its early computing tasks, is currently attached to the accounting department. An existing organisation structure for Caterpillar, Glasgow is shown in Figure No: 3.3 with the new proposed organisation structure resulting directly from technological developments.

Factory Line Middle Management.

Initially on the introduction of the first N. C. machine tools to Glasgow plant in 1966, the factory line managers tended to resist the change. This is apparently not an attitude peculiar to Caterpillar as considerable attention has been paid in previous research to the subject of the kinds of people in industrial enterprises who are most likely to welcome or resist change as such. Swords Isherwood and Senker in their research on the Implications of Automated Small Batch Production observed that the problem found in many British firms associated with bringing in N. C. equipment was conservatism in machine shop management, rather than intransigence on the shop floor on the part of the workforce. This conservatism appeared to develop out of lack of knowledge of N. C., a fear of the necessary re-organisation from the purchase of N. C., and a reluctance to accept increased responsibility. (13). Bhattacharyya on the other hand showed that it took in some cases, all of 2 years to get the new N. C. machine tools de-bugged and running smoothly. This situation caused middle line management much frustration and a resistance to further change due to the early unreliability of equipment. (22).

Generally, the observations made of the Caterpillar Glasgow plant situation tends to confirm the common industrial psychological and sociological hypothesis of a curvilinear relationship between job status or position in the firm on the one hand, and receptivity to technological and other changes on the other. That is to say, positive orientations to change have tended to be strongest at the two ends of the organisational hierarchy or continuum. Blue collar workers with job security, improved wage motivations or new status consciousness have tended to exhibit relatively little overall resistance to change (that is, despite

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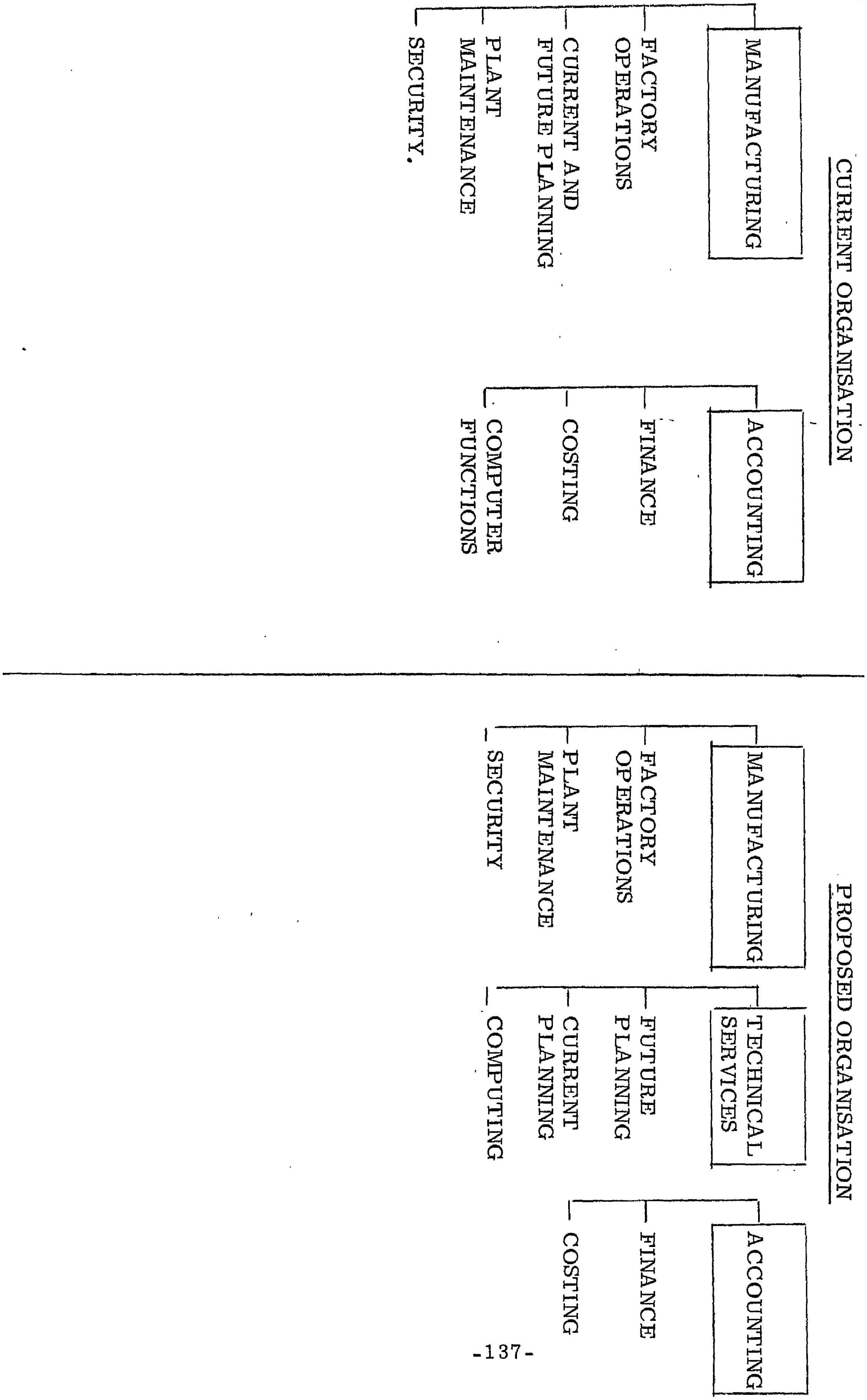
Figure No: 3.3.

GLASGOW PLANT - DEPARTMENTS CONTROLLING NEW TECHNOLOGY



their union's apparent stand for a share of the benefits from the new technology), while at the other end of the scale, technological progressiveness or a market propensity to develop and utilise new technologies, or to make changes, has tended to be a feature of managers and other key personnel with a high degree of professional education and training. Caterpillar's management structure (Figure No: 3.3) displays 2 basic groups, the central manufacturing middle management and the other group occupied by the service functions to this central strata. The former group responsible directly for the day to day output from the machine shop and assembly, exhibited the greatest degree of resistance to change due, it is felt, to the interruption to production it tended to bring to their individual areas. (Production output is the major means of measuring these managers and their resultant success in terms of annual salary review). The fact that many of the new changes were imposed on them by peer management groups in the service areas and most relevant of all, they saw each change as a new round of struggles with hourly union stewards. This latter point was very often unfounded fear of situations that never really came about based on major management/union battles which have been already described in the text.

Champions for Technological Development.

While it was shown that the middle management in the factory operation tended, for their own specific reasons, to resist changes related to technology, by contrast some of their peer management group were champions for the changes. In Glasgow Plant, although previously stated, that much of the new technology was transferred technology from the American parent, it was also noted that technological changes were often the work of individuals in various departments pressing for changes irrespective of whether the result of this change directly affected his or her department.

Two short case studies illustrate this as follows:-

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Case Study No: 3. 5 - Central Breakdown Reporting Systems.

The maintenance manager in 1970 at Caterpillar, Glasgow had no real measure of downtime on production machine tools nor was there any analysis of the causes of downtime, effect on production, replacement or repair cost relationship, etc. He knew that there was little chance of getting this work done manually as the data was too voluminous, nor did he see the opportunity for computer time in the next few years. Yet, despite many setbacks, some obvious sabotage by hourly maintenance men, and not a lot of support from fellow managers, he succeeded in installing a telewriter system in all maintenance stations so that breakdown calls could come to one central point to be recorded and automatically fed by telephone wire to the maintenance man for action. The data cards were all designed with the idea that eventually they could be fed into a computer programme thus building up a data bank on each machine tool. In the short term he installed a manual mechanical sorter system, such that information could be extracted on the downtime performance of critical machine tools. The whole system is now operating very successfully on a computer programme but without this individual manager's application and drive, the project would never have got off the ground.

These observations were also made by studies made by Langrish and others (15) and also by Schon (30), that there was an argument for the importance of the technical organisation entrepreneur or product champion in stimulating change in industry.

Case Study No: 3. 6 - VDU Installed at Receiving.

The manager of quality assurance pushed consistently since 1974 for a major improvement in material handling efficiency especially related to material as received from suppliers, the department responsible for materials eventually got a computer service extended to the receiving depot which linked terminals and visual display units.

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The major benefits were concerned with a more accurate knowledge of inventory, reduction in capital costs and material flow efficiency but the side benefits gained by the quality assurance division were a better measurement of suppliers' quality as received in plant and less damage to material due to reduced handling.

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3.9 - RETURN ON INVESTMENT RELATED TO NEW TECHNOLOGY.

Caterpillar, Glasgow Plant, first invested in N.C., machine tools in 1966 initially to improve productivity and improve accuracy of components being produced. Latterly, the investment in this technology also included reasons such as, complexity of components and the fact that existing conventional equipment was worn out.

It was essential, for the financial viability of the plant, that the anticipated return on investment on this N.C., equipment and other capital equipment be gained. Caterpillar look for minimum rates of return of 20 percent on all projects, with the exception of projects raised for quality, safety or health reasons. Appendix F has a copy of the current form used by Caterpillar to calculate return on investment values, it has 8 specific stages, viz -

- Installed cost less disposed assets and rework costs.
- Next year analysis.
- Return on average investment.
- Recommended action.
- Capital allowance - proposed investment.
- Labour costs and savings.
- Machine repair.
- Other manufacturing factors (tooling, scrap).

This system of analysis has been developed over many years of experience at Caterpillar. The system is dynamic as it is continually reviewed to meet new changes, such as tax conditions and other possible capital allowances.

Reasons why Return on Investment for new technology fails to make the anticipated returns.

Bhattacharyya in an extensive study on Penetration and Utilisation on N.C./C.N.C., machine tools in British Industry (22) published in November 1976, showed that only 5 percent of all the firms in the study

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had 60 percent or more utilisation rates. The reasons for this relatively low utilisation were given as:-

- o No proper organisation to handle N.C. system such as software, planned maintenance and proper leadership.
- o Poor training of operators.
- o Component designers not involved in N.C.
- o Tooling preparation was poorly organised.
- o Programming of software was remote and slow.
- o N.C. was used where a conventional system would have been suitable.

The 5 percent of firms who got 60 percent or over utilisation had all of the above 6 factors well under control. Bhattacharyya illustrated the utilisation by display of the following:-

Machine Utilisation Figures as a Percentage of Shift

Setting Up & Tape Proving:	Tape Running Time:	Maintenance & Repair:
35 (25)	40 (50)	15 (12)

Lack of availability of operator, tools or materials.
10 (13)

( ) Firms in Construction and Vehicle similar to Caterpillar.

In his study in 1970 of 5 British companies on their approach to numerical control of machine tools, Huggins showed how failure resulted in the realisation of R.O.I. These failures resulted in inaccurate calculation of overheads placed against the N.C. machine, inaccurate machining costs, lack of training of maintenance, poor scheduling of raw material to the machine, an over-estimated claim for indirect savings such as accuracy, reduced stocks, reduced lead times and tooling costs, and finally the lack of any proper teamwork related to the N.C. system. Huggins makes 10 proposals to ensure success with the N.C. system and maximise R.O.I. His 10 rules were as follows: (31)

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1. Define objectives for the N. C. system.

2. Formulate a long term plan for N. C.

3. Select N. C., machines with care.

4. Establish realistic machine hour rates.

5. Train all staff properly.

6. Continual feedback to ensure objectives are met.

7. Apply N. C., disciplines to conventional machining.

8. Develop organisation structure for N. C.

9. Meet specifications with the N. C., machine.

10. Review the original objectives and revise if necessary.

John Ettlie in a similar study of 10 organisations in the mid west of America in 1972, showed that when success in terms of utilisation was concerned, there were 9 common indicators among these companies achieving this high utilisation. The 9 factors were as follows:-

1. Emphasis on best location in the machine shop concerning integration with present work flow, trucking, storage of material, pre-set tooling area, maintenance and programming facilities.

2. Total involvement and commitment by all concerned with the N. C., machine at concept stage through to installation stage.

3. A person assigned to programming and given all the necessary computer support.

4. Parts for N. C., were planned ahead, designed to suit N. C., more emphasis on complex parts.

5. Firm had a specific purpose in mind for the N. C., machine and justified it with a rigorous method.

6. Training of all personnel connected with N. C., given special attention.

7. Successful firms in the study had had previous N. C. experience i. e. earlier machines or had lured employees in with N. C. knowledge.

8. Both top and middle management support of the decision to adopt the new N. C., tool.

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9. Communications were important for top management support at the time of decision to purchase N. C., machine.

Swords Isherwood and Senker carried out matched case studies of machine shops in British and West Germany. They concluded that a significant barrier to maximising on utilisation of N. C., was related to poor maintenance organisation and a general reluctance amongst managements to accept new responsibilities. They had to ensure a return on investment, if a machine tool breaks down one was losing the output of 5 machines and that is very serious (13). From the above-mentioned studies therefore, Caterpillar, Glasgow will not be unique in terms of why the initial return on investment shown by the analyst in his analysis, does not always reflect the anticipated return in real terms, and invariably it takes longer to make the return. This phenomenon is not created by poor analytical work nor by inaccurate data at the stage of calculation, but more so as follows:-

1. The machine tool or equipment supplier fails to meet the promised date for the machine tool acceptance trial. (This dilemma is most common with British machine tool builders and least with German machine tools suppliers).

2. When the machine tool acceptance trial is conducted, normally on the builder's site, rejection of the machine is caused by components failing to meet the required specification or for ill-fitting machine guards.

3. The delivery, installation and commission of the equipment takes longer than anticipated due to numerous factors.

4. Early difficulties are experienced with tooling in terms of meeting the required cutting speeds and feeds.

The above are almost all technical problems but the most common miscalculation of all, relates to labour effectiveness and this is assuming that the question of manning as previously discussed has been resolved. (This important observation on labour effectiveness was not made by Bhattacharyya, Swords Isherwood and Senker nor Ettlie in their studies, although they do refer to availability and training of operators as being crucial to successful utilisation). Effective labour utilisation calls for the operator to be cutting metal for an 8-hour shift

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less personal allowance time and tool changing set-up time.

As is the case at Caterpillar, this metal cutting must also be continued through other working shifts, i.e., evening shifts and night shifts, to assure that maximum utilisation of the asset can be realised. Recent research in the study by Abbot (14) and, indeed in the practical example at Goodyear Tyre factory near Glasgow, where in 1979 reluctance on the part of workers to accept shift and overtime work on Friday evenings and nightshift, ultimately led to the complete closure of the factory, much to the astonished disbelief of the local union stewards who had led their members against the management's plan to enforce the extra shifts to maximise utilisation of equipment and change a loss making enterprise to one of profit making, by having workers attend on these specific shifts.

In the Caterpillar case, shift work has never been a real issue for complaint as the system has been working for 20 years and, indeed, some of the employees have been on these shifts constantly for 20 years. Often the question of shift discontentment comes due to rotating of people from one shift to another, a practice which is common in many factories. This system is not used at Caterpillar, and concludes that shift work is not a cause for restraint on new technological change. However Caterpillar does suffer below-expected results from new capital equipment that cannot be explained in terms of technical or organisational difficulties, but this phenomenon of restriction of output is one that is not peculiar to Caterpillar, as it has been shown in the literature that mal-functioning takes place whether related or not to incentive or other wage related systems. Operators do not work constantly or continuously for 8-hour shifts less fixed personal time, especially when on measured day work with no incentive schemes, this is despite adequate supervision and other support systems. Start and stop times are not adhere to, tea-breaks become extended, set-ups with new tooling take longer, raw material does not arrive on time, and so on. The overall outcome is that planned capacity is not realised during normal hours, extra overtime hours

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are worked, often contrived, and the return on investment takes much longer to obtain.

The above dilemma points to a slack management operation of both new and established technology but in the real sense very often the start of those apparently uncontrolled shop floor situations comes about by some external force. The hauliers' strike at the beginning of 1979 resulted in the non arrival of raw materials, management decided not to lay off the work force, work runs out and people have nothing to do. This becomes the norm for a time, people get into habits, such as newspaper reading, extended tea-breaks and such, and when the material starts to flow, it becomes a major task to cut the habit and get back to efficient work.

This research study at Caterpillar would agree with the argument of Ettlie and Huggins on the factors required to ensure successful utilisation, and in the findings of Bhattacharyya, that an organisation especially set up to handle N.C., is a prerequisite to successful utilisation. Further to these findings related to return on investment, the Caterpillar experience of more or less evolutionary development of the N.C., technology, would argue for much closer control of labour effectiveness at the cutting point of the machine tool and for a regular audit of all the factors related to R.O.I., for each machine tool, to ascertain why the return is not being achieved as per the original calculation. Correction and the non repeativeness of these possible weaknesses would make a major contribution to the overall return on investment. Another less measurable saving in investment in N.C., is in fact that of operator skills, as to achieve the same degree of accuracy with conventional equipment, would require a highly skilled machinist. While these advantages cannot readily be measured in monetary terms, they can be highlighted as part of the real effectiveness of the new N.C., technology.

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3.10 - ADVANCE COMMUNICATION OF NEW TECHNOLOGY.

Caterpillar Glasgow plant has a formal channel for communications with hourly blue collar trade unions, as several committees with representatives from both union and management exist. A Joint Works Committee (J.W.C.) discuss all points of negotiation of wages and conditions with management, a Joint Plant Consultative Committee (J.P.C.C.) meet every second week to discuss subjects concerning safety and health, cafeteria, toilets and any general points of complaint. Management use this committee as a means of advising unions formally of market changes which are affecting the sales of the prime product but information on changes in technology either process or product, are allowed to filter informally down through the organisation. Management through experience tend only to answer specific questions as given without being drawn on speculation of possible changes. When a major change has to be implemented,the practice used after the aforementioned informal method,is to run a special meeting with the JPCC followed almost immediately by a group meeting on the line or area directly affected by the change (often this meeting is conducted by the local supervisor who has been given very clear briefings on the consequences of the change). Sometimes, depending upon the extent of the change a noticeboard announcement is displayed within hours of the first communication.

This practice does not obviously always work without some degree of displeasure and/or stoppage, but it has clearly been shown to be the lesser of two evils,as has happened so often with very advanced technical communications which the average shop floor employee neither understands nor wants to know about. Equally the members of the JPCC., despite their office in the hierarchy of the trade union within the plant are not trained to effectively communicate technical matters to their members,especially without the aid of visuals used by management. Invariably the communication which finally gets to the shop floor worker infers some threat to his security and he resists in the best manner he and his fellow workers know how, to impress on management their unwillingness to participate in the new technological change.

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Three brief case studies are given to illustrate the experience at Caterpillar, Glasgow Plant.

Case Study No: 3.7 - Communicating the New Paint Line Technology.

In 1970 a highly advanced paint process was introduced in the plant, the whole system had cost almost one million pounds at that time. This new facility replaced an old antiquated paint tunnel system where the tractor had to be driven into the booth and then painted following a preparation rub down and wash phase. The new facility was the very latest technology for paint application and dispersement of overspray by specially designed air flow systems. The tractor would be placed on a carrier, pulled through the area by a chain conveyor with operatives stationed at predetermined points to rub down, wash, prime and finish paint, finally applying transfers. The new facility was again a major technological achievement for the plant and in their enthusiasm for the system very close communications were held with the painters through each stage of the development. Work standards division had established time elements measured for each man on the conveyor and calculated that the daily output of prime product could be completed on one shift with a given number of people. To achieve this the conveyor had to move at an optimum speed of 12 inches per minute and the union were advised of this proposal well in advance. Subsequently at the introduction to the system the operators suggested that they were on a learning curve and that the conveyor should be run at 7-inches per minute, the line management conceded to this in their effort to get things going, only latterly realising that additional manpower and overtime were necessary to get the same given output. The paint process has never yet reached 12 inches per minute, the same operators are in the area and daily output is just achieved, provided there are no hold-ups prior to paint. The management in this instance had been outflanked by a too knowledgeable work group.

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Case Study No: 3.8 - Communicating The New Weld Technology.

The much acclaimed militant Boilermakers' Society (BMS) members were in 1972 given a short demonstration of a new type improved weld gun fed by a (C. 0_2) carbon dioxide gas fuel source and told bluntly that this was the latest technology which the Company had adopted worldwide for improved welding and environment. The management, in cognisance of the welders' normal hard line resistance, had held off this demonstration to the very last moment, timing it such, it came a few weeks before the annual plant shutdown. During the shutdown piped supplies of C. 0_2 gas was installed in the weld area, new lightweight weld guns were obtained and when the plant re-opened the welders were handed equipment and told to get on with it. There was little communication and absolutely no disruption due to the new technology of welding. The welders considered they had gained better work conditions and the management had gained improved welding, reduced costs and higher output. Importantly the welders had not been given time to ponder all the possible problems that would come about after getting the equipment.

Case Study No: 3.9 - Communications, The Engine Line Change.

At the outset Caterpillar Glasgow plant manufactured all diesel engines for the bulldozers assembled at this plant; in 1969 the rationalisation programmes resulted in the engines for the smaller range of tractors being transferred to the new Caterpillar plant in Belgium where this size engine would be used extensively for another range of product being made at this new facility. When the decision was made to remove this engine from Glasgow, no formal communication was made to the trade union until it was necessary to reduce inventories of raw material, at which time the members of weekly unions would begin to handle the paperwork to control the phase out of the engine, and therefore one union would eventually informally advise the other union of the forthcoming change. Management then formally advised the hourly unions, and in a group, the actual engine assemblers on the assembly line. There was some concern voiced by several hourly employees but no disruption occurred and a very few weeks later the engine was phased

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out, with minimum communication being made. By contrast the new engine for the 1981 model has also to be manufactured outside the Glasgow facility; it will be made in America and shipped as a complete unit to Glasgow. This meant the phasing out of all engine production at Glasgow, as the current model will be replaced and will become obsolete. The decision to import the new engine is again one of unit cost economics, as the American plant making engines is producing very high volumes.

As this change in the engine was only one part of a very large change in both product and process technology at Glasgow, it was considered that advanced communications in a very formal manner should be made. On the day following the first presentation to the most senior hourly union representatives, there was a work stoppage on the engine line (despite the fact that all the assemblers had been given guarantees of new jobs without loss of grading). The stoppage then led to a 2-day strike, a ban on overtime and latterly, a general work to rule, which greatly disrupted the supply of engines to the existing line and also stopped management's plan to increase the stock of completed engines, to permit the earliest possible removal of the assembly line to make room for another installation connected with the new 1981 model. The communication had been advanced, detailed and well presented but it lead to disruption, the assemblers felt that their future was now insecure and they responded to the advanced communication by taking a drop in earnings now because of a concern for the future.

There are many examples of the folly of advanced communication to hourly paid unions and employees at Glasgow Plant of Caterpillar. The radical changes to the aforementioned numerical controlled machine tools proved clearly that too early discussions prior to the arrival of the equipment lead to long discussions with unions, hold-ups in the shop and much disharmony, yet when the management brought in 2 new N.C., turning lathes without any advanced communication, the operatives accepted the manning decisions without any problems. The previously discussed case of the electrical maintenance engineers was another

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prime example of advanced communications and involvement which led to major industrial strife over an extended period of time.

Most prior research on the concept of communicating new technology plans to employees advocate advanced communications as a prerequisite for successful, in terms of fewer problems, introduction to the organisation. Examples of this thinking as related to N. C., machines are found in Bhattacharyya, but he goes beyond the concept of communicating the intention of bringing in N. C., equipment to that of having a full scale education and training programme for all levels of employees (22). Swords Isherwood and Senker observe in their research of both British and German firms using N. C., equipment that some British firms had serious disruption resulting from a failure to consult workers and/or trade unions. In the case of the German firms, they indicated that this could not happen due to the legal framework of industrial relations (13). Ettlie identified forewarning as one of 26 independent variables which influenced the successful utilisation of N. C., equipment. He defined forewarning as the amount of prior knowledge employees and unions had of the purchase and delivery of the new N. C., machine tool. This factor was measured by information on when and which people were notified, and whether they were notified face to face, through written communication or by rumour (23).

On the overall question of technological change and resistance to that change, Woodward states, "people who say that good communication is the only requisite for overcoming resistance to change, we feel are going too far. This does not imply that communication techniques are unimportant, but you can only communicate to the individual what the environment contains and if any changes proposed are against his better interest, if, for example, they are likely to restrict him and increase constraints, no matter how well you communicate, you are obviously not going to overcome his resistance. If an individual is going to be worse off explicitly or implicitly in any

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way when the proposed changes have been made, any resistance is entirely rational in terms of his own best interest. The interests of the organisation and the individual do not always coincide. Inevitably, you cannot escape re-opening the bargaining situation when you introduce any kind of technological change" (26).

Finally and looking to the longer term on the whole question of communication of new technology to trade unions, shop floor workers and all levels of staff, it would appear that some greater form of trust and confidence is required, almost desperately in the British scene. This trust and confidence must be shown by both sides, that is managers and unions, not only at national level but more importantly and effectively at plant shop floor level. Management for their part must continue to seek improvements in costs and quality by the acquisition of more advanced technology, but they must be equally willing to demonstrate the benefits of that improved technology with the employees at all levels in the plant, while at the same time extending guarantees of security of continued employment for specific periods of time (in that if redundancy comes to a plant it must not be as a result of the new technology's impact on the plant). Similarly trade unions for their part and especially at shop floor level, must give guarantees of no strike, no stoppages and no disruption due to the introduction of new technology.

The above proposal will not be easy to implement nor control but, if the survival of the individual plant and the manufacturing industry at large is in question, because of the stop/go performance of a multitude of individual concerns in Britain with the introduction of new technology, then some formulae has to be found. It is hoped that this section of the research has served to prepare the way for that formulae.

3.11 - THE INFLUENCE OF NEW TECHNOLOGY ON GLASGOW PLANT.

New technology and in particular N.C. equipment has had some effect on the whole organisation of the manufacturing facility at Glasgow Plant. How much of this effect has caused the profit margins and return on assets to improve continually over the last ten year period would be extremely difficult to isolate. The N.C. equipment for example, was not acquired in one period but was spread over a 12-year span thus having an evolutionary rather than a revolutionary impact on the machine shop of the Glasgow Plant.

Notwithstanding the 12-year span of moving from 2 N.C. machine tools in 1966 to 26 N.C. machine tools in 1978, it is estimated that 104 conventional machine tools and their operators were displaced due to this new technology in that time. Obviously had the plant attempted to make this change over a shorter period, the impact would have been quite considerable on many aspects of the plant's operations. However the current technology was not available nor was the plant apparently ready to absorb it into its organisation, so the situation did not come about. It is planned to almost double the number of N.C. machine tools by 1982, but it is considered that the impact of this investment will not be as substantial as for the first group, mainly due to the now established experience and organisation structure changes, formal and informal, which have been necessary to meet the needs of the current N.C., family of machine tools.

The percentage of numerical controlled machine tools to conventional machine tools as of 1978 at Glasgow plant is 6.3 percent. Table No: 3.6 shows the total N.C. types of machine tools with the date of installation. The total machine tool population in Glasgow Plant as of December 1977 is given in Table No: 3.7. To determine if there was any effect on results of operations related to the date of installing the N.C. equipment, the following statistics were developed -

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Total List of Numerically Controlled (N.C.) Machine Tools with Electronic Control Systems Identified.

Type	Function	Control	Date of Installation
Cincinatti (2)	Tape Drill	General Electric 2000	1966
Cincinatti (2)	Tape Drill	General Electric 2000	1967
Kearney & Trecker (4)	Machining Centre	Square D Rapac	1968
Cincinatti (4)	Tape Drills	Cincinatti 220/230	1970
Kearney & Trecker (1)	Machining Centre	General Electric 2500	1970
Warner Swasey (4)	Turning Lathes	General Electric 2500	1970
Kearney & Trecker (2)	Machining Centres	Computer Numerical Control	1974
Cincinatti (3)	Special Borers	Cincinatti A.S.	1975
Warner Swazey (2)	Turning Lathes	General Electric 550	1978
Cincinatti (1)	Tape Drills	Cincinatti A10	1978
Allen Bradley (1)	Turning Centre	Program Logic Control	1978

( ) = Total Number of Machines in Group.

Note:
The above total of 26 N.C. machine tools will be increased by a further 23 N.C. machine tools by the end of 1981.

The 1977 status of all machine tools in the Glasgow Plant is continued on the following page.

N.C. is defined as Numerical Control.

C.N.C. is defined as Computer Numerical Control.

MACHINE TOOL POPULATION

Metal Cutting Machine Tools in Glasgow Plant 28-12-77 excluding Indirect Machines.

	Operator Employees:	Machine Tools:
N.C. Machining Centres, N.D. drills and N.C. lathes	46	24
Borers	51	44
Drilling Machines	134	124
Gear Cutters	29	29
Grinding Machines (excluding abrasive machines and honing machines)	48	46
Broaches *	16	14
Lathes	86	71
Milling Machines	53	58
	463	410

* NOTE: Many machine tools are double shifted. Balance of machine tools is 360 indirect machines, making a grand total of 764.

Table No: 3.8

Year	No: of N.C. m/cs Added	Accum. Total	Emp'ment Direct Hourly	Change plus or minus	Return on Assets	Change plus or minus
1965			843		£ 2.76	
1966	2		978		3.45	
1967	2	(4)	1027	+49	7.74	+4.29
1968	4	(8)	1001	-26	13.56	+5.82
1969			1009		10.79	
1970	9	(17)	1029		10.34	
1971			855	-174	12.09	+1.75
1972			794		11.83	
1973			984		18.19	
1974	2	(19)	979		16.69	
1975	3	(22)	990	+11	29.22	+12.53
1976			945	-45	30.03	+0.81
1977			958		52.75	
1978	4	(26)	960		38.14	

Table No: 3.8 shows that the year following the installation of N.C. machine tools resulted in a change in hourly direct employees. (The hourly direct include both machine shop and assembly, therefore increases and decreases could have resulted from changes in model build, as for example, the redundancy in 1971 and 1972 resulted in a substantial drop in employee numbers mostly related to assembly). However it is evident that there has been a steady drop in hourly direct employees with the gradual accumulation of numerical controlled machine tools. The return on assets shown in the year following the installation of N.C. equipment shows a greater change than in other years, with the exception of 1972/1973. This exception is explained as being a combination of reduced labour costs with the aforementioned redundancies, coupled with an increase in sales volume that year.

These results suggest that there has been some positive correlation between the installation and use of the N.C. technology and shifts in employment together with an improvement in return on assets over the 12 years span of accumulating N.C. machine tools. The important implications here are that as Caterpillar Glasgow plant intend to double the number of N.C. machine tools by 1982, then the positive correlation

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to profit and return on investment should continue, all other factors being equal, that is, market and sales. Discounting the fact that these new N. C., machines will cause the displacement of a number of conventional machine tools, this will make the ratio of N. C., to conventional machine tools at Glasgow something in the order of 12 to 15 percent, perhaps higher. This percentage would put the Glasgow Plant, according to the findings of Bhattacharyya, in one of the highest ratio rankings of firms using N. C., equipment in Britain. Bhattacharyya however states in one of his conclusions of British users that "it is unlikely that complex systems will penetrate any further to a substantial extent because most firms do not process highly complex components, or have the finance to invest or have the capability from the point of view of trained personnel to exploit complex systems" (22). Certainly these factors are all applicable to the Caterpillar Plant at Glasgow, although the finance will be available if ROI can be justified. The question of trained personnel will again be a challenge which will be met probably in an evolutionary process over the years as the equipment is acquired.

3.12 - OBSERVED EFFECTS OF NEW TECHNOLOGY.

The objective of chapter 3 was to report the findings of a pilot study made on a single manufacturing plant. The purpose of this final section to this chapter is to draw together these findings as they relate to the 6 factors of the enterprise namely, organisation structure, management, strategies, machine shop environment, control systems and people, and to gain further information to support the central argument of this research that new technology is having an impact on these factors. The factors are displayed in Table No: 3.9 and are briefly discussed as follows:-

<u>Organisation Structure.</u>

Section 3.8 of this chapter discussed the effect of the numerical control machine tool technology on the structure of the organisation. It was shown that the manufacturing hierarchy was under such pressure due to new technologies that a split was necessary so that a new department was created to be concerned almost entirely with new technologies. The current and proposed structures are shown in Figure No: 3.3 page 137. Essentially the pressure to change was identified as a vertical effect, in that it could not be resolved with merely the widening of the span of control of the senior manager. The necessity to assign job duties and responsibilities to individuals possessing a high level of technical knowledge was clearly evident. Functional lines of authority had already been established informally between the planning group and the N. C., users at the machine tool operating level but direct levels of authority remained unchanged, in that the N. C., machine tool operator is supervised by a production supervisor and not by the monthly paid staff engineer who controls the operation of the machine tool.

<u>Management.</u>

Top management initially did not give full support to the investment of the new N. C., technology mainly due to their concern for obtaining a return on investment. Latterly and with increasing profit

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margins as shown in Table No:3. 3 page 107, the top management group changed to a full supporting policy. Middle management were observed to resist the new equipment for 2 main reasons, firstly a concern for the reliability of the complex controls, and secondly, as the new equipment brought problems from the shop floor union group, there was therefore an initial reluctance to accept responsibilities for the equipment by the middle management group. This resistance tended to moderate as the N. C., equipment became more reliable and the early trade union disputes disappeared. Evidence in the text (see section 3. 8 and Champions for Technological Development, page 138), showed that much innovation for new technology tended to emanate from middle management ranks.

Strategies.

Although Caterpillar Tractor Company have operated a strict management by objectives policy for a number of years, there were several observed effects on these objectives indirectly related to the introduction of the new N. C.technology. It was shown that the key objectives such as return on invested capital improved in conjunction with profit and sales. Indeed all of the measures shown in section 3. 4 of this chapter indicated a positive direction with the introduction of N. C., equipment. At the outset of the new N. C., machine tools, no long term plans were in evidence, it appeared to be a question of trial and error with many different types of machine tools and control systems. Currently a more positive approach is underway but the long term plans are more related to the product than the process, which may still be a weakness in the overall system if maximum effectiveness is the major strategy. Education and training policies appear to have moved from a zero base, to an as required approach, and thus appear to be haphazard. It was noted in the text,section 3. 6 that a special team had been created within the planning division to be solely concerned with N. C. technology.

Machine Shop Environment.

In this research environment is concerned with the physical nature of the new technology and its impact on the machine shop layout. As was

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shown in the text and with reference to Table No:3.6, there was a steady growth of N. C. machine tool equipment from 1966 onwards but the selection of the early models as previously mentioned tended to be haphazard. Indeed the strict discipline for machine tool capability checks did not exist at the beginning and this resulted in problems concerned with specifications of component parts. The decisions concerning location of N. C. equipment again initially was haphazard. There was no thought given to group technology, work flow lines or some logical integration with conventional machine tools. The first N. C. machine tools were surrounded by wire fences and lockable doors to prevent people interfering with the complex controls. Regrettably this policy also resulted in disadvantages with the movement of material and other factors. Current policy is moving towards a group technology concept with families of N. C., machine tools and conventional machine tools performing complete production all operation runs. The policy for maintenance was discussed at length in the text in section 3. 6 page 119,, and it was shown that a policy of in-house maintenance was adopted from the beginning to cope with the needs of the new technology.

Control Systems.

Section 3. 4 of this chapter discussed at length the control system operating at Glasgow Plant. The contribution by the new technology of N. C., machine tools was closely monitored and as was previously concluded, served to provide an increased performance. The detailed system for analysing the actual return on investment was discussed in section 3. 9, and many reasons were discussed concerning why ROI is not achieved by firms, but in the Caterpillar case study, it was observed that operator utilisation was a major mis-calculation and resulted in the extension of time periods until the return investment was achieved. The whole success of the new technology and therefore its effect on the enterprise is strongly correlated to the efficiency achieved at the point of usage.

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People

Chapter 3 showed that many people at various levels in the structure had been affected by the new N. C., machine tools. Some employees as was shown in section 3. 5, were affected almost surreptitiously by shifts in employment. In that N. C., equipment was introduced some operators were transferred without loss of grade to other conventional machine tools and when other employees left the firm by retirement or other reasons, then they were not replaced by newly hired employees. However Table No: 3. 5 shows that since the introduction of N. C., equipment and discounting the years of redundancy, hourly blue collar employees have increased while weekly and monthly groups have decreased in numbers. On the effect of new technology on skill, no observed change was noted for operator level employees, if anything there was some indication of increased skill. The maintenance group did certainly gain new and higher skill levels with the introduction of the new equipment, so equally did some of the weekly and monthly staff engineers, who were involved in programming and systems for this equipment. One group, as reported in the text, who appeared to lose, was the first line supervisor whose skill and knowledge in scheduling and machining techniques appear to diminish with the increase of N. C., technology.

Absolutely no resistance was observed from the hourly or weekly payroll employees on the proposal to introduce new N. C., machine tools. This is not to say that there were no problems, for as Woodward stated, "you cannot escape re-opening the bargaining situation when you introduce any kind of technological change". (26).

The effect of the new N. C., equipment on the overall job satisfaction of the users was not tested in detail, but observations showed no real evidence of dissatisfaction such as absenteeism, increased labour turnover and the like. The new equipment did have an observed effect on manning policies on machine tools, payment structures and the status of the equipment operator. All of these subjects were discussed by case study in this chapter.

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Table No: 3.9

OBSERVED EFFECTS OF NEW TECHNOLOGY

SINGLE MANUFACTURING PLANT N.C. MACHINE TOOLS

Factor	Element	Change Type:	Effect
Organisation Structure	Horizontal Pressures	B	Minimal
	Vertical Pressures	A	New Division
	Direct Authority Lines	D	None
	Functional -do-	C	Informal
	Information flow lines	B	Numerous
	Work flow disciplines	B	Improved
	Informal - Formal	B	Formalised
Management	Support-Top Manager	A	Moderate to Strong
	Support-Middle Manager	D	Low
	Involvement	C	High
	Acceptance-Responsibilities	C	Low to High
	Innovators.	A	Middle Levels
Strategies	Objectives	B	Unrelated to Related
	Long Term Plans	C	Minimal
	Education-Training	D	Nil
	Teams-Teamwork	A	Informal
Machine-Shop Environment	Growth	A	Steady
	Selection	B	Haphazard
	Location	C	Compromised
	Maintenance	A.	Organised
Control Systems	R.O.I. Contribution	A	Rigorous Monitor
	Utilisation	B	Poor to moderate
	Efficiency	B	Low to Improving
People	Employment Shifts	A	Marginal
	Skills	B	Increasing
	Resistance	D	None
	Integration	D	None
	Satisfaction	C	No Change
	Manning	A	Reducing
	Status	B	Increasing
	Influence	C	Increasing

Change Type - A-One step Change, B-Cumulative Change.
C-Continuous Change, D-Nil or Not Observed.

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CONNECTING SUMMARY

- Chapter 3 opened the main argument of this research project by taking the study directly into the single manufacturing plant of Caterpillar Tractor Company at Glasgow. As a background to the strategy used to establish the Glasgow Plant, a brief history was given detailing the various early problems with this subsidiary of an American multinational related to planning the establishment, transferring technology and in particular, problems with people. As the manufacturing technology of numerical controlled (N. C.) machine tools was the turning point for technological change at Glasgow, this N. C., technology was the causal effect that led the company towards advanced measuring machines. It was judged important to the pattern of the research that the N. C., machine tool technology as it related to the Glasgow facility, be studied primarily. The resultant effects of N. C., technology were therefore discussed, and in particular, how this was to have an impact on organisation structures, management production systems, the decision-making process, and people at all levels in the Caterpillar plant at Glasgow. Specific conclusions were established for this first part of the study of the single manufacturing plant and the consequences of new technologies. These conclusions were outlined in the text of chapter 3 so that they can be later correlated with the results obtained from the forthcoming analysis.

- The objective of chapter 4 is to research the impact of measuring machine technology on the single manufacturing plant. There has been no known previous research done in this importand branch of manufacturing industry; most previous research work has been with numerical controlled machine tools as far as the manufacturing plant was concerned, and with computers in the office functions of manufacturing industry,

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CHAPTER 4 - New Measuring Machine Technology in the Single Manufacturing Plant.

4.1 - THE OBJECTIVE OF THIS CHAPTER.

The objective of chapter 4 is to study the effects of new measuring machine technology on a single manufacturing plant. The specific aims of the study will be to analyse the following factors:-

1. Developments of inspection and measuring machines.
2. Effects of new measuring machine technology on the organisation.
3. Psychological advantages gained by people with new technology.
4. Acceptance of change of jobs due to the integration of new technology.
5. Problems associated with de-skilling, less knowledge and manpower reduction due to new technology.

The text material will be further supported by information committed to Appendix, which will cover the following subjects:-

- Savings achieved by improving co-ordinate measuring machine capacity.
- Results of an experiment carried out to establish the time savings when using manual, semi-computer and full computer-assisted measuring machines.
- How an attitude survey was designed and launched. 2 sample questionnaires are also included with the appendix material.

Highlights of Aims and Findings.

There were specific reasons why the Caterpillar Tractor Plant at Glasgow had to move towards more sophisticated measuring systems. Among the major reasons were the development and utilisation of numerical controlled (N. C.) machine tools as described in chapter 3. These N. C., machines increased output, improved accuracies and fostered the design of more complex components which hitherto could not be machined in one piece but generally had to be fabricated or machined by a variety of machine tools. Inspection had several alternative methods of meeting these above requirements and these are discussed in the text. One alternative was

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the measuring machines in use at Glasgow Plant. This section of the research project is supported by an exercise conducted at the plant in order to test the claims made by suppliers of these measuring machines; that substantial time savings can be achieved in the measuring process. The results of this exercise are contained in the Appendices.

Organisation of the quality control department was observed to be subjected to several phases of change due to the introduction of the new measuring machine. These changes were related in particular to horizontal pressures on the existing span of control and vertical pressures on the existing hierarchical levels of management. Initially as the new measuring technology was introduced, informal organisation systems were established as a means of effecting a communication stream from the planners to the users. Eventually these informal systems were formalised and new channels were established for authority, information and workflow activities.

The impact of new measuring machine technology on the people most closely associated with the work of inspection, appears to have had some psychological advantages to these people. Through an attitude survey, the opinions of inspectors assigned to these machines and of inspectors who remained on conventional measuring equipment were collected. Important questions concerned with status, confidence, concern, influence, power and satisfaction were investigated in this section of the research project. Reference is made to prior research in the literature which has some relationship to this study, and comparisons are drawn against other findings and conclusions.

The next section of this study examines the attitude of people to the possibility of integration of jobs due to the future merging of technologies. This will be a very difficult and on-going problem, not only in industry, but in many other business activities. Indeed the problem has not yet manifested itself in manufacturing industry the way it has developed so dramatically in, for example, the newspaper printing business: the Times newspaper dispute in 1979 is an example (32). Manufacturing industry for many reasons could not change so quickly in that the process is evolutionary rather than revolutionary. First signs of change in manufacturing industry brought on by new technologies appeared with the introduction of numerical controlled machine tools as discussed in chapter 3, but these changes tended to displace people rather than attempt to alter their task. This section of the study looks at the problems associated with changing the task and the degree of acceptance to this change by the individuals who would be associated most directly.

Previous research in the literature suggests that automation or forms of new technology which simplify the task, will invariably lead to a de-skilling of the operator, cause less demand for technical knowledge or experience, and eventually result in fewer people. The reaction by craft inspectors to the consequences of new measuring machine technologies on their skill, knowledge and security was tested in the attitude survey. An interesting spread of responses were obtained ranging from a posture of high concern to one of being encouraged by the progress of technology, irrespective of the consequences to the individual.

The final section of this chapter attempts to draw together the overall observed effects of the new measuring machine technology on the single manufacturing plant. The observed effects on some of the elements of the previously identified factors of the enterprise namely, organisation structure, management, strategies, machine shop environment, control systems and people are displayed in Table No: 4.4, and briefly discussed in this final section where the text matter in the previous sections of the chapter was considered insufficient to explain the findings.

The overall conclusions drawn from this section of the research project are discussed and listed in the final section of this chapter.

Some of the findings from the 2 questionnaires shown in Appendices I and J, have not been discussed in the text of this chapter, as it was considered they were insignificant to the argument of this thesis.

Related Prior Research.

The introduction of measuring machines at Caterpillar, Glasgow Plant as discussed in this chapter, is clearly related to a need to match the increased production brought about by the growth of other technologies such as, advanced numerical controlled machine tools, to confirm the vastly improved accuracies of these machine tools in terms of production capabilities against blueprint specifications, and to achieve the realisation of a return on investment from the aforementioned considerable capital outlay.

In chapter 3, reference was made to the reaction by various labour groups to the changing pattern of technology over the 20 years of the plant's existence at Glasgow, and in particular to the general policy adopted by the local trade union leaders on the whole question of new technology. The purpose of this chapter is to explore in depth the effects of one type of new technology on one particular group of employees and to try to ascertain their attitudes and opinions, and their primary tasks within the machine shop environment. There have been numerous amounts of research done of the overall question of technological change, job satisfaction and work roles and this is reflected in the published literature on these subjects: however most of this previous research tends to be rather general and non-specific within the industrial scenario. For example, and going back over 20 years to 1952, Charles Walker and Robert Guest investigated the problems associated with men working on a car assembly line of General Motors in America. Although this research was of a pioneering type and did help to lay the foundation for further research in this area of job satisfaction and job enlargement, the central technology, both product and means of production, was secondary in that it could have been a sewing machine assembly line or alarm clocks - the findings would have been to some degree parallel (33).

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Similarly in the study by Chinoy (34) on car assembly-line work, he found that the work demands minute specialisation on a sub role action or task basis. The work is mechanically controlled in pace, repetitive and requires very little skill and only surface attention. He goes on to describe how the worker has little sense of control over the job or of making any significant personal contribution to the final product. Both researchers made recommendations of various ways in which levels of intrinsic work satisfaction on assembly lines might be raised by job enlargement, job rotation, the formation of team groups of workers, and the exercise of "human relations" skills by foremen. Since that time organisations such as Volvo in Sweden have attempted to make revolutionary changes to the original Henry Ford assembly line and recently Fiat of Italy have demonstrated in the media their development of the robot assembly line.

Emery and Thorsrud have attempted to lay down a set of general principles of good job design for all types of technical-production systems (35). These principles were obviously in part inspired by the classic study of E. L. Trist et al, of 2 alternative modern means of organising coal-mining work in North Durham within the broad limits imposed by technology (36). Blauner distinguishes 4 main types of technology on the basis of degree of mechanisation and standardisation of the product - craft, machine operation, assembly-line and process - and hypothesises that, other factors being equal, the problem of alienation or job dissatisfaction will be greater in the assembly-line types of industries where the fragmentation of skills and the process of rationalisation of the production of standardised items has been carried further (37).

In contrast to the abovementioned studies, this section of research does not attempt to embrace a large workgroup such as an assembly line worker nor does it look at general skills or job design, it specifically penetrates deeply the "craft" element identified by Blauner and centres on the particular engineering skills of the manufacturing industrial inspector and directly relates itself to the

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technology central to the performance of his task within the factory. From this very aspect, it is considered that this research is unique and unparallel in any previous studies within the industrial manufacturing environment, and therefore argues a special case for the introduction of new technology. The so called craftsman employed within the industrial enterprise has a higher degree of status than the semi or unskilled employee. Inspectors within this craftsman group are again of a different elite probably related to the fact that the nature of work causes the craft inspector to arbitrate the work of other craftsmen, or in the case of Caterpillar, the work of semi-skilled machine operators. All inspectors at Caterpillar, Glasgow are time-served engineers, a basic prerequisite for qualifying for the job.

4.2 - DEVELOPMENT OF INSPECTION AND MEASURING MACHINE AT CATERPILLAR, GLASGOW.

Until July 1968, Glasgow Plant had depended upon conventional means of inspection and measurement mainly related to large granite surface tables as a base datum. Measuring instruments such as height gauges, micrometers, calipers, steel rules, block gauges and other similar tools had been the only basic technology available since the Industrial Revolution, with many refinements over the years. Despite the apparent age of the technology, these instruments in the hands of skilled inspectors could measure to accuracies of tenths of a thousand part of the imperial inch and thus were able to adequately control the quality of the production within the established specifications and tolerances as described in the blueprint of each component.

The significant change at Glasgow Plant which forced some new thinking on the inspection methods was brought about by the increase in productivity realised from the N. C., and other equipment, as described in the previous chapter, which was installed and operational in the mid 1960s. There were several alternatives open to the inspection management at that time to meet the increase, some of these alternatives were as follows:-

1. To employ more inspection manpower with more conventional equipment, i. e. surface plates.
2. To measure statistically by taking random samples of the production in the hope that the total population would be covered and trends identified for correction.
3. To sub-contract some inspection work outside the plant to some special service group.
4. To reduce output or rationalise production with other Caterpillar plants and thus increase volumes with fewer parts.
5. Work additional hours such as overtime to cover the work.
6. Find a faster means of measuring the given volume of components without dropping the accuracy of measurement.

Only alternative No: 6 was acceptable to Glasgow Plant at that time. There was no way that additional labour would be added to the indirect

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labour workforce and the risk element in trying to statistically check small batch production was too great. The question of sub-contracting of work for inspection was not only impractical and costly, but it just would not have been agreed to by the hourly trade unions, as they would claim that work was being taken away which could have been covered by their members on overtime if necessary or by employing more people. Geographic distance made it impractical for any rationalisation of the production with other Caterpillar plants and the cost would have been prohibitive. Overtime work must be considered as a buffer for emergencies and cannot or should not be planned into the capacity of the function.

Caterpillar plants in America had gained some experience with measuring machines by 1967 as the major plant at East Peoria, Illinois had been using this technology from 1962. Therefore some guidance was available to the Quality Control management at Glasgow on what was on the market which suited the typical Caterpillar component. In November 1967 a request for investment was made for a model 72A Portage Mark Off machine complete with attachment and table. (Plate No:4.1). This machine was requested to cope with the steadily increasing load of work on the surface plate in the Castings Receiving Section. This section was responsible for the inspection of all castings and forgings received by the plant and had been experiencing increasing difficulty in coping with the volume of new castings and forgings being introduced and the large volume of current material passing through the area at that time. This area was identified as the main bottleneck for inspection and therefore the best place to realise an effective return on investment, and the machine was installed in July 1968 at a total cost of £4,825. A second machine was requested for investment in January 1968, this was a Ferranti Cordax Measuring Machine, Model 300 with 3-axes simultaneous read-out, but was purely a manual type of control machine as shown in Plate No:4.3. This machine was requested by the Inspection Division to provide a more efficient inspection facility for checking pump parts, which were produced on Heald Borematics and miscellaneous parts produced on a new

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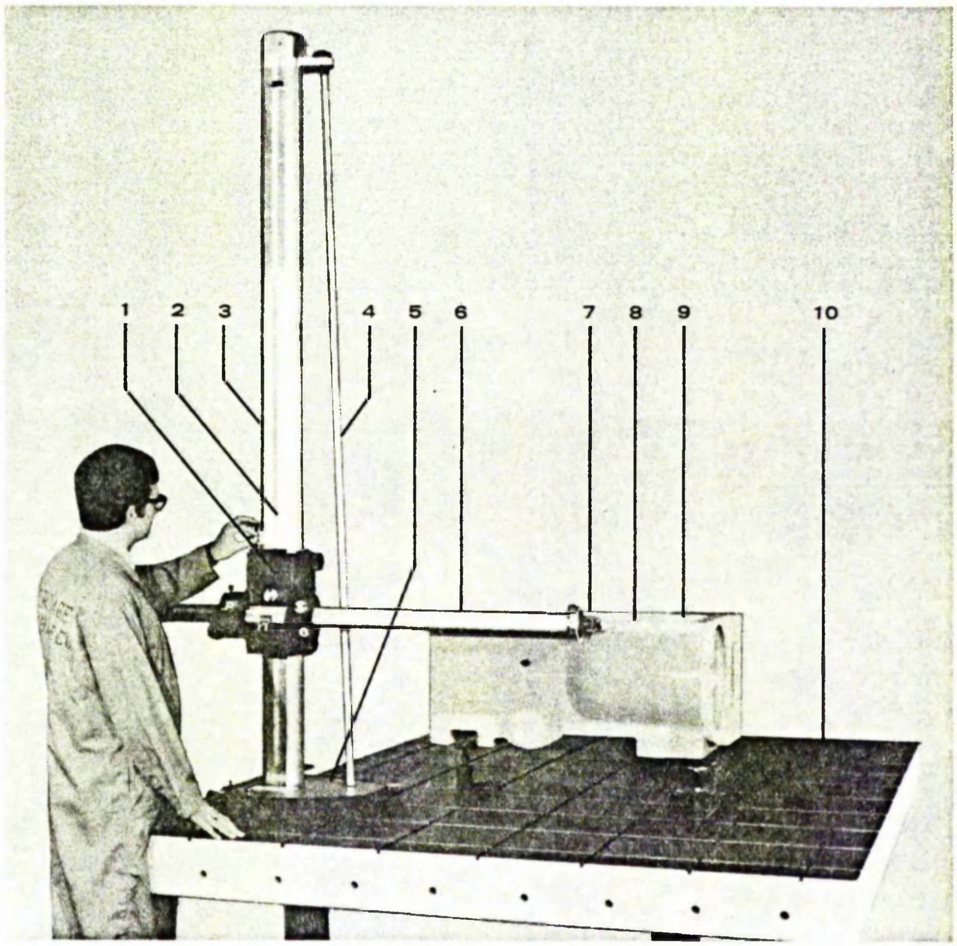
The Portage 72A Mark Off Inspection Machine

Standard Layout Machine



Standard Layout Machine Nomenclature

1. Head Assembly
2. Linear Scale Bar
3. Column
4. Counter Weight Pulley
5. Base
6. Horizontal Cross Arm
7. Control Rod
8. Combination Scriber
9. Workpiece
10. Table

Cincinnati N. C. machine. Based on Glasgow's Planning Division visit to other users of a similar machine and on information received from Caterpillar's American Joliet and San Leandro plants, it was estimated that measurements would be completed in one third of the normal surface plate time, resulting in attractive labour savings and reduced machine waiting time. At that time the conventional surface plate checking was causing serious hold ups on the aforementioned machine tools. The inspection check was required to ensure dimensional accuracy on the first part produced, prior to commencing the production run - this is called Set-Up Approval. The machine was finally installed at the hydraulics machine line in July 1968 at a total cost of £8, 423. However in 1969 corporate rationalisation of Glasgow plant's product line moved production of pumps back to America and the measuring machine was relocated to a miscellaneous small parts area check-out, where it was used mainly for checking hole patterns, for a wide variety of components.

In May 1969 a request for investment was raised for an American manufactured Portage Inspection machine model 350 with 3-axes readout and print-out, supplied with a 48" x 48" set up plate, to be installed in the final checkout area (Plate No: 4. 2). This request was made on the grounds that the area had been an inspection bottleneck for some time, due to the range of large castings and welded fabrications with close tolerance machine characteristics. One large part such as a bevel gear case or an engine block for the largest of the three prime products could tie up the surface plate for a whole eight hour shift. Comprehensive checking fixtures had previously been used, but these were expensive to make, awkward to use, bulky to store and were found to be inflexible and inaccurate. These factors resulted in insufficient coverage by Inspection of quality and quantity. It was forecasted that the position would further deteriorate as more N. C. machines were introduced in this area, as these would increase production capacity and require a rapid feed back of "first off" information from Inspection. The inspection machine was installed in August 1970 at a total cost of £42, 554.

The Portage 350 Inspection Machine

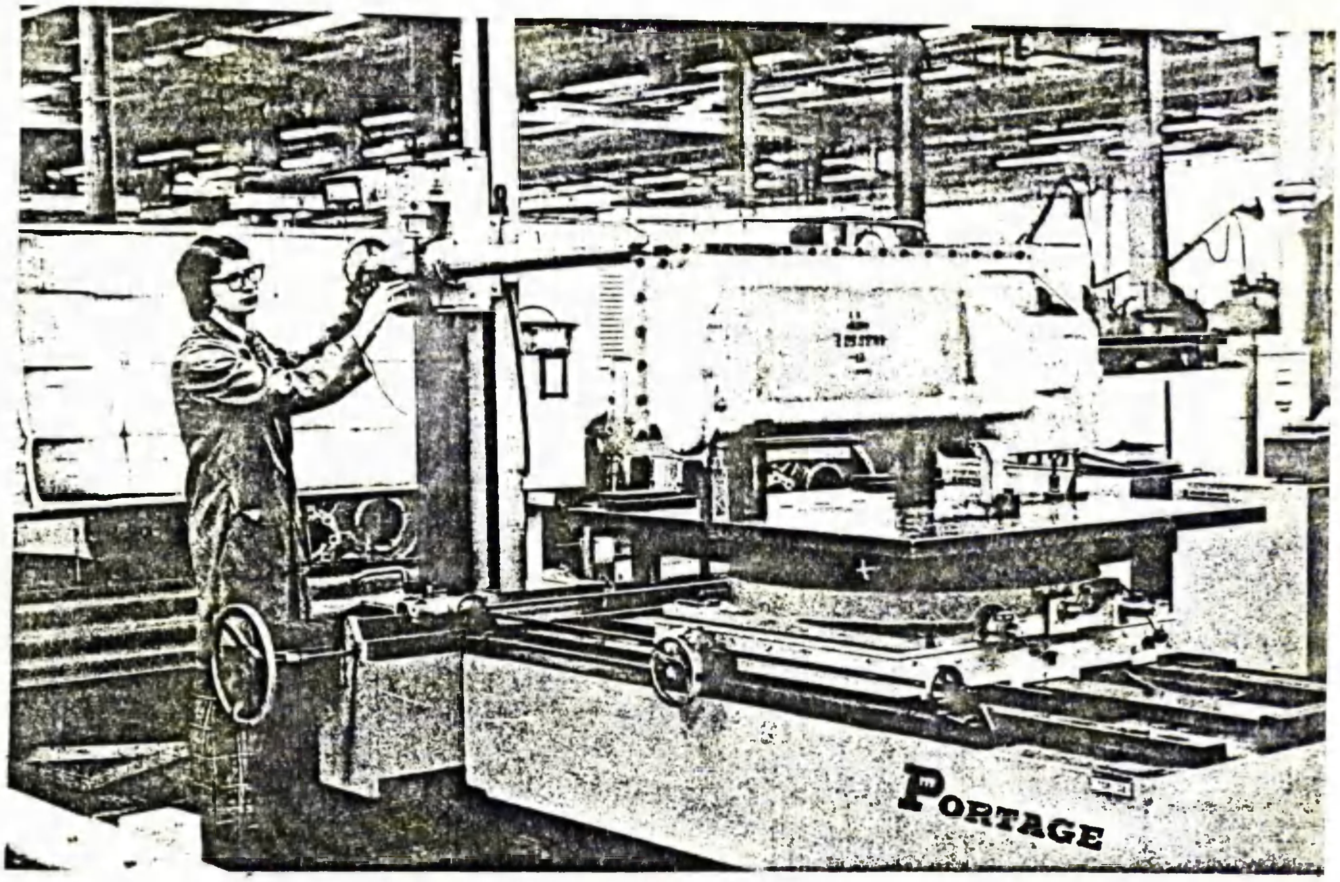
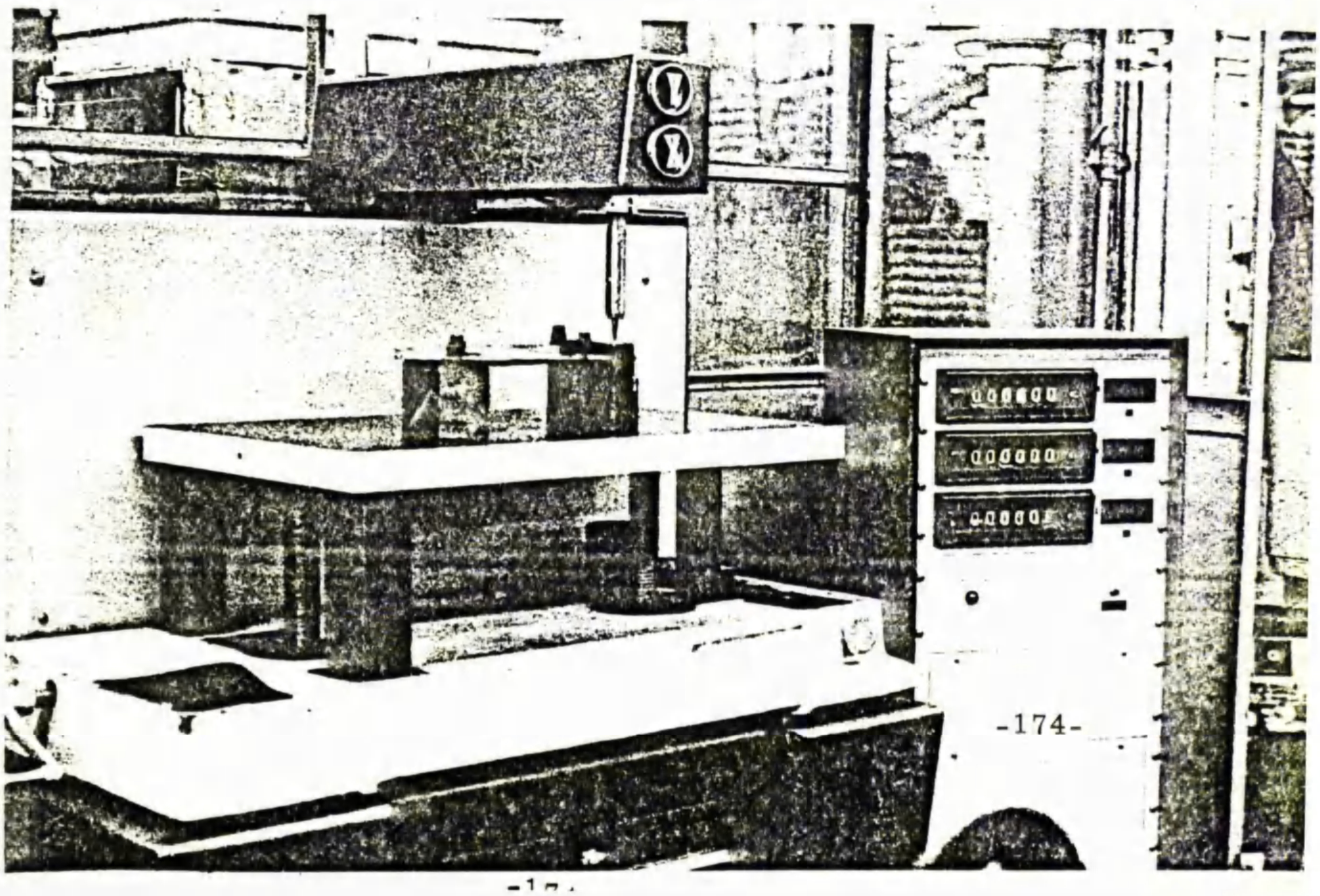


PLATE No: 4.3

The Ferranti Cordax 300 Manual 3 Co-ordinate Measuring Machine



Five years later in May 1975 another project was raised to investigate the co-ordinate measuring machine capacity against the demands of the shop floor at that time and to forward proposals for improvement, if the investigation warranted such improvement. The report highlighted that whilst the two original CMMs in the machine shop were fully burdened and manned on 3-shifts, they were only now checking approximately 20% of the production checking requirements. It was therefore recommended that to cover present and future demands on Quality Control, two computer-assisted CMMs be purchased; one to cover the numerical controlled hydraulics, undercarriage and miscellaneous small parts areas which were predominantely a large batch type of production system area, and a second to cover the miscellaneous large parts area which was a small batch high value type production area. The forecasted annual saving by investing in 2 such machines was estimated as £44,330 based on a return on investment analysis as shown in Appendix G. A selected range of computer-assisted co-ordinate measuring machines manufactured by L.K. Tools, D.E.A. and Ferranti were reviewed at suppliers' and other users' premises by Quality Assurance personnel. Each machine was evaluated for quality of manufacture, design, measuring accuracy, measuring stroke, travel on all axes, computer software package and cost. One measuring machine considered suitable for each application was proposed by each manufacturer for assessment. The CCMM for the miscellaneous large parts area would service an approximate total of 50 production machines, comprising of numerical controlled Cincinnati horizontal borers, Sunstrand borers and standard machines such as Scheiss borers, Herbert Devlig jigmills, Ex-cello borers and Morando auto lathes. The CCMM purchased for this area would require a repeatability accuracy of $\pm$ 0.0002" based on the tolerances required from components produced in this area, and its stroke travel on all axes had to be capable of measuring the largest components, for example cylinder blocks for a 300 H.P. diesel engine. The three machines evaluated were:-

A. L.K. Maxi check 4670 - 53.

B. D.E.A. Dez 'H'.

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C. Ferranti Saturn 2000S.

The results of the comparison and evaluation were as follows:-

Vendor	Ferranti	Indus. Sales	SIP
Manufacturer	Ferranti	L. K.	D. E. A.
Model	Saturn 2000S	model 4670-39	Beta DE2H
Table Surface Area	80"x54"	96"x60"	63"x31"
Probe Stroke			
'X'	78"	68"	70"
'Y'	49"	46"	39"
'Z'	39"	$46\frac{1}{2}$"	39"
Resolution	0.0002"	0.0001"	0.0001"
Accuracy			
'X'	±0.0012"	± 0.001"	±0.001"
'Y'	±0.0012"	±0.0008"	±0.0008"
'Z'	±0.0006"	±0.0008"	±0.0006"
Computer Group	PDP8/M8K	PDP8/F8K	PDP8/8K
Daylight	39"	53"	34"
Delivery	6 months	3 months	2 months
Cost	£35,834	£48,925	£74,287
Cabinet	£100	£100	£100
Installation	£2,154	£2,154	£2,154
Total Cost	£38,088	£51,179	£76,541

Reason for selection of the first computer assisted measuring machine.

The Saturn 2000S was selected on a suitability and cost savings basis. Generally all comparisons were compatible but the Saturn provided greater reach on 'X' and 'Y' axes, the marginal difference in accuracy was considered negligible. The Quality Assurance Division witnessed a demonstration of this machine at the Ferranti Plant near Edinburgh and were impressed by its capabilities. (Plate No: 4.5). A second CCMM for the numerical controlled area would service an approximate total of 66 production machines comprising of numerical controlled Milwaukeematic "E/A" machines, Milwaukeematic Series 200s, Warner Swasey S.C. 28 and standard machines such as Ex-cello borers, Morando lathes and Archdale multi-spindle drills. The parts produced in this area are complex, closely toleranced, for example ± 0.005"

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The D. E. A. Gamma Computer Assisted Measuring Machine

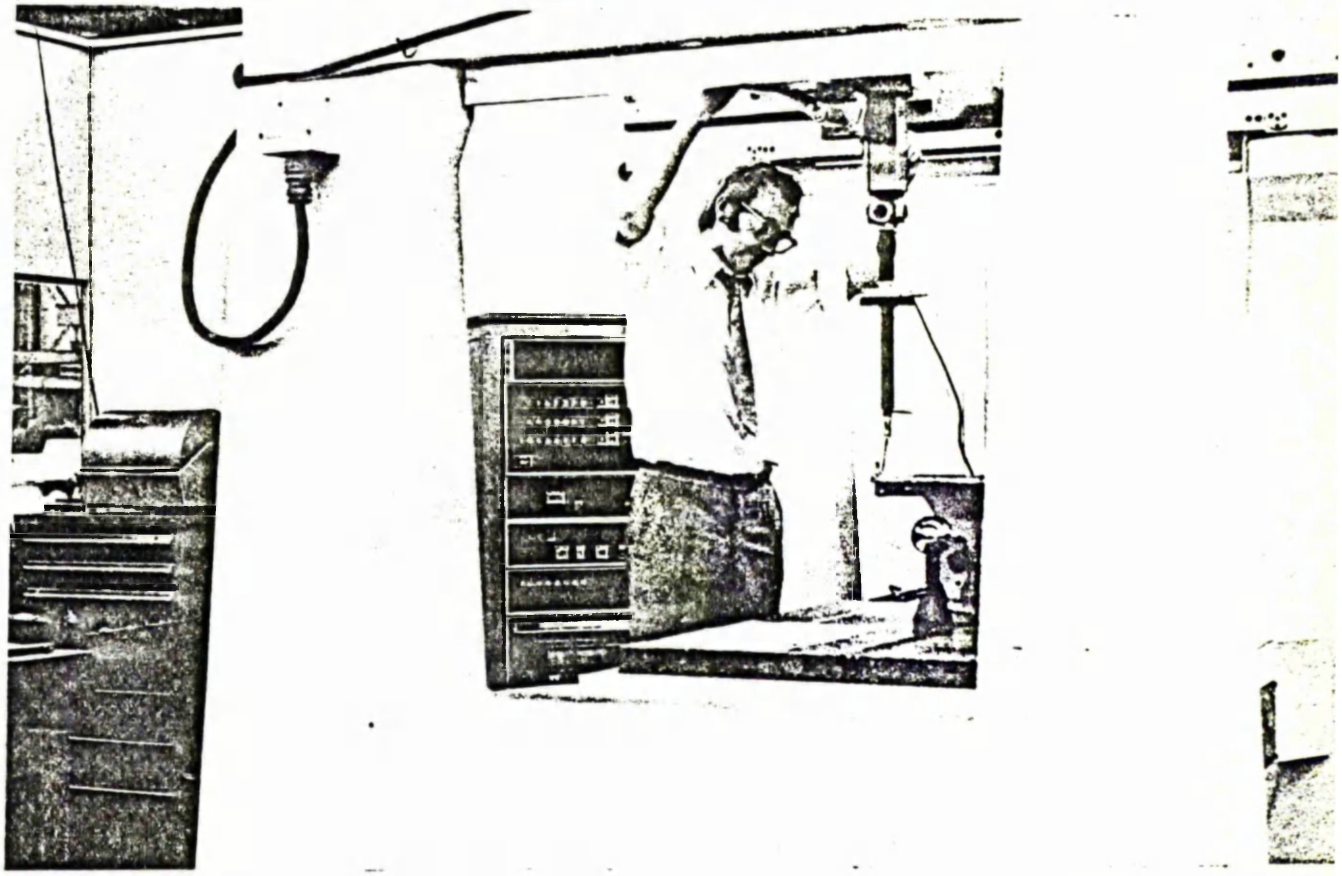
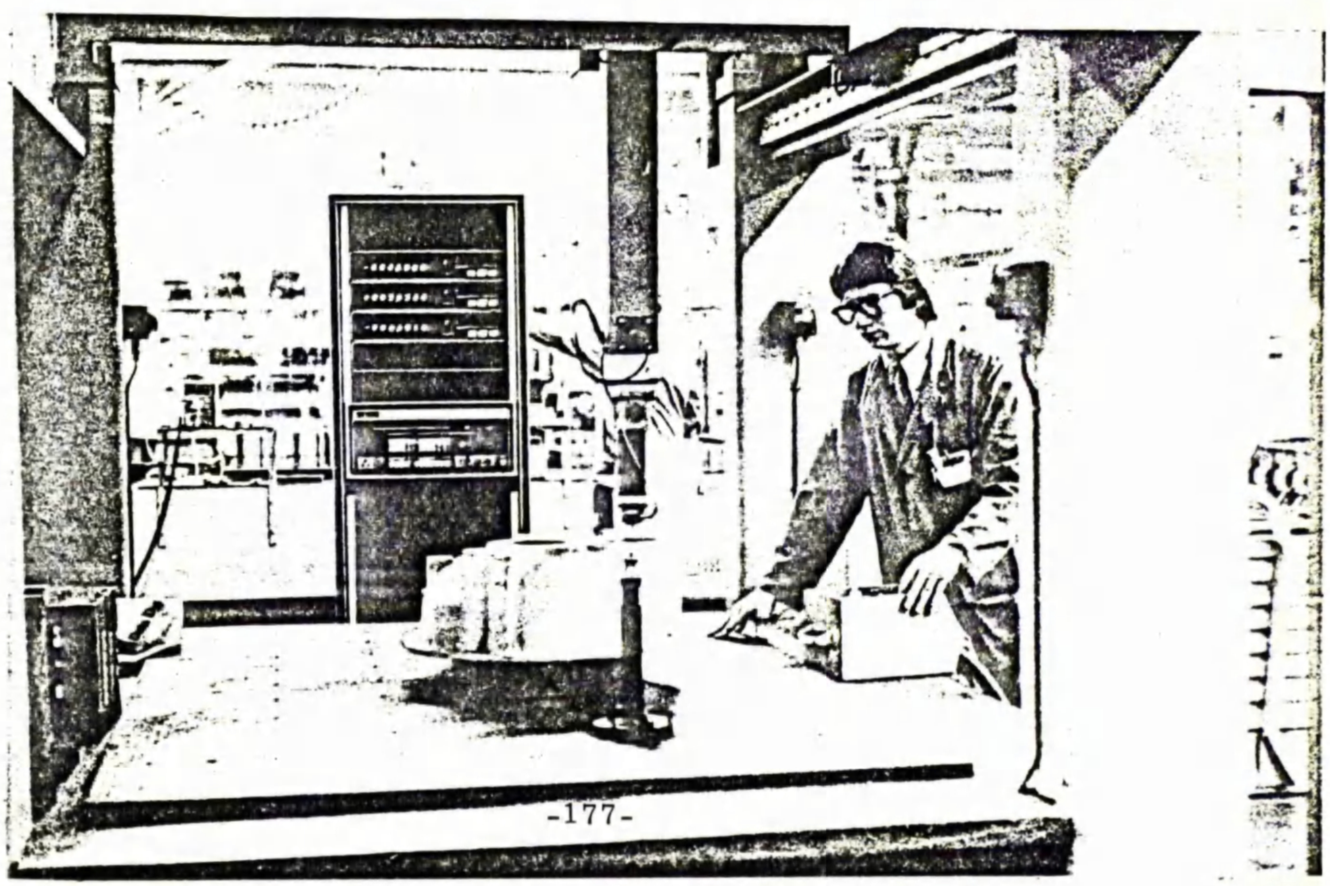


PLATE No: 4. 5

The Saturn 2000S Ferranti Computer Assisted Measuring Machine



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and are produced in high volume. The requirement therefore was for a CCMM machine with a high degree of measuring accuracy in the ± 0.0003" region and adequate stroke travel on all axes. The three machines evaluated were:-

A. L.K. Maxi Check 4646-39.

B. Ferranti Cordax 3000.

C. D.E.A. Gamma 'B'.

The results of the comparison and evaluation were as follows:-

Vendor	S.I.P.	Ferranti	Indus. Sales
Manufacturer	D.E.A.	Cordax	L.K.
Model	Gamma B Man 8	Cordax 3000	4646-39
Table surface area	47" x 35"	--	72" x 60"
Probe Stroke			
'X'	39"	30"	46"
'Y'	32"	20"	46"
'Z'	20"	16"	33"
Resolution	0.0001"	0.0001"	0.0001"
Accuracy			
'X'	0.0003"	±0.0002"	±0.0008"
'Y'	±0.0003"	±0.0002"	±0.0008"
'Z'	±0.0003"	--	±0.0007"
Computer Group	DECPDP8/8K	PDP8/M4K	PDP8/F
Daylight	34"	--	39"
Delivery	3 months	9 months	3 months
Cost	£57,748	£41,492	£47,558
Duty	£5,774	£4,192	£4,758
Installation	£1,938	£1,938	£1,938
Cabinet	£100	£100	£100
Total Cost	£65,560	£47,722	£54,354

Reason for selection of the second computer assisted measuring machine. Plate No: 4.4

The D.E.A. Gamma B Man 8 was selected on a suitability basis, as the L.K. machine did not provide accuracy while the Ferranti Cordax was limited on its 20" Y-axis probe stroke and had a nine month delivery. The proposed machine met the requirements on probe

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stroke and accuracy, the latter being of prime importance and delivery of secondary importance - therefore the additional cost was considered justifiable.

The Present Situation

The D. E. A. Gamma was installed in March 1976 and the Ferranti Saturn in August 1976. The former machine was compatible in terms of computer software programming with the equipment currently being used in most of the American facilities of Caterpillar, while the Ferranti Saturn was not. This presented an initial problem for Caterpillar, Glasgow, as one of the basic philosophies and success stories of the company worldwide was as discussed before, the high degree of interchaneability of tractor parts no matter which of the worldwide manufacturing units produced them. It was therefore imperative that computer measuring machine tapes be equally interchangeable. With excellent support and back-up from Ferranti in Edinburgh, the Caterpillar, Glasgow Plant was able to resolve the problem and thus achieve compatibility between the Ferranti Saturn and the D. E. A. Gamma systems. This interchangeability permitted valuable flexibility in the inspection function since if either machine was in a queueing or breakdown situation, the other could be used to do the check, component size permitting. The machines were both manned on first and second shifts, with a plan to train a further operator for the Saturn measuring machine.

By 1978 there were 450 computer measuring tapes produced to measure specific parts for several critical dimensions and it was anticipated that, as these tapes increased in number, then the measuring machines' burdens would increase to the point where they would be manned on all 3 shifts. The actual number of machine operations which would eventually have aprogramme tape had not yet been determined as identification of suitable applications was complex. There were approximately 10, 000 different production type operations carried out in the factory and excluding paint, protection coating,

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deburr, shotblast, heat treat, wash and other non cutting or forming operations, the figure reduced to approximately 6,000 machining operations. Many of these did not call for this type of inspection, so only a fraction of the operations would merit a tape from an aspect of economic utilisation. An estimate of this final figure would be of the order of 1200 - 1500 tapes. Today there are 24 numerically controlled machine tools and a large variety of automatic and semi-automatic machine tools and related equipment. (See Table No: 3.6 page 154). This advanced metal cutting technology is producing high volumes of components in small to large batch type production systems generally on a 5-day week over 3 continuous running 8-hour shifts. This situation has greatly increased the demand on the inspection function for a fast turn round on "first-off" approval and routine checks to reduce waiting time. The investment in computer assisted co-ordinate measuring machines was a viable, timely and necessary development of overall technology at Glasgow Plant.

Time Savings Gained with Computer-Assisted Measuring Machines.

What percentage of time saving is Glasgow Plant gaining on the CCMMs in comparison with surface plates and CMMs? A special exercise was set up within the factory to attempt to answer this important question, the details are given in Appendix H. This investigation confirmed CCMM manufacturers' claims of fast turn round on set up pieces and less man hours involved in inspecting. The highest value was 96.5% saving on a large final drive gear for the tractor drive system, which had to be set up twice on the surface table to get calculated co-ordinates from the base pitch circle and the included angle, whereas the CCMM inspector had only to lay the gear flat on the table and probe each bolt hole. (Plate No: 4.6). The least saving was 25% on a timing gear housing and the prime reason for this was the single setting carried out on the surface table, which could not be greatly improved upon by the computer system. Indeed this showed that a saving of 25 percent was gained purely on calculation time by the computer over the manual method. The CCMM also gave an average saving of 33.9 percent over a CMM, again indicating

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that the inspector gained this time by being able to verify his results quicker with computer assistance. The maximum saving between a computer-assisted system and a manual measuring machine was 75 percent on a cylinder head which involved a large amount of hand calculation on the CMM. There were no savings on 2 parts; power take off housing and power take off cover, which would suggest that some parts are particularly suited to the non computer-assisted systems. Since the time involved inspecting parts was greatly reduced, a production machine would have much less waiting time after it was set up and before it is given approval to run the job. This therefore gave a better utilisation of machine tools, production labour, and a faster flow of production and less "work in progress" overall.

A point which should be highlighted is that, from the results, one CCMM inspector should perform the work of 4 surface plate men in the same time period but there are many variables to be considered, not least the skill and experience of the CCMM operator of the geometry of the piece part to be checked and the accuracy required in the dimensions. Some parts readily lend themselves to the CCMM technique, whilst other may be a waste of CCMM time, obviously parts must therefore be carefully chosen for CCMMs. (Plate No:4. 6 appears with Appendix H).

4.3 - THE EFFECTS OF NEW MEASURING MACHINE TECHNOLOGY ON THE ORGANISATION OF QUALITY CONTROL AT CATERPILLAR, GLASGOW.

The specific aims of this section of the research project are to determine what effects of changes have been necessary to the organisation structure and systems of quality control at the Glasgow Plant of Caterpillar Tractor Company. In detail the following analysis will be made with regard to changes to -

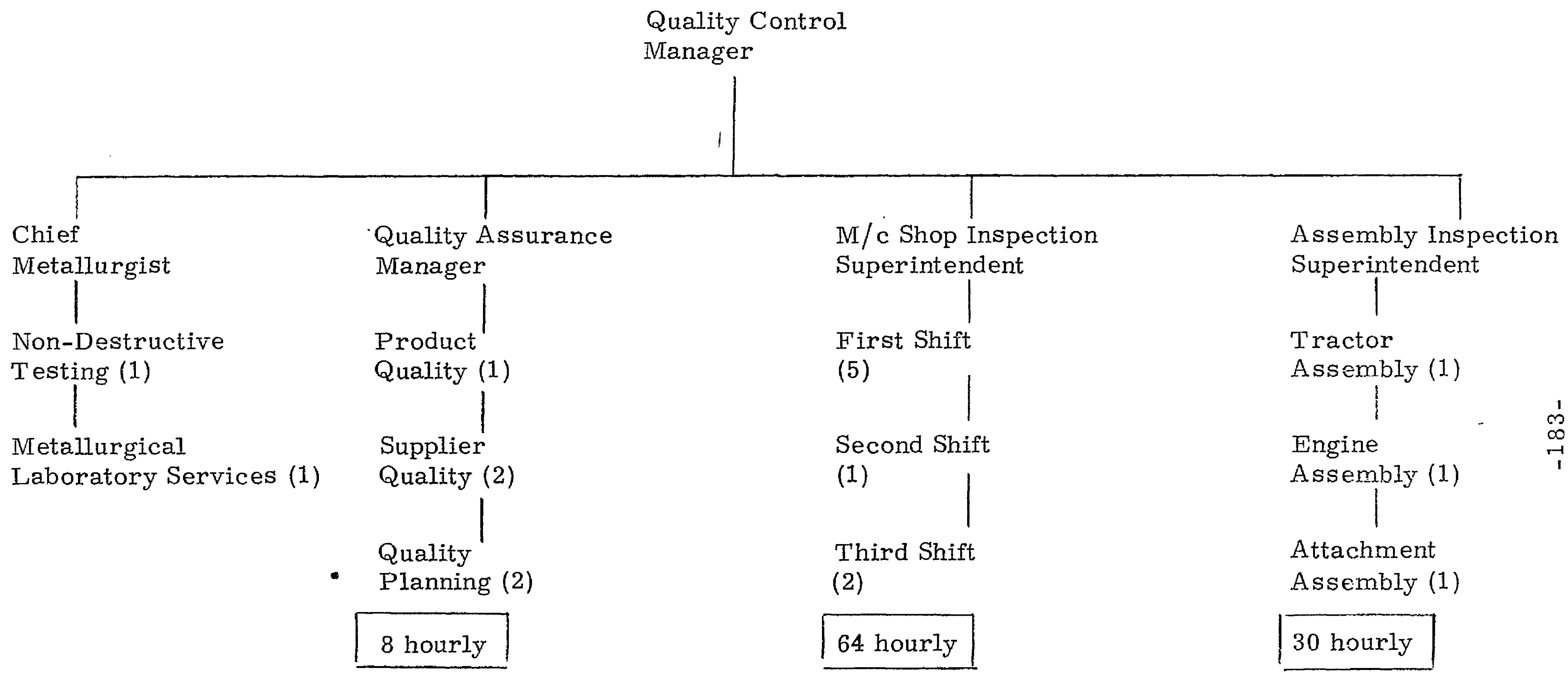
- Span of control due to horizontal pressures which require greater and more effective interpersonal relationships between the individuals concerned with the new technology.
- Numbers of levels of management and vertical pressures which would require the necessity to assign job duties and responsibilities to individuals possessing a high level of technical knowledge with the new technology.
- Established lines of authority (direct or functional).
- Information flow lines.
- Workflow disciplines.
- Informal and formal organisation systems.

<u>Organisation Structure Prior to the Introduction of Computer-Assisted Measuring Machines.</u>

The organisation of quality control at Caterpillar, Glasgow prior to the introduction of computer-assisted measuring machines in 1975 is shown diagramatically in Figure No: 4.1. The span of control for the department was 4 while the maximum span within the sub division was 7,this being at machine shop inspection where the superintendent had 4 first shift supervisors, 1 second and 2 third shift. The number of levels within the department structure was 4,consisting of quality control manager, superintendents, inspection supervisors and weekly paid planners of metallurgists or hourly paid inspectors. There were a total of 105 hourly paid inspectors working in the assembly or machine shop inspection areas. This represented a span of control of approx. 11 hourly inspectors to each inspection supervisor within a given area of the factory. The superintendent of each section of quality control

ORGANISATION STRUCTURE OF QUALITY CONTROL AT CATERPILLAR TRACTOR CO. LTD. GLASGOW PLANT

AS AT 1974.



Managers	5
Monthly Staff	18 ( )
Weekly Staff	25
Hourly paid	102
Total	150

directed his supervisors who in turn gave authority to the inspectors for the performance of their assigned tasks. Communication channels were standardised and fairly closely linked with the above hierarchy of authority although there was also a good degree of exchange of advice, consultation or information between each of the inspection supervisors. All hourly inspectors were time served engineers many with academic or technical qualifications. There were no incentive or bonus payment systems operating in the plant but all inspectors were on the top skilled craft grading in a structure with seven grades.

Work Assignments for Quality Control up to 1974.

There were 4 major sections within the quality control department as shown in Figure No: 4.1 - namely metallurgy, quality assurance, machine shop and assembly inspection. The metallurgical and assembly activities are not part of this research project and will therefore not be discussed further.

Quality assurance division had the responsibility for working with suppliers of purchased finished material, castings, forgings and other unformed steels. The essence of this activity was to minimise the amount of rejected material which could arrive at the receiving dock or into the machine shop for processing. This division had 2 other major duties. One was to have liaison with the user of the prime product either the agent or dealer selling and/or the customer using the equipment. The liaison activity was to provide feedback on quality problems from the user to the manufacturer. The second duty for quality assurance was to act as a service to the machine shop inspection by controlling, issuing and calibration of gauges, and to carry out audits on machine tools to determine if these machines were capable of maintaining quality standards of production. The people within this organisation structure for quality assurance as shown in Figure No: 4. 1. consisted of a manager one supervisor and three monthly paid staff engineers, six weekly paid planners and eight blue collar hourly paid inspectors who handled the aforementioned gauges and calibration studies on the shop floor.

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The machine shop inspection was the largest division within quality control consisting of one superintendent, 8 monthly supervisors and approximately 67 blue collar inspectors organised over a 3-shift 24-hour system. The duties of this group were primarily concerned with controlling the quality of production coming from the machine shop. This control was generally designed to serve 2 key purposes simultaneously namely,

1. To provide data for making decisions on the product, that is, does the product conform to specification?

2. To provide data for making decision on the process, that is, should the process run or stop?

Due to the interrelation between process and product variables, process inspection involved observation of process variables as well as inspection of the product. Machine shop inspection at Glasgow plant had 2 distinct systems as follows:-

1. <u>Set-up Approval - Patrol Inspection.</u>

   Some processes are inherently so stable if the set-up was correct the entire lot will be correct within certain limits of lot size. When the first part was run off after initial set-up, the inspector had to make a check, to do this check he may have been able to check all critical dimensions at the machine with hand instruments or he may have had to take the component back to a surface table - much depended upon the geometry of the component. In most instances the production machine operator through his supervisor would not start to run the batch until approval was given on the "first-off" but it did happen that the decision was made to run even if the initial component was rejected. This practice was not peculiar to Caterpillar but was a function of decision-making by the production personnel through their own experience of the machining of the parts and their need to run the schedule to meet the assembly line. However an average of 85 to 92 percent of the running components had set-up approval and the conflict between inspection and production was minimal. As the batch was running and at the start of each new shift, the component was again checked by a patrol inspector. Sometimes the interval between checks was shortened if the component had a history of problems. In any event the machine operator was held accountable for the quality of his production and had to measure and check frequently during the batch run.

2. <u>Check-out Inspection.</u>

   A lot by lot inspection procedure namely, check-out was carried /...

after the production division had concluded its operation and in the case of Caterpillar, immediately prior to going to assembly or to the replacement parts distribution centers. Depending upon the component, sampling of the lot could go from 5 to 100 per cent but Caterpillar refrained from using statistical random sampling tables on these batches mainly because of the small quantities, a much more meaningful exercise was to keep "medical" history cards on the performance of each part by machine tool. Check-out inspection to some degree was a heavy added cost burden to production because it involved extra material handling, added floor space, loss of some order in production, added inventory, and consequently capital was tied up. Great difficulty was found in fixing individual responsibility for faulty or rejected components, especially when 3 running shifts were involved.

A further area controlled by the machine shop inspection superintendent was that of receiving inspection. This consisted of one supervisor and 8 hourly paid inspectors whose prime responsibilities were to screen in-coming goods to ensure that these goods conformed to Caterpillar specifications.

Inter-Relationship between Quality Assurance and Machine Shop Inspection up to 1974.

Summarising the extent of inter-relationship between these 2 divisions of the quality control organisation at Glasgow would be as follows:-

- Formal organisational links existed between the managers of each division.
- Supervisors of machine shop inspection areas would exchange advice and consult with the quality assurance supervisor and weekly planners. This was more informal than formal information systems.
- Reports on machine tool capability studies were issued by quality assurance through the organisation structure to machine shop inspection simultaneously with the issue to maintenance and planning divisions for their appropriate actions with the correction of the machine tool if necessary.
- No functional lines of authority existed between the quality assurance and the machine shop inspection.

Organisation Structure after the introduction of computer-assisted measuring machines in 1975.

The Beginning of a Change.

Section 4.2 of this chapter discussed the development of inspection and

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measuring machines at Caterpillar, Glasgow. It was shown that the first manual measuring machines had been introduced in the late 1960s but the first computer-assisted machines did not arrive until 1975. Therefore prior to 1975 there was no requirement for a special planning activity to support these early manual systems except perhaps the recommendations on what components should be put over these machines. In 1975 with the introduction of tape programmed measuring machines the need for a special planning group was created.

As was stated in the previous section of this chapter, in replacing equipment with higher capital cost equipment, it was essential for the financial viability of the operation that expected productivity materialises and that full utilisation of the new equipment was achieved. The question of workforce attitude to this aspect of measuring machine utilisation will be discussed elsewhere, but it is necessary and interesting at this point to review the technical aspects of the effects of measuring machines on the production system. The main advantages claimed by manufacturers of computer-assisted co-ordinate measuring machines were as follows:-

1. Fast turn round of set-up pieces checked.
2. Faster flow of production.
3. Less man hours involved in inspection.
4. Better utilisation of the machine tools which are serviced by the measuring machines.
5. Repeatability of results.
6. Greater accuracy of measurement.
7. Less work in progress.
8. Machine provides a permanent print-out of results.
9. Training of operators can be as short as 4 hours.
10. Can give temperature correction for work pieces.
11. Reduced cost of fixtures and gauges.

These advantages had not all been validated by Caterpillar's own experience but savings in inspection time resulting from the use of

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computer-assisted CMMs in comparison with surface plates and manually operated CMMs had been validated and these results will be shown shortly in this study. Computer-assisted CMMs also had some disadvantages, these were:-

- o Downtime does occur on CCMMs whereas a surface table has zero downtime.
- o Programming staff must be hired or trained.
- o Peripheral equipment must be purchased for office use, example a card punch/verifier machine.
- o Staff are required to operate peripheral equipment.
- o Inspectors, supervision and management require training.

NOTE: For the purpose of abbreviations, CMM is a manually operated co-ordinate measuring machine. CCMM is a computer assisted co-ordinated measuring machine. See also Abbreviations - page xi.

At Caterpillar, Glasgow Plant in 1975, these disadvantages were minimised since planning personnel within the manufacturing department were already employed on N. C., machine tool programming and tape punching machines and tape operators were already employed producing N. C., machine tapes. Also, extra staff in the quality assurance division were not required for the new equipment since it was considered that the CCMMs reduced the time required to be spent on inspection gauge and fixture design, hence one planner was redeployed initially on CCMM programming jobs. This planner was promoted to the highest technical weekly grade along side the aforementioned N. C., machine tool programmers. Special training was given to the weekly planner by the supplier of the CCMM which in this case was Ferranti of Edinburgh. This planner in turn began to train hourly inspectors on all shifts who had been selected and assigned to these machines by the machine shop inspection management. It was observed that changes began to take place in the organisation system as follows:-

- o Informal communication channels developed between the inspection supervisor and the CCMM weekly staff programmer.

- Lines of functional authority began to appear between the CCMM inspector-operator and the weekly staff programmer.

These changes seemed to be based on the growing dependability by the inspection supervisor and the measuring machine operator on the weekly planner due to his technical competence.

The Second Change.

With the introduction of the second computer-assisted measuring machine (CCMM) and the assignment of more components for measurement, further changes were necessary on the organisation structure. More blue collar hourly paid craft inspectors were assigned to this equipment until a team of 12 inspectors covering 3 shifts were appointed and in some stage of training. 2 additional weekly paid staff planners were assigned to CCMM tape programming and to assist the first planner on training hourly inspectors and the diagnosing of problems associated with measuring machines. These 2 extra planners were not moved to the top weekly grade but were promoted one grade above the other quality assurance planners. This second promotion led to some discontentment among the remaining quality assurance weekly planners on the lower grades and lines of demarcation began to appear in the various tasks not directly associated with measuring machines. The problem was not one of inadequate salary levels but mainly a question of wage differentiation between planners who had previously been a homogeneous work group all on the same salary grading and due to the new measuring technology were now split into 3 different salary gradings within the weekly structure.

Changes in the machine shop inspection systems.

The inspector-operators of the new measuring machines found that their role of inspection had changed because work would flow from machine tools to them instead of the inspector going to the work in the machine tool. The throughput of work on the measuring machines increased at such a rate that when 2 inspectors retired in 1976 and another in 1977, they were not replaced. The loss of 3 inspectors was only mildly contested by the hourly trade union at that time. It /...

was considered by some inspectors that replacement of the retired inspectors would lead to less overtime working among all the inspector group. Another observation at this point seemed to indicate that the craft inspectors thought it was a case they could not win in the long term, as the facts were evident to them that less work had to be measured by hand due to the advancing measuring technology. This observation tends to correlate with the findings of Sayles in his discussion about the conservative work group who were craft work groups whose disputes were always related to what were viewed as attacks on status of that particular craft work group (27). If anything the measuring machine technology appeared to enhance the status of the inspector but consequently reduced the numbers involved or required. The resistance to this change on the inspectors has therefore been minimal at Glasgow Plant.

The machine shop inspection supervisor appears to have been drawn closer to the quality assurance supervisor in an almost formal information channel. The key questions on what can and what cannot be checked on the new measuring machines together with the growing frustrations of downtime with the complex measuring machines had led to a higher frequency of contact. The observation made in chapter 3 that the production foreman's role in the machine shop was being reduced to one of man management due to advancing technology such as computer controlled N. C., machine tools, is not applicable to the inspection foreman, who continues to have a wide range of inspection activities which are not covered by measuring machine technology and therefore is not subject to the same effect or impact as that of the production supervisor.

<u>The Third Change and Current Situation.</u>

A new relationship had to be developed between the quality assurance and machine shop inspection divisions in order that increased efficiency and high utilisation could be gained with the co-ordinate measuring machine equipment. To achieve these improvements, the following changes were introduced:-

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- A new division was created known as product quality - this removed the responsibility of customer liaison from the quality assurance division.

- Receiving Inspection was transferred from the authority of the machine shop inspection division to quality assurance so that the machine shop could concentrate on internal quality problems only and problems concerning suppliers be embraced by quality assurance division from the receiving docks back to the suppliers.

- The quality assurance CCMM planning group were given a clearer functional authority with the CCMM inspector-operators and were able to issue stop and start instructions in the interests of additional efficiencies and improved utilisation.

Observations on the results from the above changes would suggest that some improvements have been achieved without any apparent intergroup deterioration of relationships. A diagram of the current organisational relationships between the two quality control divisions and the manufacturing machine shop is given in Figure No: 4.2.

Conclusions on organisation changes.

Observed conclusions from the effects of new measuring machine technologies on the organisation structure at Caterpillar, Glasgow are as follows:-

- Span of Control (Horizontal Pressures)

  It was observed that horizontal pressures created by the new measuring technology in the quality assurance division ultimately led to the need for a wider span of control at the top of the structure. With a corresponding increase in the number of planners within the quality assurance planning section, the span of control did not widen, but the tasks of half of the planners changed. The span of control in the machine shop inspection decreased in an effort to give greater emphasis to the new measuring technology. The resultant effect was a more effective interpersonal relationship between the individuals concerned with the new technology.

- Levels of Command (Vertical Pressures)

  There were no additions or reductions of levels of command observed due to the new technology. The reassignment of the weekly planners' duties eventually increased their influence but they did not move outwith the previously established structure.

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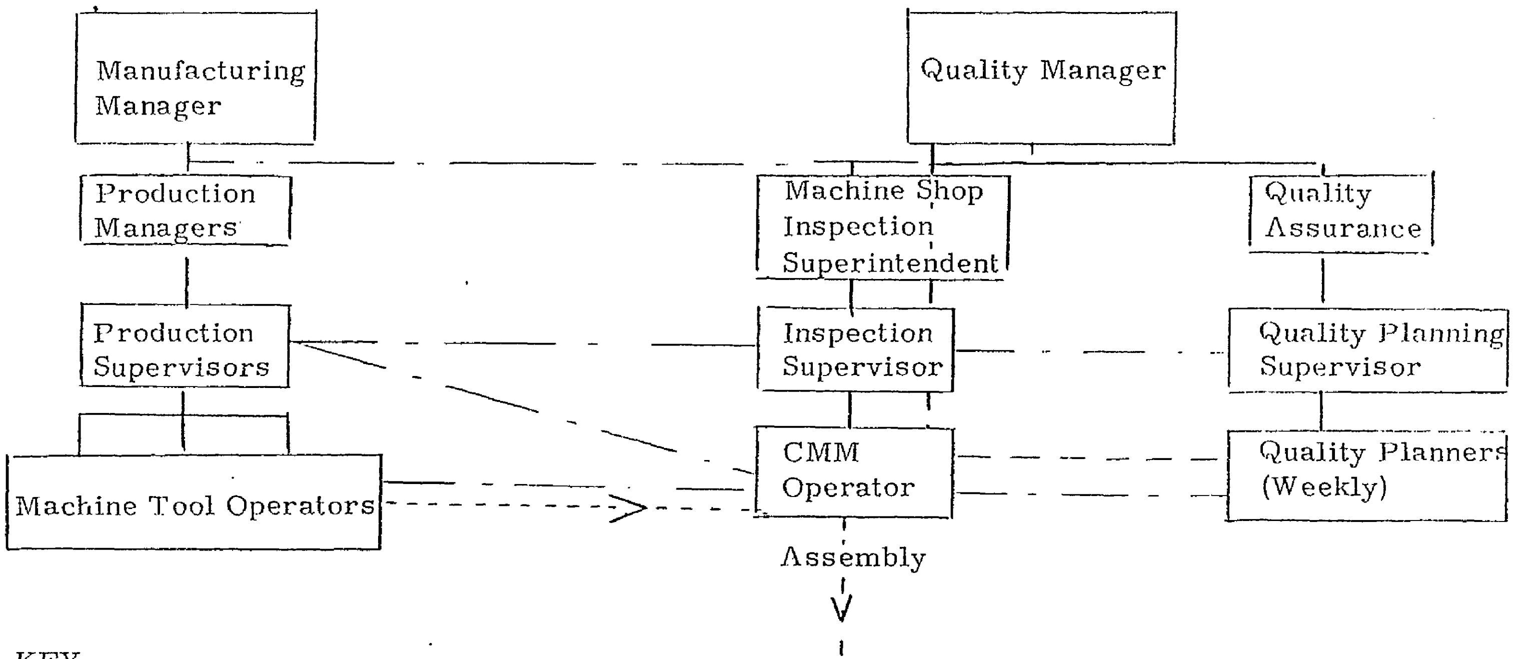
Figure No: 4.2

DIAGRAM OF THE INTERRELATIONSHIP BETWEEN DEPARTMENTS AND WITHIN THE TWO DIVISIONS OF QUALITY CONTROL AFFECTED BY THE NEW MEASURING MACHINE TECHNOLOGY. WEEKLY PLANNERS HAVE FUNCTIONAL AUTHORITY OVER THE CCMM INSPECTION-OPERATORS.



KEY
Line Authority ————
Information Flow —— - ——
Functional Authority — — — —
Part or Product Workflow. - - - - - - -

- Lines of Authority.

  The weekly staff planners initially took functional authority with the CCMM operators - this was eventually accepted as the most effective method of operation. Direct line authority remains with the inspection supervisor.

- Information Flow Lines.

  The dependence upon the new technology forced new demands upon the need for closer communication links between the white collar office function and the blue collar machine shop function at both supervisory and non supervisory levels.

- Work Flow Disciplines.

  Material to be checked is moved physically from the machine tool where it was formed into a component to the inspector at the measuring machine and then to assembly or storage. Previously work was checked at the machine tool by the inspector. (Random inspection continues to be carried out at the checkout stations as previously discussed but this is also reducing due to the increased throughput by the measuring machines).

- Formal and Informal Organisation Systems.

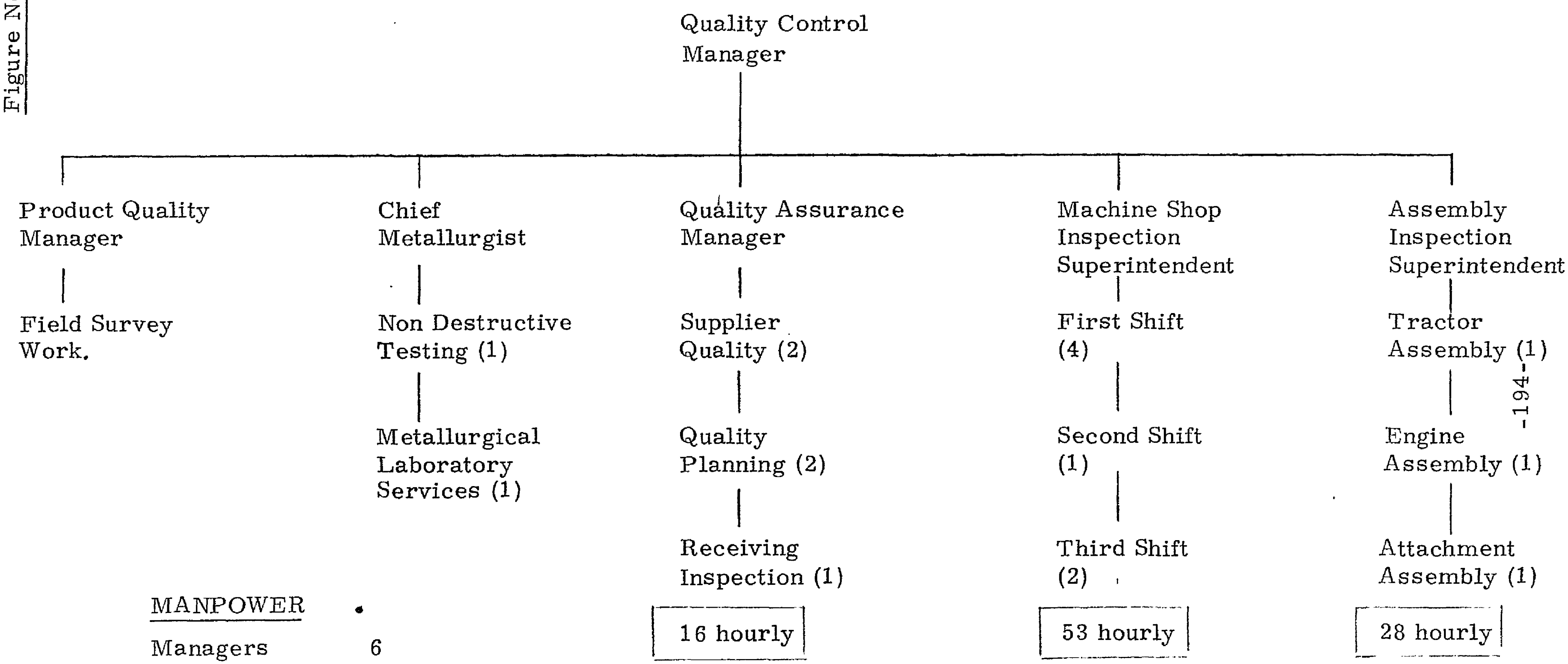
  Much of the informal systems which grew up initially with the measuring machines' early introduction have been converted into formal procedures. Informal systems remain with the relationships between CCMM inspection-operators, machine tool operators and production line supervisors, this is due to the difference of departmental function.

- Manpower Changes.

  Figure No: 4.3 shows that the managers have increased from 5 to 6 with the increased span of control and monthly paid staff have reduced from 18 to 17 with the promotion of one man to manager level. Weekly staff employees have remained constant at 25 but with increased influence as previously discussed, and blue collar hourly inspectors have reduced from 102 to 97 - three retirements in the machine shop and two inspectors who left the company for other reasons from the assembly inspection group. (These inspectors were not replaced in assembly for reasons not associated with the measuring machine technology).

Figure No: 4.3

ORGANISATION STRUCTURE OF QUALITY CONTROL AT CATERPILLAR TRACTOR CO. LTD. GLASGOW PLANT AFTER 1975.



MANPOWER

Managers	6
Monthly Staff	17 ( )
Weekly Staff	25
Hourly Paid	97
TOTAL	145

4.4 - THE PSYCHOLOGICAL ADVANTAGES GAINED BY PEOPLE WITH NEW TECHNOLOGY.

Craftsmen operators of new measuring machines at Caterpillar, Glasgow claimed that they have gained increased status and other psychological advantages since their assignment to this new technology.

The purpose of this investigation on the feelings and opinions of craft inspectors, assigned to operating the new measuring machines, was to determine the following points in relationship to the effects of the new technology.

- Had the operator experienced any change in his status?
- Did the operator feel more or less self assured with his job performance?
- Was there concern over the complete comprehension of the utilisation of the equipment?
- In his relationship to machine operators, did the operator feel that his influence to persuade had changed?
- Did the operator feel that his power of authority derived from the intrinsic details of the task had changed his subordinate or super-ordinate relationship with the production line supervisor?
- Was the operator more or less satisfied with the nature of his work activity?

From the limited prior research in the literature to the whole question of how skilled craftsmen have reacted to new technology, and in particular, technology which apparently tends to de-skill or where less knowledge is required, findings suggest that the effect on the operator has resulted in him having a negative attitude to the new technology. Abbot observed in a recent study of 9 engineering firms in Britain that from a long term and general point of view, technological development of an outstanding nature has tended to affect, and to be most resisted by the skilled craftsmen within firms. Abbot further observed that in some cases, managements had introduced weekly premium payments for the operators of new machinery as a

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pacificatory tactic where resistance was encountered (14). While there has been much prior research on the attitudes of unskilled operators affected by automation, Bright (38), Sayles (27) and to a lesser degree, on the effects on people who service the new technologies such as maintenance, toolmakers and computer staffs, Scott (39), Mumford (40), there has been few reports on craftsmen whose central tasks have been changed by new technology. One exception to this has been the work of Hall and Miller, who noted in their research that in addition to fear of redundancy and loss in earnings, the major sources of opposition to mechanisation on the part of skilled craftsmen traditionally have been fear of loss of intrinsic job satisfaction and status as a result of dilution of skills (41).

This research is of interest as it examines the reaction and attitudes of craftsmen related to new technology applied directly to their intrinsic tasks. In addition to testing the attitudes of the 48 craft inspectors who were assigned to the new technology over a period of years, the research also included other craft inspectors who were working with conventional measuring technology, such as surface plates, hand measuring instruments and fixturing. This group of craft inspectors were included in the whole attitude survey in an attempt to establish a control group not subject to change, close to the new technology but not using it. There were a total of 24 craft inspectors in the control group.

Table No: 4.1

Results of the Attitude Survey

Changes in Status.

All of the operators in the group of 48 considered that they had experienced an improvement in their status since their assignment onto the new technology. Approximately 26 operators or slightly more than half of the group stated that they had gained much more status, while the balance of 22 operators thought they had simply gained more status. Analysing this positive result in greater depth produces some interesting implications, as the operators did not enjoy any of the following extrinsic benefits due to the new assignment.

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TABLE No: 4.1

OPERATORS AND NON-OPERATORS FEELINGS ABOUT MEASURING MACHINES

RESPONSES TO QUESTIONS 7 AND 6 IN QUESTIONNAIRES SHOWN IN APPENDICES D & E)

VARIABLE RATING / FEELING	ACTUAL FEELINGS OPERATORS (N = 48)					EXPECTATIONS CONTROL GROUP (N = 24)				
	MUCH MORE	MORE	ABOUT SAME	LESS	MUCH LESS	MUCH MORE	MORE	ABOUT SAME	LESS	MUCH LESS
STATUS	31	17	-	-	-	3	15	6	-	-
SELF ASSURANCE	15	16	17	-	-	2	11	11	-	-
CONCERN OVER NEW FANGLED TECHNOLOGY	1	12	24	11	-	4	11	9	-	-
INFLUENCE OVER MACHINE OPERATORS	2	22	24	-	-	2	5	15	2	-
POWER OVER PRODUCTION SUPERVISOR	6	32	10	-	-	7	10	7	-	-
SATISFACTION WITH WORK	8	11	15	14	-	11	10	3	-	-

FIGURES GIVEN ARE ACTUAL INSPECTOR NUMBERS

- Job evaluation grading and wage level remained the same.
- Conditions of work in the environmental sense were unchanged.
- No special benefits such as clothing and other personal attire were given.
- The craft inspectors selected for the operating jobs were more or less those whose work was being absorbed by the new technology. Therefore there was no special qualification such as years of service, older, younger, physical or other conditions set down as prerequisite for selection.

The above factors indicate that the operator derived the feeling of increased status purely from the intrinsic nature of the new technology. The measuring machines at Caterpillar, Glasgow were large structures with peripheral support equipment such as mini computers, electronic controls, automatic printing facilities, all of which were new and foreign to the machine shop. Initially when the equipment was installed other employees came to observe the equipment in operation similarly as happened with the N. C., machine tools when they were first installed at Glasgow Plant in 1966 (see chapter 3, page 122).

The actual operation and workings of the measuring machine could not be so easily interpreted by an onlooker as would be an N. C., machine tool. The reason for this was that the inspector-operator had to follow a sequence of probings where he would appear to be simply touching the component in measurement with an electronic steel pencil. Each touch was followed by an auditable contact and a corresponding automatic printing on a typewriter. Technically the blueprint geometry of the component had been previously digitised and programmed into the mini computer memory. The inspector-operator merely inputs actual digitised measurements into the mini computer which are checked electronically against the blueprint. One can compare this above electronic wizardry with the conventional hand skills and human arithmetical calculative exercises previously carried out by the inspector and conclude that the inspector-operator would derive greater satisfaction from the new technology and therefore increase in status in relationship to other inspectors. The 24 members of the control group were less conclusive with respect to their expectations of status had they been given the opportunity to operate the new measuring equipment. Approximately 18 of the control group thought they could gain status while 6 inspectors considered their status would not change. This group of inspectors while not actually operating the new equipment, would have a good understanding of how the equipment operated and to some degree, comprehend much better than the non inspection employee, what the input and output activities were all about. This notion implies that apart from the difficulty of knowing what status one would derive without actually experiencing it, the control group inspectors indicated that they expect less impact or feeling of change due to the new technology.

Self Assurance.

Self assurance in this section of the research is defined as having the confidence to perform the task on hand. Statistics obtained from the attitude survey on questions 1, 2 and 3 (see Appendix I) showed that the operators of the new technology had on average 2 years 2 months experience on the new measuring machines, were 36 years of age and had had 8 years 1 month experience in the inspection field in total. In addition to this, all of the operators were time-served craftsmen in general engineering and, according to question 14 of the survey, almost all had educational qualifications in either London's City & Guilds or National Certificates. Table No: 4.1 shows that the operator group by majority felt more self assured about working on the new equipment. In total 31 operators felt more or much more against a group of 17 who could not discern any difference in self assurance.

Analysing these results would indicate that while there was some initial learning on the operation of the measuring machine, the craft inspectors on average had come to this new assignment with a considerable degree of experience and technical qualifications as shown

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in the abovementioned statistical analysis. Indeed the inspector if necessary, could have taken most components and measured them by conventional methods. The new technology, was in the interpretation of this analysis, an extra tool in the inspector's work basket. This attitude is replicated in a similar manner with the expectations of the control group who, without knowing the full advantages of the measuring machines, carried sufficient confidence from past experience for 13 of their members to expect more self assurance.

Concern for new fangled technology.

The electronics and associated computer equipment did not apparently cause any high degree of concern among the operators of the new equipment. Exactly half of the operator group expressed a neutral attitude to this question while 13 claimed some concern. (It was not established whether there was any difference in experience between the operators expressing less concern and those expressing more, but it could have been basically a question of differences in learning curve position which would alter with time). The members of the control group showed that they expected to have concern, at least initially with the new equipment. A total of 13 indicated this against a balance of 11 who felt that they would have about the same type of technological challenge as they had in their current assignments.

Influence over machine operators.

The principal task of the industrial craft inspector in manufacturing industry is to serve the production operation by detecting errors or faults in the product or components and offering his judgement for corrective action. In many circumstances the strength of that judgment is related to the supportive technology through which he achieved these results. The aim of this question was to determine had the new measuring machine changed the inspector's persuasive influence over the machine operator such as advising that operator to correct a fault or possible potential fault in the machine tool. Table No: 4.1 indicates that there was a division of opinion among the operator-inspectors. Half of the group felt there was no change while the other half had the /...

the opinion that their influence had increased with the machine operator. The control group were less confident about their expectant influence over the machine operator as 15 inspectors took a neutral position; 2 thought they would have less influence and 7 anticipated more. Again the difficulties for the control group were in not having had actual experience, coupled with 2 other factors namely, the existing inter-relationship with the machine operators and the current quality level of the output. A high scrap percentage is unlikely to decrease simply due to an improved method of measuring (although it could help to detect trends). There was no significance drawn from the response to this question by both operator and control groups.

Power of Authority with line production supervisor.

Relationships between work groups has been the subject of much research in the literature. Chinoy observed in his study of the car assembly work, a large gulf existing between management and shop-floor operatives; the foreman's capacity to exercise "human relations" skills was extremely constricted by physical-technical conditions (34). The work of Leonard Sayles is interesting in this connection. He identifies 4 behavioural patterns observed in working groups and he calls these apathetic, strategic, erratic and conservative. The conservative work group he describes as the craft work group whose disputes are always related to what are viewed as attacks on the status of that particular work group (27). This research, having shown that the status of the craft inspector had apparently increased, now observes that there is a changing relationship between the inspector-operator of the measuring machine and the production line supervisor in terms of authority of task. The formal relationship between the inspector and the production line supervisor is not a direct line of man management authority. The relationship is functional authority as the inspector has his own supervisor. However the production line supervisor has a direct access to the inspector and is dependent to some degree on that inspector's aforementioned judgment and also his co-operation. The aim of this question was to determine if the operator of the new

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measuring technology had considered that his power of authority concerning task decisions had changed. (It has already been shown in Chapter 3 that the production line supervisor's role tended to reduce to that of man mangement due to the development of N. C. equipment and the effects of the computer). Table No: 4.1 in this section of the research strongly implies that the operators had considered that their power had increased as only 10 out of the total of 48 operators showed a no change attitude, the balance of 38 claimed that they had gained increased power. The control group also indicated their expectations of greater power as 17 saw more or much more power.

Analysing this result would imply that not only has the operator of the new technology increased his knowledge and capabilities but the new technology has caused the production line supervisor to be more dependent upon the inspector operating the equipment. The machine shop is developing technologically into one advanced metal removal system on one hand and one advanced measuring system on the other. The component is cut or shaped to a predetermined programmed geometry in a N. C. machine tool, then measured in a predetermined programmed measuring machine. The power of task authority lies with the person who can best communicate and interpret the input and output of this technology. According to the findings of this research this power is moving to the craftsman-operator, the craftsman in Sayles' terms is not having his status attacked but on the contrary he, the craftsman is attacking the line supervisor's status or work group.

Satisfaction with work.

The inspection operators on the new measuring technology although claiming increased self status and self assurance, indicated in the attitude survey that they were not in agreement over their satisfaction with work activity. Only 19 of the operators said they felt satisfaction with the work activity while 15 expressed an opinion of no change and the balance of 14 considered that they had less satisfaction. Contrasting this result was the attitude of the 24 members of the control group who expressed a very strong indication that they expected to have

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more to much more satisfaction; only 3 inspectors in the control group stated that they expected to have no change.

Examination of these results again has to be related to the changes made to the task of the operator which may result in an attitude of less satisfaction with the measuring machine assignment after the initial learning phase. Some of these changes were -

- The operator remains at his machine, whereas previously he moved around the shop checking components. The components now come to him for checking.
- His work load has become programmed and assigned to him from statistical analysis with the accent on prevention rather than cure. Previously he had some freedom of choice of work to check.
- He has to follow the programmed sequence for measuring work. (He does have the option of manually checking but this can be subject to human error).

These are a few of the possible reasons for dissatisfaction or for not having more satisfaction in the operator group. The significance of the control group expectations of greater satisfaction is assumed to be related to this group being aware of the advantages of this equipment, but not having experienced some of the apparent disadvantages as described above.

Conclusions from this section -

The findings from the attitude survey as related to psychological advantages gained by people with new technology are -

- All operators have increased in status.
- A majority of the operators felt more self assurance.
- The operators were divided on the question of concern about the new technology but this was considered to be related to differences in experience with the equipment.
- Half of the measuring machine operator group thought their influence over machine tool operators had increased; the balance claimed no change.

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- Almost all of the operators considered their power of authority with the production line supervisor had increased.

- The operators had not on the whole increased their job satisfaction with the new assignment.

The conclusions related to the expectations of the control group inspectors if assigned to the new technology, were as follows:-

- Status would increase.

- Self assurance would increase.

- Concern for the new technology would only be high initially.

- Influence over the machine tool operator would not change.

- Power of authority with the production line supervisor would increase.

- Greater job satisfaction would be achieved.

4.5 - THE ACCEPTANCE OF CHANGE IN JOBS DUE TO THE INTEGRATION OF NEW TECHNOLOGIES.

The integration or merging of craft skills in manufacturing industry due to the advancement of technology is a difficult and increasing problem. The rapidly advancing numerical controlled machine tool technology and the technological changes associated with co-ordinate measuring machines could in time result in a combined technology. This would move the inspection concept from an after-the-event inspection to an in-process or immediate post-process inspection. As such the greatest increased efficiency would be gained because the measurement and error feedback actions would be automatic and virtually immediate. The above merging of technology would also cause a change in the associated labour either integrating or displacing according to the human needs required of the newly combined technology.

The specific aim of this section of the research is to establish what attitude the inspector would have to the consequences of having his current work integrated fully with the production activity. Each of the 48 inspector-operators of the co-ordinate measuring machines and the 24 inspectors in the control group were asked the following question as part of the overall attitude survey.

- As measuring machines become more accurate and results almost infallible, do you think the inspector should become part of the production team under a line supervisor? (Question 20 - Appendix I and question 11 - Appendix J).

The inspectors were asked to select one of 5 variables according to their attitude to the above proposal. These variables were as follows:-

- Strongly disagree with the integration proposal.
- Mildly disagreed with the integration proposal.
- Neither agree nor disagree with the integration proposal.
- Mildly agree with the integration proposal.
- Strongly agree with the integration proposal.

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Results of the attitude survey - Table No: 4.2
Integration of the inspection and production activity.

The 48 inspector-operators on the existing co-ordinate measuring machines had been subject to a major change in their work activity by moving from conventional to measuring machine inspection systems. This group were also aware of the rapid technological advances made in the measuring machine systems from the first manual system introduced at Caterpillar, Glasgow in July 1968 to the computer-assisted systems introduced in August 1976 (see section No: 4.2). Therefore the eventual merging of machine tool and measuring technologies was not going to be of traumatic news to them; they were in fact witnessing an evolution of technology. Awareness of the change however does not infer acceptance nor intransigence by the people closely associated with the change. The results of the survey as on Table No: 4.2 showed that 16 or approximately 33 percent of the 48 inspector-operators strongly disagreed with the proposal while 14 or 29 percent had mild disagreement. Only 8 or 16 percent were uncommitted and 10 or 20 percent of the total had mild agrèement for the integration proposal.

The control group's 24 inspectors were on the whole against the proposal as 19 inspectors or 80 percent of their group indicated mild to strong disagreement while 5 inspectors or 20 percent had mild agreement with the proposal.

Analysis of these results provides some interesting implications on the whole question of advancing manufacturing technology. First of all, why should the inspector-operators of the current measuring machine technology disagree or agree with any proposals to integrate or merge their functions with production? The following points could be made by those who disagree:-

1. The nature of manufacturing industry will always require an independence of production arbitration function to ensure that quality specifications are not subordinated by quantity requirements.

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TABLE NO: 4.2

SHOULD INSPECTION BE TOTALLY INTEGRATED WITH PRODUCTION

RESPONSES TO QUESTIONS 20 AND 11 IN QUESTIONNAIRE SHOWN IN APPENDICES D & E)

GROUP / VARIABLE RATING	STRONGLY DISAGREE	MILD DISAGREE	NEITHER AGREE NOR DISAGREE	MILD AGREE	STRONGLY AGREE
OPERATORS	16	14	8	10	-
CONTROL	12	7	-	5	-

FIGURES SHOWN ARE NUMBERS OF INSPECTORS

2. The manufacturing technology will never be foolproof.

3. The roles of the inspector and the production personnel, that is the machine tool operator and/or production foreman, could not be harmonised within a production system due to differences in skill, knowledge, status and decision processes.

4. The trade union would oppose it purely from a possibility of eventual redundancies affecting their members.

Discussion of the above 4 points is as follows:-

1. The nature of manufacturing industry did originally result in the separation of the manufacturing or production management and quality or inspection management functions due to confusion of objectives. The primary role of manufacturing is to maximise output: the primary role of quality is to ensure that this output meets agreed product or component specifications. In the real situation these roles do not always coincide much to the detriment of the enterprise involved. The evolution of the quality function in industry has been largely related to the consequences of labour intensive manufacturing industries where human error and unreliable capital equipment had to be countered by other human systems namely inspection.

   The trend towards more capital intensive manufacturing with much higher levels of reliability should result in the slow dismantlement of the traditional and established inspection system. This dismantlement will be difficult for the inspection group to accept mainly due to these long established traditions.

2. The fully automated factory is according to the Delphi-type forecasts (42) a very real possibility for the late 1990s. The quality reliability of machine tool equipment currently in machine shop manufacture although much improved since the second world war, still requires much more improvement before systems become foolproof and output consistently within specification.

3. Craftsmen tend to defend their status, skill and knowledge, the literature on prior research shows that any changes will be resisted as a measure of this defence. Shepard explored the question of whether a worker's relationship to technology and degree of job specialisation influenced in a predictable way his integration into or alienation from work. Shepard showed that the degree of differentiation in the division of labour is related to technology in a similar way in both the office and factory and that automated technology reduces the levels of alienation among both office employees and factory workers (43). The findings from this research would indicate that with the integration of technologies, there could be corresponding increases in alienation between the 2 groups of workers merged with the new combined technology.

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This at least would be the situation in the short term.

4. Trade unions are growing more concerned about the consequences of advancing technologies (see Appendix E for a statement by the TUC on their instructions to their members on how to negotiate with employers on the subject of new technology). At the local level of trade union involvement within manufacturing plants, resistance will be a factor where their members are displaced and lose wage rates or have the possibility of losing their jobs completely through redundancy. However the actual advancement of the technology as has previously been shown in chapter 3 will not be resisted in the interests of overall employment.

The reason why a greater percentage of the control group should disagree with the proposal to integrate than the inspector-operator group is assumed to be related to the basic fact that these inspectors have not had the opportunity to experience the first step in transition from conventional to measuring machine technologies and consequently may have some fear of the total changes brought about by a complete integration. This fear could be related to redundancy, problems of deskilling and/or the need for retraining to some new discipline.

The reasons why 10 inspectors in the measuring machine group and 5 inspectors in the control group should have a positive agreement with a proposed integration of jobs, are somewhat difficult to ascertain. These reasons could be associated with an acceptance of the inevitable consequences of advancing technologies or a consideration that new job opportunities will emerge out of the combined technology for the individuals involved.

Conclusions to the question of integration.

Since the Industrial Revolution, there have been substantial shifts in the pattern of employment, but the economy as a whole has adapted to technological change and to an ever-expanding labour force, especially in manufacturing industries. In the last decade signs at the plant level of the economy are that technological change is still taking place but to an ever-reducing labour force. This section of the research shows that the human problems associated with merging 2 different technical functions could prove to be a major constraint to the

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advance of that technology within manufacturing industry. Actual realisation of a full scale operating computer-integrated manufacturing system, providing fully automated self-optimising computer control of a factory, still lies in the future and will be of an evolutionary process.

4.6 - PROBLEMS ASSOCIATED WITH DE-SKILLING, LESS KNOWLEDGE AND MANPOWER REDUCTION DUE TO NEW TECHNOLOGY.

Prior research in the literature suggests that automation and related new technology in manufacturing industry will ultimately lead to de-skilling of labour, cause less demand on operator knowledge or experience and reduce the number of people required at the metal cutting or forming side of the business.

The aim of this section of the research project is to determine what reaction there would be to the above change when applied to craft inspectors due to the introduction of automated or semi-automated inspection through the use of computer-assisted measuring machines. A group of 48 inspector-operators of measuring machines and 24 inspectors on conventional measuring technology were asked the following questions as part of the attitude survey:-

- How much does it concern you that as machines, even measuring machines, become more and more automated, this could affect the following -
  1. Less skill to operate.
  2. Less knowledge required.
  3. Fewer operators.

The inspectors were asked to classify their reaction to this by selecting one of the following variables:-

- Very Concerned.
- Concerned.
- Not Concerned one way or other.
- Encouraged by progress of technology.

(See Question No: 21 - Appendix No: I, Question No: 12 - Appendix No: J).

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Results of the attitude survey - Table No: 4.3
Less skill to operate.

Slightly over half of the 48 inspector-operators of the existing measuring machines were very concerned about de-skilling of their jobs. A further 16 or 33 percent of the group recorded that they were concerned. Only 6 inspector-operators indicated a neutral result to this question. A similar result was given by the control group where all of the 24 inspectors recorded a degree of concern for the de-skilling notion. This above result from both groups implies a general reluctance by the inspectors to forfeit their craft skills due to the development of technology which has or could further simplify their job tasks. It has been recognised for several decades that time-served craftsmen undergo several re-training phases in their industrial lifetime. This has been generally related to the obsolescence of materials and methods together with improvements in tooling. These changes have however been slow and evolutionary without having major impact on the individual or the firm. The movement from one phase to another and the retraining, very often self training, on the new method has somehow added to the craftsmen's experience as he has not necessarily forgotten the obsolete skills. The new measuring machine method adds very little to the skill of the craftsman inspector and tends to completely obscure previous skills. The conclusion from this analysis is that the craftsman inspector is very much aware of the pending developments and has a high degree of concern for the consequences.

Less knowledge required.

Inspectors using conventional inspection or measuring equipment require a very wide variety of knowledge ranging from materials, machine tools, tooling, processing systems, together with the handling of his own measuring equipment; an ability to solve complex mathematical problems; a knowledge of the people using machine tools and finally an ability to communicate with people. The possible dilution of this knowledge caused 34 inspector-operators or 71 percent of the total to indicate a degree of concern. A group of 12 gave a neutral

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TABLE No: 4.3

TOWARDS THE AUTOMATED FACTORY

(RESPONSES TO QUESTIONS 21 AND 12 IN QUESTIONNAIRES SHOWN IN APPENDICES D & E)

UPPER FIGURE IS OPERATOR GROUP RESPONSE
LOWER FIGURE IS CONTROL GROUP RESPONSE

FACTOR / VARIABLE RATING	VERY CONCERNED	CONCERNED	NOT WORRIED ONE WAY OR ANOTHER	ENCOURAGED BY PROGRESS
LESS SKILL TO OPERATE	26 / 8	16 / 16	6 / -	- / -
LESS KNOWLEDGE REQUIRED	10 / -	24 / 16	12 / 8	2 / -
FEWER OPERATORS	22 / 15	2 / 5	16 / -	8 / 4

FIGURES ARE NUMBERS OF INSPECTORS.

response and 2 inspector-operators thought that the progress of technology to be more important than the reduction of individual knowledge. The 24 members of the control group were by majority of two-thirds concerned about the reduction in knowledge required with the balance of one-third not concerned.

Analysis of this result suggests that while some new knowledge will be gained by the inspectors by working with the new technology, this gain does not offset the reduction of knowledge required to perform the measuring task. The experienced craft inspector does not lose his acquired knowledge by moving to the measuring machine but a much less experienced or knowledgeable craftsman or perhaps a non craftsman could achieve the same level of measuring competence using a measuring machine as the highly experienced craft inspector in the same period of learning time. No major significance can be drawn from the result obtained from the control group.

Fewer operators.

The claim by the manufacturers of measuring machines that measuring components can be reduced by up to 90 percent of the time it took to do the same task by conventional methods, must, it would seem, lead to a reduction in inspection manpower. The proof of this claim of time improvement was tested at Caterpillar, Glasgow and recorded in this project (see Appendix H).

The reaction by the 48 members of the inspector-operator group was most interesting because despite half of the group recording concern (22 very concerned and 2 concerned), 16 inspectors were not worried one way or the other, and 8 actually indicated encouragement with the progress of technology. To contrast this, the control group had almost 75 percent of their 24 members showing high concern with the balance of 4 inspectors being encouraged by the progress of the technology. The conclusion to be drawn from the above could be basically related to the fact that the inspector-operators are already in possession of the new technology and feel more secure than the control group members who may consider themselves by implication to be the inspectors who will not be required.

Conclusions to the question of de-skilling, less knowledge and fewer operators.

The summary conclusions from the above findings are as follows:-

1. Inspectors are most concerned about the possibility of de-skilling their craft.

2. Inspectors are concerned to a lesser degree about the reduction of knowledge required.

3. Inspectors already on the new technology are less concerned about fewer operators being required than the inspectors who are not using measuring machine technology.

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4.7 - OBSERVED EFFECTS OF NEW TECHNOLOGY.

The objective of chapter 4 was to study the effects of new measuring machine technology on a single manufacturing plant in an attempt to further support the argument that new technology is having an impact on specific factors of the enterprise. The results of this study are displayed in Table No: 4.4 under each of the factors identified as being subjected to impact and therefore affecting some elements to the degree that a change was observed. These factors are discussed as follows:-

Organisation Structure.

Section No: 4.3 showed that the new measuring machine technology caused pressures of both a horizontal and vertical nature to emerge which resulted in a wider span of control in the structure but not an increase in hierarchical levels. The lines of authority were duplicated due to the concept of power being where knowledge was available. Information lines moved from a line to line system to a staff to line system with a network as shown diagramatically in Figure No: 4.2. Work flow disciplines had to change because the inspector changed from a roving to a stationary work system. Components had then to be routed to the inspector instead of him going to where the component was processed. Much of the informal organisation structure which was established at the outset had to crystallise itself into a formalised structure.

Management.

All the support and pressure exerted for the new measuring machine technology came from middle management. Section No: 4.2 of this chapter traced the development of the measuring machine technology from a consideration of 7 alternatives to the eventual decision to invest in 2 computer-assisted measuring machines. Top management took a somewhat neutral stance on this investment, for reasons already discussed in the text, such as the measuring machine did not make or add value to a component, but if anything added cost, because of extended workflow levels, additional handling and the higher probability of rejection due to increased capabilities of the measuring machine on the question of dimensional accuracy. However middle management saw the necessity to maintain quality standards despite the increased throughput of production from the N. C., machine tools. An acceptable return on investment mainly related to a reduction in waiting time for the production machine tools resulted in top management giving approval for the project. The continuous support by top management on the use of advanced measuring machines at Glasgow Plant is based on a factor of management by exception. If, for example, no problems are reported from customers using the prime product, nor from the management who are assigned to assemble the components, then the need to continually check and measure these components tends to become less demanding. On the other hand, if continuous problems are being reported from these aforementioned sources, then top management would want to know why the problems are not being caught at the measuring machines and therefore the demand on the equipment increases. Middle management for their part are conscious of inconsistencies from N. C., machine tools and other conventional machine tools and seek to accept a responsibility to ensure minimum problems emerging from the machine shop due to faulty or defective components, therefore maximum utilisation is made of the measuring machine technology.

It has been observed that with the introduction and use of measuring machine technology, there was an increase in the number of further innovations directly related to the equipment. These innovations emerged mainly due to the increasing potential from the microprocessors controlling the measuring machines. Statistical data could be harnessed about components'measurement characteristics which could provide very useful information to middle management on machine tool capabilities, forecasted scrap and rework costs, and many other benefits which until now had to be manually computed. The middle management group were in the majority of cases the main innovators of these technological changes at the Glasgow Plant.

Strategies.

Caterpillar worldwide have operated with a management by objectives system for approximately 15 years. Each function within the enterprise has interrelated objectives. Quality control at the plant level is committed to a policy of advancing the quality or customer acceptance level of the prime product and parts produced within the plant. The initial effect of new measuring machine technology on the achievement of these objectives was only marginal but as the new technology was further utilised with more and more components being measured, the achievement of measurable objectives in quality control became much easier to obtain. The measuring machines at Caterpillar, Glasgow created a need for a special planning team as was discussed in section No: 4.3 of this chapter. The members of this team had already been employed as individuals in the quality control organisation but the introduction of the new technology resulted in the formation of the team. The emergence of a team leader in an unofficial capacity was noted mainly because this individual had more technical knowledge of the new equipment; his need or ability to lead and direct people was not important in an authoritarian aspect but more so in a functional manner. The relationship between this team leader and line management is shown in Figure No. 4.2.

Machine Shop Environment.

The environment in this instance is concerned with the physical nature of the new technology. Section No: 4.2 of this chapter described the degree of growth of measuring machine equipment over a period of years from 1968 to 1976. This growth was in line with the acquisition of N.C., machine tools as discussed in chapter 3. The N.C., equipment had major impact upon the machine shop environment at Glasgow while the measuring machine technology was noted to have an effect mainly upon the people most closely associated with the use of this equipment. The overall effect on this inspection group environment was shown to be a cumulative type of change. Section No: 4.2 has shown that very careful analysis was made for the selection of the measuring machines in order that the acquired equipment would fulfil the exact specifications designated by Caterpillar. Some difficulties arose on the question of best location of the 2 computer-assisted measuring machines within the machine shop. Ideally the optimum location would have meant minimum delay between the production machines tools and the point of measurement while at the same time avoiding problems associated with dust or temperature which could contaminate the delicate measuring equipment. Of the 2 computer-assisted measuring machines at Glasgow, one was located in the most suitable position in the machine shop to maximise on the advantages and to minimise the aforementioned disadvantages, while the second machine was a compromise between quality control and planning division and did not satisfy all the needs of each group. This appears to be a trivial manner on the surface but it is of fundamental importance to the effectiveness of the function using the technology. It is equally important to the findings of this research as the new technology central to the study is not of primary dependence to the enterprise but more of a fringe technology not unlike the computer, without which the business could continue to function albeit less effectively. In summary, the location of the measuring machine technology must be part of a total integrated plan or system for the whole machine shop. The maintenance of the measuring equipment is very much supplier orientated mainly due to the electronics associated with the basic controls. Caterpillar at Glasgow, while able to perform some maintenance activities, are dependent upon these external services to cover major problems, the new measuring technology unlike the N. C., machines tools discussed in chapter 3, had virtually no impact upon the maintenance group at the plant.

Control Systems.

The important question of how successful the implementation of new measuring machine technology at Glasgow plant was can only be judged by the final results obtained, but this aspect may not be as easy to determine for this technology as it would be for say a machine tool which can be accurately and quickly assessed based on its productivity over a measured period of time. The new measuring machine technology /...

must be judged on the effectiveness of its service to the machine shop in terms of minimising waiting time by the machine tool until confirmation of the accuracy of its output is given. If this confirmation can be given in a faster rate by using the new measuring machine technology over that of conventional measuring technology, then the difference in time must be reflected in the real return on investment. Caterpillar, Glasgow demonstrated by careful analysis that between 60 and 70 percent improvements could be achieved between old and new technologies and thus justifiably considered that the innovation had been a success for the firm. What conclusions can be drawn from this section of the study to ensure success of all similar types of process innovation? Certainly it would appear essential that a considerable amount of prior study be made of the concept of the new technology against the apparent need of trying to determine if there were any possible alternatives to the measuring machine solution. It was noted that maximum use was made of the multinational experience by seeking advice on the best types of measuring machines available and this was followed up by visits to other British users and British suppliers. Comprehensive studies were made of components being made in the plant to determine possible uses for the measuring machine, especially the computer-assisted models. Component complexity, value and volume were ascertained together with a listing of the most critical components in the relationship to possible failure within the tractor or final product. It is concluded therefore that the above activity prior to the acquisition and immediately after commissioning of the measuring machine technology in the plant, underlines the prime importance of eliminating technical, organisation and utilisation snags.

The second major conclusion form this Caterpillar study is concerned with ensuring that a good return in investment is achieved in the real activity by the maximisation of machine utilisation during the working shift, this activity is detailed in Appendix G under the heading of "Savings achieved by improving CMM capacity at Glasgow Plant". It is important for total success that ultimate and ideal goals be set for /...

the loading of the measuring machine to maximum capacity. It was shown in section No: 4. 3 that manufacturers and suppliers tend to highlight the many advantages of the new measuring machine technology, 11 such advantages are given in the text. However there are disadvantages with the technology and each firm or plant has to carefully judge how these advantages and disadvantages will affect the organisation in terms of impact on structure, systems or people. Where possible, validation tests should be carried out on measurable factors such as speed, accuracy, repeatability and other such factors. The concern for maximum return on investment (ROI) at Caterpillar, Glasgow is high and the control systems related to ROI and the new measuring machine has already been shown to be of major effect in section No: 4. 2 of this chapter. The effective utilisation of this equipment continues to be a challenge to the management group. The constraints against effective use cover problems associated with shortages of parts resulting in no time being available for the inspection. (This problem is of course not peculiar to measuring machines, indeed the measuring machine should minimise time for measurement). Human problems have also been observed, with inspectors unilaterally deciding to measure by conventional methods rather than by the measuring machine. This attitude by the inspector could be related to his wish to retain his hand skills and knowledge, or a basic distrust of the measuring results: whichever the reasons it has a negative effect upon the utilisation of the equipment.

People.

The next conclusion from this study is concerned with people and initially those involved with the preparation of computer programmes for the computer-assisted measuring machine. In chapter 3 detailed reference was made to the question of communication as related to all levels of the workforce within the organisation. It was strongly recommended that blue collar hourly payroll workers should receive the least advance notice possible about any pending change involving new technology and that monthly paid supervision be involved at an early stage in order that they make a contribution to the proposal and

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also help to smooth the way for its implementation in the shop. Now the weekly paid white collar planners need to be treated differently again with respect to communications because on one hand they have a vested and personal interest in the growth of their individual jobs, while on the other hand, they belong to a unionised body which in the Caterpillar case, is branched into the hourly unions, that is TASS (white collar) is a branch of the AUEW (blue collar). The first factor is an intrinsically related factor to the planner's task and technological growth can be highly motivational, therefore advanced communications are an essential for preparing the planner for handling the new tapes to control the new measuring machines. The second factor would naturally lead to early and informal type communication with blue collar workers and perhaps lead to some unnecessary disruption. The experience and therefore conclusion at Caterpillar would suggest that a "soon as possible" communication be made to weekly planners about concepts of future technology especially when their close involvement is necessary at the early stages and continued involvement at later stages with the technology. The use of the informal communication either intended or not at Caterpillar has proved to be more beneficial than detrimental.

One of the initial points developed in the 4 possible outcomes from this research was the finding of a "Method of converting manual skill to knowledge skill". This point is further discussed as the research tries to define the craftsman as being of a higher status than other manufacturing employees and the craft inspector as being a special elite within that group. The line between the aforementioned white collar planner and the blue collar craftsman inspector is very thin indeed and the conclusion at Caterpillar is to help the blue collar employee grow in his task by further training and not take the reverse route highlighted in other research by his continuous de-skilling. This change is somewhat reflected in the organisation structure of Caterpillar, Glasgow plant's quality control where the span of control has a maximum value of 5 and a maximum of 5 levels inclusive between the most senior quality manager and the hourly paid inspector.

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Table No: 4.4.

OBSERVED EFFECTS OF NEW TECHNOLOGY

SINGLE MANUFACTURING PLANT CO-ORDINATE MEASURING M/Cs.

Factor	Element	Change Type:	Effect
Organisation Structure	Horizontal Pressures	B	Wider Span
	Vertical Pressures	D	None
	Direct Authority Lines	C	Duplication
	Functional -do-	B	Increased
	Information flow lines	A	Increased
	Work flow disciplines	B	Work to Man
	Informal - Formal	C	Moving to Formal
Management	Support-Top Manager	B	Marginal
	Support-Middle Manager	A	Variable
	Involvement	B	Direct User
	Acceptance-Responsibilities	B	Direct User
	Innovators.	B	Direct User
Strategies	Objectives	C	Minimal
	Long Term Plans	D	None
	Education-Training	B	Haphazard
	Teams-Teamwork	B	Formalised
Machine Shop Environment.	Growth	A	Substantial
	Selection	B	Controlled
	Location	B	Compromised
	Maintenance	C	Minimal Internal
Control Systems	R.O.I. Contribution	A	High
	Utilisation	C	Uncontrolled
	Efficiency	C	Low
People	Employment Shifts	A	Fewer Blue Collar
	Skills	B	Increased
	Resistance	D	None
	Integration	D	None
	Satisfaction	B	Moderate
	Manning	C	Seniority
	Status	A	Increased
	Influence	A	Increased

Change Type - A-One step Change, B-Cumulative Change.
C-Continuous Change, D-Nil or Not Observed.

The reflection is based on the aspect of growth in that the quality assurance division has become of greater importance in its overall role of prevention of quality problems; it has not grown numerically in personnel but the staff members of this division have adopted by design, an advisory and training role in order to help the lower level blue collar workers to make a more effective contribution. In conclusion therefore this research shows that Caterpillar are attempting to increase the skill of the blue collar craftsman by opening up his task to include work previously thought to be the domain of the weekly paid white collar planner. A good example of this is shop floor computer programming by the craft inspector. 8 elements of the factor concerning people and the observed effects of new technology were discussed in the text of this chapter.

Section No: 4.4 discussed the responses to the attitude survey covering status, self-assurance, concern for new equipment, influence and power relationships with other employees and finally job satisfaction. It was concluded from the findings that all of the above conditions had been subject to some degree of change due to the new measuring machine technology. Section No: 4.5 researched the problems associated with the acceptance of job change due to the integration of new technologies. It concluded that integration of job tasks will prove to be a major constraint to the merging of new technologies despite the fact that the hardware technology maybe readily available; the human problems will tend to slow down the process of total integration. Section No: 4.6 investigated the question of de-skilling, less required knowledge and fewer inspectors necessary due to the use of measuring machines. It concluded that inspectors were very concerned about deskilling of their craft, mildly concerned about less knowledge being required and not concerned about fewer inspectors if already operating a measuring machine but most concerned if not already using the measuring machine technology.

Overall Conclusions.

Appendix K described how the attitude survey was developed and

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although there is nothing new in the approach adopted in this research, it does conclude that pilot studies with experimental questionnaires are almost mandatory if a high quality final questionnaire is required for the research. 3 different pilot runs were conducted at Glasgow Plant and 3 times the questionnaires were redesigned towards the search for a near perfect vehicle. The concept of the "change" and "control" groups was used to determine if there were any discernable attitudinal differences between inspectors using the new technology and those inspectors not using it; this proved to be a very useful tool in the final analysis of the 2 questionnaires used in this research study at this stage. It further provided a good datum base for the design of the questionnaire for the full multinational organisation and for the major survey of 287 firms in Britain and American.

The overall findings from the attitude survey including those specifically discussed in the text, had some very interesting and useful conclusions, some of these are described as follows:-

1. Younger craftsmen employees are being placed on the new technologies either by management design or by reluctance on the part of the older employees to start to learn new disciplines perhaps through fear or lethargy.
2. The research showed that less than 30 percent of the co-ordinate measuring machine operators had been in the inspection function 5 years ago and that 92 percent of the responses indicated that the employee had got a job move, promotion or sideways, directly due to the advent of some new technology not necessarily measuring machines.
3. Contrary to other research findings which showed new technologies to be de-skilling operatives, this study shows that craftsmen's technical skills are being raised marginally.
4. No major behavioural signs of dissatisfaction are apparent. Absenteeism averages 4.5 percent against 8.5 percent for all blue collar workers, turnover was almost negligible at 2 to 3 per cent and grievances non existent.
5. The control group, that is inspectors not operating CMMs stated they would welcome an opportunity to work on the new technology even if it had meant a drop in wage rate.
6. The operator group claim that they had gained an increase in status since they moved onto the measuring machine.

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7. There were no financial or other benefits for the inspector to move to the equipment as he was already a top level craftsman.

8. There was absolutely no resistance to the new measuring technology.

9. No alienation was observed between groups. Relationships had improved between both the CMM inspector and the production supervisor and also the CMM inspector and the machinist.

10. The CMM inspector considered that his influence over the machinist had increased and his power of persuasion had increased with the production supervisor.

11. Production supervisors in the viewpoint of the CMM operator had become much more dependent upon the CMM operator and the white collar planner.

12. The CMM operators admitted to the importance of faster checking but did not show concern for the fact that ultimately this could lead to the need for fewer inspectors.

13. A most important factor to management of less downtime on production machines was rates as being unimportant by almost half of the group.

14. It was observed that CMM operators appeared to shield their skills by implying that the new technology was not easy to operate.

15. The computer on the shopfloor appears to continue to carry a mystique about its operation.

16. The majority of both CMM operators and other inspectors could not accept the future concept of having their current role integrated with the production group.

17. Blue collar employees who already work on the latest advanced technologies are less concerned about future problems of deskilling, less knowledge required and fewer jobs, than those who do not work on the new technologies.

(Appendix L provides detail of responses to questionnaires used in the single manufacturing plant study - see page 523).

CONNECTING SUMMARY

- o Chapter 4 completed the investigation of the single manufacturing plant on the observed effects of new measuring machine technology on different aspects of the enterprise. It was shown how co-ordinate measuring machines were introduced to the plant and the effects these machines had on the organisation of quality control. Evidence was obtained from various analytical studies on both the financial and time-savings derived from the use of co-ordinate measuring machine technology. An in-depth attitude survey was carried out on the basis of the experimental and control group technique to establish what behavioural changes had been felt and observed by people directly and indirectly affected by co-ordinate measuring machine technology.

- o The research project is widened in chapter 5 in order to study the impact and problem of new co-ordinate measuring machine technology on a multinational organisation of 23 plants in different areas of the world. The organisation and systems of control are similar but the findings will show differences in reaction to the introduction and use of this new technology.

CHAPTER 5 - New Measuring Machine Technology in the Multinational.

5.1 - THE OBJECTIVE OF THIS CHAPTER.

The objective of chapter 5 is to study the results of a field study on a multinational organisation concerning the impact and problem of new measuring machine technology. The specific aims of this study will be to -

- o Report on types of measuring technology used.
- o Examine changes in organisation structure.
- o Analyse the extent of resistance to change.
- o Analyse behavioural changes in inter-group and inter-personal relationships.
- o Consider attitudes to integration and dissatisfaction.
- o Analyse the effects on status and job interest.

The text will be supported by further material committed to Appendix which will cover the following -

- o The research design for the multinational plants. (see Appendix M).
- o Tripartite questionnaire sent to Caterpillar Plants worldwide to obtain the basic data. (see Appendix O).
- o Basic history of Caterpillar Tractor Company worldwide supported by organisation structures, plant details on year founded, product and area. The significant financial trends from 1968 to 1977. (see Appendix N).
- o Overall response from tripartite questionnaire. (see Appendix Q).

Highlights of Aims and Findings.

According to information recently published by the headquarter's group of Caterpillar Tractor Company in Peoria, Illinois, U.S.A., Caterpillar is the largest private company owner of co-ordinate measuring machines (CMMs) in the world. This research will discuss the various types of CMMs used by the company worldwide, where they are located plant by plant, and the balance between American based and non American based plants. The reasons why certain CMM technology was chosen will be shown and again some differentiation will be reflected between American and non American plants. The source of first knowledge of new technology has been a subject of several previous research activities, Langrish et al attempted to establish the source of new innovations and the contribution made by various authorities engaged in research related to new technology. (15). The aim of this section of the research was to establish from which of several possible sources did the multinational plants learn about new technologies. This question is in fact developed later in the research with multiplex plants. The decision to invest in an expensive measuring machine should not be taken too lightly and this study attempts to discover to what extent the multinational plants carried out pre investigation studies before making the decision to invest.

Chapters 3 and 4 of this research showed that considerable shifts in employment and changes in organisation structure were made due to the impact of new technology. This section of the research attempts to study the same question, that is, has the introduction of the new measuring machine technology created horizontal and vertical pressures which have utlimately lead to changes in the structure, and what, if any, changes in manpower have resulted from the effect of this technology. 23 organisation charts are studied and discussed together with the details of manpower at each of the plants throughout the worldwide organisation. Common features are listed for all plants followed by a similar analysis of the major differences. Changes made at specific plants are identified and compared with all other Caterpillar plants and the benefits derived from central services are explained, thus minimising the possibilities, or indeed the need, to duplicate skills and knowledge.

The basic theories of James R. Bright on the problems of resistance to technological innovation are tested (38). Bright originally identified 12 reasons why new technologies or technological changes are opposed - these reasons have been re-interpreted in this research /...

and reduced to 9 reasons why people would resist changes associated with the introduction of new measuring machine technology. The results presented by 23 Caterpillar plants worldwide are tabled and discussed in this section. This question will once again be discussed later in the research with a much larger population of firms. One of the key arguments of this research is that new technology will have some impact on the people most closely associated with it in the firm. This section attempted to show what degree of effect the new measuring technology has had on the inter-group and inter-personal relationships of craft inspectors, machinists and production supervisors. The findings from the study of the single manufacturing plant, as given in chapter 4, will be compared against those of the multinational plants for changes in influence, power and relationships. This subject will be further studied later in the research project.

Recent reports in the media have highlighted the real concern of people related to the disappearance of certain skills and the integration of specific tasks, both brought about by the introduction of new technologies. The Times Newspaper and Independent Television labour disputes during 1979, are examples of these technological developments. The problems associated with integration of tasks is developed in this section of the research, as it was in Chapter 4, and the responses given by 23 quality control managers are tabled and discussed. As a secondary part to the above, a question is posed concerning the effect of de-skilling of craft inspection work as a result of the new technology. This question is fundamentally concerned with job satisfaction as related to the gradual removal of skill and knowledge requirement on the performance of given measuring tasks.

Status and job interest were both the subject of study in chapters 3 and 4 of this research thesis. The question is continued in this section of the research in an endeavour to establish if the status and job interest of craft inspectors in the multinational plants of Caterpillar have been affected by the introduction of the new technology. Again

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this topic of status is discussed later in the research project with a much larger population of firms and comparison of the findings will be discussed.

The final section of the text develops the central theme of the research and attempts to draw together the observed effects of new technology as it is seen in the multinational plants of Caterpillar Tractor Company. Information for this section is not only drawn from the previously discussed section of the main text, but also from the Appendices which are directly related to this chapter on the multinational plants. Therefore each of the 6 major factors are discussed, namely - organisation structure, management, strategies, machine shop environment, control systems and people. The supportive material given in the Appendices discusses the approach used for this particular section of the research and shows in particular the strategy used to test, validate and measure the questionnaire research vehicle.

The 23 key elements of enquiry in the tripartite questionnaire are explained in detail in this appendix, showing the intention behind each question. All of the question matter used in the questionnaire is not reported directly in the text discussion of this chapter, as it was considered not directly applicable to the central theme of this study. All the results of these questionnaires as responded to by the multinational plants are summarised in the Appendices, in order that particular aspects of the findings can be extracted as evidence on the argument of impact of new technology on firms, to be used in this chapter or in later chapters of the research project.

A complete copy of the tripartite questionnaire is contained in the Appendices related to this chapter. The history of Caterpillar Tractor Company worldwide is given to provide supportive detail on organisation structures, details on when each plant was founded, size in terms of people and area, together with some financial data which describes the trend of the company over a 10-year period. The

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policy and strategy concerned with product and process technology is also discussed within this basic description of the multinational organisation.

Why this section is important to the Research Project.

The purpose of this section of the study is not to investigate or research in particular the problems of new technology associated with multinational companies, however as the single manufacturing plant in the research as discussed in chapters 3 and 4, is an affiliate of a multinational organisation, then it deems it important to study the relationship between the 2 groups. The results of this part of the research could have some important contributions to management of affiliates or subsidiaries of multinational organisations, either established or planned for the future in Britain or elsewhere. The multinational organisation is today a very common part of the manufacturing industry scene as it is equally prolific in other activities, such as retailing and distribution, insurance, banking and finance, etc. Much criticism has been levelled at the multinational corporation for all sorts of reasons but mainly concerned with people and economics. Many people agree with respect to technology, the multinational has an important role to play. Schumpeter and others have placed more emphasis on the role of the giant corporation in stimulating technical advances in modern economy. (44). Clive Jenkins in his recently published book, "The Collapse of Work", discusses the trans-national companies in relationship to technological development and suggests that the 2 basic reasons for the multi or trans-national development of advanced technology are the availability of finance and resources to be devoted entirely to research and development (45). In a report on "The Impact of Multinational Corporations on Development and on International Relations" by the United Nations Department of Economic and Social Affairs in 1974, the following statement was made: "The multinational corporations have become the most important sources of a certain type of technology. Their affiliates can draw upon the knowledge of the entire organisation of which they are a part........... in practice, however, the full

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transfer of knowledge may not take place; partly because it is not always suitable for use by the affiliate and partly because the parent company will not always wish to make it available". (46).

As previously stated, it is not the purpose of this research to enquire into the special problems associated with multinational companies as related to technological development and the particular methods adopted by these companies, although this particular subject lends itself to some detailed research for the future. It is clearly evident from this research on the growing pains of Caterpillar Tractor Co., Ltd., at Glasgow in the late 1950s and early 1960s, (see chapter 3), that many special and particular problems arose purely due to the multinational connection. Bass and Barrett observe some of the particular developments of multinationals in recent years. They show for example, I. B. M., as a multinational who not only trade in Europe but also finance, manufacture and develop products using their combined resources in many countries. 2 of the 10 models of the I. B. M., 360-series model computer were, according to a report by Larsen in 1969, developed completely in Europe. Other examples show that the carburetor of an engine may be designed in Britain from research done in Belgium, it may be manufactured in Germany for assembly in a motor car in Brazil (47).

Caterpillar Tractor Company for their part, do not, for reasons previously given, attempt to disperse their product research, nor indeed some aspects of their process technology research, to any other country outside America. The approach by Caterpillar to the question of process technology, which is central to this research, is slightly different. It was previously reported in chapter 3 that the planning division in each Caterpillar facility had the necessary autonomy to find the best equipment to manufacture the components and product assigned to that plant. Regrettably there is no real scope for experimentation with various processes, each piece of capitalised hardware has to be assigned to a project and shown as a sound return on investment by the format displayed in Appendix F. All major experimentation takes place in a special department attached to the parent manufacturing plant in Peoria, Illinois. This section is staffed completely by Americans with a broad objective of finding improved and cheaper ways and means of making Caterpillar parts. This group simply known as Building W, use robots, develop special materials, experiment with new cutting tools, build microprocessors for all types of manufacturing control. There is no restraint on experimentation except perhaps an annual budget. The findings and outcome from this special group are transmitted to each plant where it is considered benefits can be derived. The major difference between this process technology development and the product development is that this group have research teams who visit Caterpillar plants and facilities around the world, to tap ideas for further development.

The spectre is often raised, and in particular 10 years ago by Servan Schreiber's book "The American Challenge", that European business is being dominated by American companies. In fact he lists the "United States in Europe" as one of the world's largest economies. Economic control does not necessarily mean management or labour dominance. For instance, in Europe IBM employed in 1970 some 69,000 people but only 200 of these were Americans, Caterpillar in a similar way employ approximately 6,000 people in Britain, less than 0.5 percent are Americans. However Servan-Schreiber observes the established multinational not the new or recently established enterprise, which according to the contribution of this research, will experience quite dramatic problems in their efforts to become integrated and grafted into the new country (48). This research has clearly shown that the problems of integration are not all created by the attitudes, traditions and practices of the residents, such as was reported by Boner, ranging from union disputes over tea-breaks in England, to dealing with the Spanish siesta with the long midday break from 2 until 5 p.m. (49). Many of Caterpillar's early problems in

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Britain were brought across by the Americans who came as pioneers to establish the new Glasgow facility. Perlmutter wrote in 1969 about the 3 approaches to how a multinational firm organises itself to adopt to its environment, these were as follows:-

1. Ethnocentric. The home country is superior to the foreign organisation in all respects, and all decisions and methods will be controlled by the home country.

2. Polycentric. The organisation is host country-oriented since foreign cultures are different and local people are able to make the best decisions about the firm's progress.

3. Geocentric. The organisation is world-oriented and a balanced view is taken of the local national interests and the objectives of the multinational firm. Managerial positions are filled by people having the most talent regardless of national background.

As the multinational organisation matures, it moves from ethnocentric to geocentric organisational patterns (50).

New technology in multinational plants is a subject of particular interest but which, in its broadest sense, is beyond the terms of reference and objectives of this research project - suffice to state that the extracts made from this study of the multinational will be of fundamental importance to this research and the balance of the findings of interest to other research work elsewhere.

5.2 - TYPES OF MEASURING MACHINES USED BY THE MULTINATIONAL.

Caterpillar Tractor Company worldwide has recently been described as the largest private user of co-ordinate measuring machines in the world not including the governments of America or Russia. It is therefore of pertinent importance to know what types of measuring machines are contained in the worldwide organisation. Appendix O contains the questionnaires distributed to all Caterpillar Tractor manufacturing plants. Section III covers questions concerned with co-ordinate measuring machines. This section of the study will analyse the following:-

1. Makes of co-ordinate measuring machines (CMM) used by Caterpillar Tractor Company worldwide.
2. Reasons for choosing these makes.
3. Source of first knowledge of the equipment.
4. Amount of pre-investigation before the decision was made to purchase the CMM.

1. <u>Makes of CMM used by Caterpillar Worldwide.</u>

Table No: 5.1 gives details of the makes and quantities of CMM used by each Caterpillar plant as of January 1978. Over 60 per cent of the machines are either computer-assisted or completely computer controlled. American based plants are reported as having 49 CMMs or 80 percent of the world total while the balance of 12 or 20 percent are located at the non-user plants' facilities. The largest individual share of the CMM population is held by the East Peoria plant with 16 CMMs or 26 percent of the worldwide total. This plant employs approximately 20,000 people and is not only the largest Caterpillar facility but one of the earliest. It is therefore not unexpected that it should house the largest number of CMMs. The original CMMs were located at this plant of East Peoria in 1962 when the technology of this type of measuring machine was in its infancy. From this aspect Caterpillar is one of the pioneering innovators for the use of this type of measuring concept. The quality assurance division of East Peoria has continued to advance its knowledge of measuring machine technology and Appendix P gives a brief history of this development progress, as related to computerised co-ordinate measuring machines.

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CO-ORDINATE MEASURING MACHINES- CATERPILLAR WORLDWIDE.

Plant Name:	Ferranti Bendix	D, E. A.	Olivetti	Portage	Boice	Shelton	Picomm	Total:	
	Make of CMM								
U.S. PLANTS:									
Aurora	1	2	-	1	-	-	-	4	
Dallas	-	-	1	-	-	-	-	1	
Davenport	3	-	-	3	-	-	-	6	
Decatur	2	1	-	-	-	-	-	3	
East Peoria	2	3	-	4	4	2	1	16	
Joliet	3	1	-	-	-	-	-	4	
Mapleton	-	-	-	-	-	-	-	-	
Mentor	2	-	-	-	-	-	-	2	
Milwaukee	-	-	-	1	-	-	-	1	
Mossville	4	1	-	1	-	-	-	6	
Pontiac	-	-	-	-	-	-	-	-	
San Leandro	4	-	-	-	-	-	-	4	
York	-	-	-	1	1	-	-	2	
TOTAL:	21	8	1	11	5	2	1	49	(80%)
OUTSIDE U.S.A:									
Glasgow	2	1	-	1	-	-	-	4	
Gosselies	-	2	-	-	-	-	-	2	
Grenoble	-	-	-	1	-	-	-	1	
Leicester	1	-	-	-	-	-	-	1	
Melbourne	-	-	-	-	-	-	-	-	
Monterrey	-	-	-	-	-	-	-	-	
Newcastle	-	-	-	-	-	-	-	-	
Piracicaba	-	-	-	-	-	-	-	-	
Sao Paulo	-	-	1	1	-	-	-	2	
Toronto	-	-	-	-	-	-	-	-	
Vernon	-	-	-	-	-	-	-	-	
Sagami	2	-	-	-	-	-	-	2	
TOTAL	5	3	1	3	-	-	-	12	(20%)
GRAND TOTAL WORLDWIDE:	26	11	2	14	5	2	1	61	
%	43	19	3	24	8	3	1	100%	

The most popular make of co-ordinate measuring machine used by the worldwide organisation was Ferranti or Bendix commanding a figure of 43 percent of the total, second was the Portage machine at 24 percent and third at 19 percent was DEA. Ferranti of Britain have a licence agreement with Bendix in America and also Tokyo Seimitsu in Japan, the models supplied by each of these 3 companies are identical, except for the brand name on the model. Appendix P provides details of the computer systems and the number of application tapes already in use for measuring machines at each of the worldwide plants. Application tapes simply mean the number of different operations which can be measured). One complex or valuable component may have to be checked several times on the measuring machine during its machining process through the machine shop, it will therefore need several application tapes and so the total of 12,568 application tapes on Appendix P does not mean that this number of individual components have computer tapes.

2. Reasons for Choosing these Makes.

The major reason for the choice of the equipment was, as far as the Ferranti and Portage measuring machines, pure availability, as in the early to mid 1960s there were no other major suppliers to compete with the abovementioned companies. However, in the late 1960s and early 1970s, many more suppliers joined the market and the reason for choice began to fall into 2 major categories namely, cost and accuracy. It was noted that American plants tended towards accuracy as being the first priority, while non American plants placed cost as the first reason, each group placed the second factor as cost for American plants and accuracy for non American plants. Other possible reasons such as table size, travel, after sales service, etc., were given low priorities next to cost and accuracy. The reasons why there should be a difference between the American and non American plants on this whole subject may be related to the justification for buying the equipment. As is common with all investments of a capital nature, specific returns must be shown to justify that investment. American domestic plants can, by the nature of their geographic location, personally visit the central General Office with their investment requests and are more able to sell the concept and need for the equipment, it is perhaps easier to sell the question of accuracy as a key need with this approach than it would be for a non American plant who would have to deliver their request by mail.

3. Source of First Knowledge of the Equipment.

Despite the procedure of submitting all requests for investment to the centralised General Office in America at Peoria, this headquarter group, as reported by all plants in the survey, were found to be rather ineffective on the whole question of communication of information on new measuring machine technology, back

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to manufacturing plants. There were no bulletins circulated on latest developments or discoveries in the measuring technology, nor was there any information given on suppliers in terms of costs, delivery or servicing of equipment, yet this information should be available at the General Office. It can only be assumed that the headquarter's reluctance to devulge this data to manufacturing plants may be seen as a signal for these plants to raise projects for more investment, but this assumption has never been confirmed. Most of the Caterpillar manufacturing plants received their first information on CMM technology from either the technical press or direct from co-ordinate measuring machine manufacturers or agents supplying this equipment.

4. Amount of pre-investigation before the decision was made to purchase the CMM.

The question of visits to other users and suppliers resulted in each plant reporting that they had visited at least 2 suppliers at the manufacturing source together with visits to other Caterpillar plants. For example, all of the American plants' quality control engineers assigned to CMM technology, had visited the East Peoria plant to exchange technological information on the use of co-ordinate measuring machines. Most of the managers responsible for the measuring machines in non American plants had also visited the East Peoria facility and had in addition, paid visits to other Caterpillar plants in their own area. For example all the Caterpillar plants in the European area had exchanged visits on several aspects of the technology.

5.3 - THE EFFECTS OF MEASURING MACHINE TECHNOLOGY ON THE ORGANISATION STRUCTURES AND SYSTEMS OF QUALITY CONTROL IN 16 WORLDWIDE MANUFACTURING PLANTS OF CATERPILLAR TRACTOR COMPANY.

It was shown in chapter 4 that the introduction of computer-assisted measuring machines at Glasgow Plant ultimately lead to changes in the organisation of quality control. The purpose of this section of the research project is to extend the study into all of the manufacturing plants of Caterpillar worldwide to carry out an analysis, which will support the argument, that new measuring technology is having an impact on the organisation. Specifically the analysis will try to establish if changes have been made with respect to the following:-

- Span of control due to horizontal pressures which require greater and more effective interpersonal relationships between the individuals concerned with the new technology.
- Numbers of levels of management and the vertical pressures which would require the necessity to assign job duties and responsibilities to individuals possessing a high level of technical knowledge with the new technology.
- Manpower changes as a result of new technology.

The Questions asked of 16 Worldwide Caterpillar Manufacturing Plants.

Parts I and II of the tripartite questionnaire shown in Appendix O requested the following organisational information from each of the worldwide Caterpillar plants.

(Note: The exact wording from the questionnaire is not used but the same meaning is given in this abridged version of the questions concerned with organisations).

1. A request for a current organisation chart covering all levels of management down to and including first levels of inspectors. Those inspectors assigned to co-ordinate measuring machines were to be identified in quantities. (Appendix O - Section II - Question No: 1).

2. What was the total personnel at this location? (Appendix O - Section II - Question No: 3).

3. How many hourly paid employees approximately?
How many hourly paid direct production employees?
How many hourly paid inspectors?
How many weekly paid inspectors?
How many monthly paid inspection people (including managers)?
(Appendix O - Section II - Question No: 4).

4. What numbers of inspection manpower were reduced as a result of using measuring machines? (Appendix O - Section II - Question No: 5).

5. Have you increased your planners and programmers to support the measuring machine technology? (Appendix O - Section II - Question No: 6).

6. Do you normally operate your CCMM on one, two or three shifts? (Appendix O - Section II - Question No: 21).

<u>The facts drawn from 16 Caterpillar manufacturing plants worldwide.</u>

Observations were made in chapter 3, section No: 3.8 regarding the parallelism between organisation structures of each manufacturing plant throughout the Caterpillar worldwide enterprise. It was suggested at that time that this uniformity of style was related to a policy of component interchangeability no matter in which plant it was manufactured. The organisation structures of the quality control department of each of the Caterpillar worldwide manufacturing plants have a strong similarity one to another. The Glasgow Plant quality control organisation chart as shown in Figure No: 4.3 is very typical, as each plant has the following basic activities:- (see Figure No: 5.1).

- o Metallurgical (including in most cases chemistry, heat treatment control and welding control).
- o Internal plant inspection (machine shop and/or assembly).
- o Quality assurance (supplier liaison, quality planning).
- o Product quality (customer liaison).

Some of the Caterpillar Plants have various alternatives to the above which incorporate parts of other departments. For example, it is noted in the Sagami Plant in Japan, that they have a material quality division which incorporates the metallurgical function as a sub

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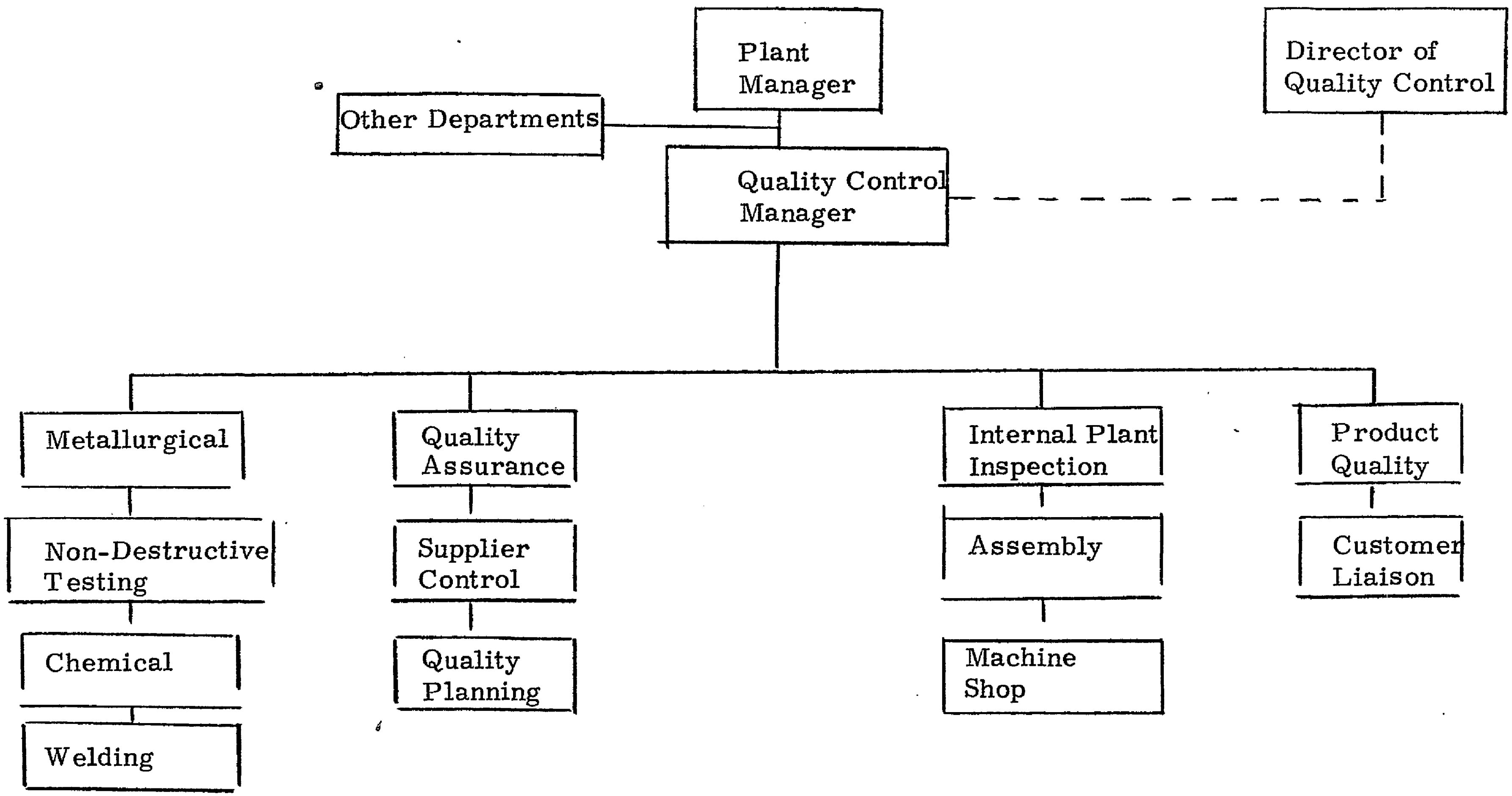
Figure No: 5.1

A TYPICAL ORGANISATION CHART OF QUALITY CONTROL ORGANISATION FOR CATERPILLAR WORLDWIDE PLANTS.



section. The Gosselies Plant in Belgium has a quality engineering division which incorporates a section of design engineering as a sub section of quality control.

The common features of each of the 16 organisation charts and related systems were -

- o The most senior quality control manager reported directly to the chief executive at each manufacturing plant.
- o All quality control managers had a functional authority with the director of quality control at the Caterpillar worldwide headquarters in Peoria, Illinois, U.S.A.
- o All structures included the aforementioned divisions in some form or another, that is metallurgy, inspection, quality assurance and product quality.
- o Each plant had compatible levels of management, that is department head, superintendent of inspection, and supervisory positions in a flat rather than tall organisation structure.
- o Each plant had compatible ratios of inspector to direct hourly paid employee (that is those employees directly engaged in producing saleable parts or assembling product). Table No: 5.2 shows the relationship plant by plant with ratio of quality control manpower to total manpower.
- o Each plant operated an annual expense budget to cover labour and operating material expenses but not capital. This budget as shown in Table No: 5.3 has remarkable consistency plant by plant throughout the worldwide organisation.

The differences in the 16 organisation charts and systems were as follows:-

- o Magnitude in numbers. The largest plant at East Peoria, Illinois had 661 hourly inspectors against a total of 94 at Glasgow, Scotland but the ratio of total manpower to hourly inspector is compatible at 5.0 and 4.7 respectively. (see Table No: 5.2).
- o The number of co-ordinate measuring machines in operation and the number of inspection-operators assigned to these CMMs. (see Tables Nos: 5.1 and 5.5).
- o The quality planning developments at each plant to support the new measuring technologies. (see Appendix P - Statistics regarding CMM usage at Caterpillar worldwide).

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TABLE No: 5. 2

MANPOWER CATERPILLAR WORLDWIDE

Plant Name:	Total Manpower:	Total Hourly:	Total Hourly Direct:	Total Quality Control:	Qual. Cont. as % of total Manpower:
U.S. Plants:					
Aurora	5407	4006	1505	270	4.9
Dallas	N.A.	N.A.	N.A.	N.A.	N.A.
Davenport	1689	1144	630	115	6.8
Decatur	5029	3865	1756	250	4.9
East Peoria	14593	11490	4887	742	5.0
Joliet	5852	4696	2624	288	4.9
Mapleton	N.A.	N.A.	N.A.	N.A.	N.A.
Mentor	2305	1600	718	90	3.9
Milwaukee	777	561	359	38	4.9
Mossville	2091	1356	314	110	5.3
Pontiac	N.A.	N.A.	N.A.	N.A.	N.A.
San Leandro	1995	1596	919	107	5.36
York	2333	1850	1111	116	4.9
	42071(69)				5.08 U.S. Average
Outside U.S.					
Glasgow	2338	1692	764	110	4.7
Gosselies	4284	3053	N.A.	185	4.3
Grenoble	2286	1621	1150	135	5.9
Leicester	795	405	179	64	8.0
Melbourne	194	91	26	8	4.1
Monterrey	N.A.	N.A.	N.A.	N.A.	N.A.
Newcastle	2048	1529	849	81	3.8
Piracicaba	823	484	191	36	4.3
Sao Paulo	2062	1334	N.A.	106	5.1
Toronto	277	178	54	10	3.6
Vernon	N.A.	N.A.	N.A.	N.A.	N.A.
Sagami	4169	2593	1597	494	11.84
61,347	19276(31)				5.56 outside U.S. Av.
Mean	3041	2198	968	169	5.32 World Average.
[illegible]		[illegible]	[illegible]	[illegible]	
Variance	N.A.	N.A.	N.A.	N.A.	
N.	21	21	21	21	

TABLE No: 5. 3

QUALITY CONTROL MANPOWER AND BUDGET PER ANNUM CATERPILLAR WORLDWIDE

Plant Name:	Inspection Hourly:	Inspection Weekly:	Inspection Monthly:	Annual Budget:	Budget per Inspection Head: £'s
			1978 Value in £000s		
U.S. PLANTS:					
Aurora	237	2	31	5023	18.60
Dallas	NA	NA	NA	NA	----
Davenport	102	2	11	2433	21.15
Decatur	220	2	28	5000	20.00
East Peoria	661	5	76	9879	13.31
Joliet	249	11	28	5866	20.36
Mapleton	NA	NA	NA	NA	-----
Mentor	76	-	14	1762	19.57
Milwaukee	29	1	8	748	19.68
Mossville	162	4	30	4695	42.68
Pontiac	NA	NA	NA	NA	----
San Leandro	96	1	10	2496	23.32
York	99	1	16	2605	22.45
				£40.5M	22.11 Av. US plants.
OUTSIDE U.S.					
Glasgow	94	2	14	1200	10.90
Gosselies	165	11	19	3993	21.58
Grenoble	-	110	25	1000	7.40
Leicester	30	17	17	NA	----
Melbourne	5	2	1	343	42.87
Monterrey	NA	NA	NA	NA	----
Newcastle	66	1	14	500	6.17
Piracicaba	29	2	5	1684	46.77
Sao Paulo	95	1	10	2277	21.48
Toronto	9	-	1	343	34.3
Vernon	NA	NA	NA	NA	----
Sagami	182	-	312	2650	5.36
				£14M	21.87 Av. outside US
Mean	128	8.5	32.66		
				£54.5M	21.99 Total World Average.
Variance	NA	NA	NA		
N.	21	21	21		

- The numbers of hourly inspectors displaced and the number of white collar planners added, directly due to the introduction of new technologies. (see table No: 5.4).

The above differences are mainly of numerical features. The significant aspect is, that from a common datum base organisation structure, all of the 16 plants have had some degree of change in the organisation structure, due to the introduction of computer-assisted co-ordinate measuring machine technology.

The Beginning of a Change.

The East Peoria Plant of Caterpillar Tractor Company was first to introduce computer-assisted co-ordinate measuring machines in the whole enterprise in 1970. A brief history of this development is given in Appendix P. The reason why this development is important to this study is concerned with the fact, that the new technology forced East Peoria to form a special team of monthly staff engineers and computer experts to develop the first master control programmes for use on the first generation of computer-assisted measuring machines introduced into the East Peoria Plant. The formation of this team was to become the hub for the computer requirements of all other Caterpillar plants worldwide, thus minimising considerably the programming requirements at each individual plant.

The East Peoria quality control organisation was therefore subjected to the following -

- Increased spans of control within the quality assurance division as a new sub division was formed to meet the programming needs of the co-ordinate measuring machines.

- Increased numbers of levels of management structure due to the vertical pressures which were created, and the need to assign a manager possessing engineering and computer knowledge to a high degree of competence, to meet the needs of the new technology.

- Manpower changes as 16 inspectors were selected from the hourly paid inspection group, trained and assigned to the new CCMMs. This eventually resulted in the displacement of 8 other inspectors who were absorbed into other work or not replaced

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when they retired (similar to the situation at Glasgow). East Peoria also reported that they increased the white collar planning by 4 people).

Changes at other Caterpillar Plants.

One other plant made substantial increases to its planning staff within quality assurance,this was Mossville,again located in Illinois, USA. These changes resulted in the creation of a sub division and the appointment of a highly qualified leader. The reason why Mossville went in that direction was due to their development and use of a larger type of computer than the East Peoria model and therefore they had to develop their own software requirements without the aid of East Peoria. The software service provided by East Peoria to all other Caterpillar Plant underplays the true technological demand, which would exist at each of these plants had the service not been available. No other Caterpillar Plant reported having to increase their span of controls nor levels of management but 12 of the plants out of the total 16 added white collar planners in various quantities to handle the needs of the new technology. In addition to this as of 1978, 13 out of the 16 plants had displaced or removed inspectors as surplus to requirements, due to the impact of the new equipment. The planners added and inspectors reduced by each plant is given as follows:-

Table No: 5.4

Plants:	Inspectors Displaced:		% of total hry inspts:	Planners added:
Aurora	4		1.7	1
Davenport	3		3	2
Decatur	1		0.5	0
East Peoria	8		1.2	4
Joliet	2		0.8	1
Mentor	0		0	1
Milwaukee	1		3	1
Mossville	6		3.7	3
San Leandro	1		1	1
York	2		2	1
Glasgow	3		3	0
Gosselies	1		0.6	1
Grenoble	2		2	1
Leicester	0		0	0
Sao Paulo	3		3	1
Sagami	0		0	0
TOTAL:	39	Aver.	2.0	19

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The figures given above show that for every white collar man added 2 hourly inspectors have on average been displaced, or on average 2 percent of the total inspection hourly paid group by plant. It is probable with the generation of more new software by this planner group that the hourly inspector manpower will further reduce with a corresponding increase in the planners.

Current Measuring Machine Status at all Caterpillar Plants.

Appendix P shows the statistics regarding the CCMM usage at Caterpillar worldwide. The table indicates that 12,568 application tapes were in existence in 1978. This means that this number of operations could be verified on a computer-assisted measuring machine instead of using conventional measuring techniques. Table No: 5.5 shows the total number of computer-assisted measuring machine operators as a percentage of all inspectors in each plant. The total numbers worldwide is shown at 102 inspector-operators or 4.9 percent of all inspectors.

Examinations of the American plants show that Milwaukee plant has the highest percentage of CCMM operators to inspectors at 17 percent. Milwaukee plant has a high degree of fabrication work in its line of product and for this reason, can make good use of measuring machine technology. The East Peoria plant while having the largest number of CCMMs is below the average percentage of total inspectors at 2.4 against an American plant average of 5.1 percent. Sagami plant in Japan has the greatest number of CCMM operators outwith America at 18 making the percentage of operators to inspectors at 10 percent. Almost all of the plants operate the equipment on two or three shifts, the exceptions being Davenport plant in America which is a new installation and probably in the course of manning up, and Leicester plant in England who do not have any machine shop manufacturing but assembly functions only.

Table No:5.5

Computer Assisted Measuring Machine Operators as at 1978.

U.S. Plants:	CCMM* Inspector Operators		% of total Inspectors		No. of Shifts Worked
Aurora	5		2		3
Davenport	8		8		1
Decatur	4		1.8		3
East Peoria	16		2.4		3
Joliet	5		2		3
Mentor	3		4		2
Milwaukee	5		17		2
Mossville	5		3		2
San Leandro	7		7		3
York	4		4		2
	65	Aver	5.1%	Aver	2.4
Outside U.S.A.					
Glasgow	6		6		3
Gosselies	5		3		3
Grenoble	3		2.7		2
Leicester	1		3.3		1
Sao Paulo	4		4		2
Sagami	18		10		2
	37	Aver	4.8%	Aver	2.1
GRANT TOTAL:	102	Aver	4.9%	Aver	2.3

*Computer-Assisted Co-ordinate Measuring Machines only.

Conclusions from the analysis of organisation.

- Caterpillar quality control organisation structures in worldwide plants are very standardised with a flat rather than tall structures. Spans of control at the top end do not exceed 7 in any one plant. The span of control for the first line supervisor of inspectors varied between 17 and 7 inspectors.

- Quality assurance divisions at 2 plants out of 16 were forced to extend their span of control by adding a special sub division to handle the new measuring machine technology.

- Most of the plants displaced blue collar inspectors as surplus to requirements due to new technology.

- Most of the plants added white collar planners to support the new measuring machine technology.

- It is almost certain that the above shifts in employment will continue as the measuring machine technology further extends into these plants.

- Communication systems are highly integrated within the worldwide organisation. Each plant being interdependent on the central headquarters and the East Peoria quality assurance division specifically for software requirements.

- While lines of functional authority operated between plants and central headquarters, each plant had total direct line authority within their own plant for the utilisation of their measuring machine technologies.

5.4 - RESISTANCE TO NEW MEASURING MACHINING TECHNOLOGY IN THE MULTINATIONAL.

The fact of resistance to innovation emerges from nearly all studies of the innovation process. The relationship between the entrepreneur (in an established organisation) and resistance sometimes appears almost to follow Newton's Third Law of Motion (action and reaction are equal and opposite). In a section on resistance to technological innovation in his text, "Research, Development and Technological Innovation", James R. Bright lists 12 reasons why innovations are opposed. These 12 reasons have been re-interpreted and reduced to 9 reasons in order to test resistance to the innovation of measuring machine technology. The forthcoming analysis on the multinational plants of Caterpillar is again repeated in chapter 6, in the study of multiplex firms. Appendix O - Section III - question 10, asked the following question of 23 quality control managers, viz:-

- It has been suggested that automation and advanced technology of any kind will be resisted for various reasons, some of which are as follows. Has this been your experience with inspection equipment in particular?

  Each quality control manager was requested to answer yes, no, or perhaps, to the following 9 reasons (the various reasons have been shortened here in the text but are shown in full in the above numbered Appendix):-

  - Status and prerogative.
  - Existing ways.
  - Skills experience and knowledge.
  - Security of employment.
  - Avoid scrapping assets.
  - Avoid altering other systems.
  - Fear of change
  - Conflict with organised groups.
  - Increases mystique.

Results of Survey.

Table No: 5.6 details the results generated from American and non American plants and shows some very interesting patterns, especially when American plants are compared to non American and then as a total group representing the general attitude of an American multinational corporation in relationship to the important question of new

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TABLE No:5.6

AUTOMATION AND ADVANCED TECHNOLOGY
RESISTANCE TO CHANGE AT CATERPILLAR - WORLDWIDE

Protection of:	Caterpillar U.S. Plants Yes:	P'hps:	No:	Other Yes:	P'hps:	No:	TOTAL Yes:	P'hps:	No:	Major Survey (Users) Yes:	P'hps:	No:
Status:	61	30	8	30	20	50	47	26	26	8	11	70
Existing Ways:	38	30	23	30	10	60	34	26	39	16	18	66
Skill:	23	38	38	20	10	70	22	26	52	9	26	64
Security:	38	38	23	20	0	80	30	22	47	15	25	59
Assets:	61	23	15	20	30	50	43	26	30	11	17	70
Other Systems:	46	23	30	50	20	30	47	22	30	11	21	66
Fear Change:	76	0	23	50	0	50	65	0	34	21	24	55
Conflict:	23	38	38	30	20	50	26	30	43	8	19	73
Mystic:	46	30	23	10	50	40	30	39	30	8	21	69
	N = 13			N = 10			N = 23			N = 140		
Overall Percentages	46	27	24	28	17	53						

N. B. Figures shown are Percentage Values from Each Survey advanced technology and/or automation of any type, which is introduced into the manufacturing environment. On the aspect of status, it is very apparent that an American employee would consider this so important that he would resist any effects on this status by automation or advanced technology. In contrast the non American plants report a much lower concern for status and indeed half of the responses show a definite no to this point and would not resist a change due to a need to protect status. The attitude survey conducted at the single manufacturing plant of Caterpillar, Glasgow would tend to contradict the overall results from non American plants, as inspection operators on the new co-ordinate measuring machines indicated their strong awareness of status on the new equipment. Chapter 4, section 4.4, page 197. When all of the 9 factors are reviewed, it is clear that major differences are apparent between the American and non American plants in 4 factors, namely that resistance to the change would be high for the protection of status, valuable assets, general fear of change and the mystique which tends to surround some shop floor skills and knowledge. The non American plants were also high in general fear of change but not as high as the American result. The non American plants expressed a high figure for the need to avoid changing other systems in harmony with inspection, but apart from these 2 moderately high figures, the non American plants tended towards a negative result for all the other 7 factors. Indeed the question of resistance to change to protect security of employment was rejected by 80 percent of the respondents. The same strong negative result was given for a need to protect hand skills and knowledge. Overall the American based plants were 46 percent positive that there would be some degree of resistance, 24 percent negative that there would be any resistance to change, and 27 percent unsure whether there would be resistance or not. Non American plants were overall 28 percent positive that there would be some resistance to change, 53 percent negative that there would be any resistance to change and only 17 percent unsure whether there would be any resistance or not.

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Basically the above results suggest that the American based quality control manager is concerned that he will have greater resistance to new technology than the non American quality control manager within the multinational organisation. This again maybe a matter of experience, as was shown previously in Table No: 5.1, the American plants have a much greater proportion of measuring technology already in use than non American plants and therefore could be experiencing resistance in the factors as shown. This subject will be further discussed later in chapter 6 when comparisons will be drawn from several studies on this important aspect of resistance to change, brought about by new technologies in manufacturing industries.

In summary the top 3 reasons given by each group as extracted from Table No: 5.6 were as follows:-

Top 3 Reasons

American Plants.	Positive -	Fear	Status	Security
	Perhaps -	Skill	Security	Conflict
	Negative -	Skill	Conflict	Other Systems.
Other Plants:	Positive -	Other systems	Fear	Status
	Perhaps -	Mystique	Assets	Status
	Negative -	Security	Skill	Existing ways

Combined Positive and Perhaps Responses

American Plants.	Status	Assets	Fear
Other Plants.	Fear	Other Systems	Conflict

All Multinational Plants

Positive Reasons:	Fear	Status	Other Systems
Combined Positive and Perhaps:	Status	Assets	Other Systems/ Mystique

The implications drawn from these results are, that overall quality control managers of 23 manufacturing plants consider that general fear of change would be the major reason for resisting the introduction of new measuring machine technology.

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5.5 - BEHAVIOURAL CHANGES IN INTERGROUP AND INTER-PERSONAL RELATIONSHIPS.

One of the important areas of this research project is concerned with behavioural changes brought about by the impact of new measuring machine technologies on the shop floor. Table No: 5.7 presents the findings from the Caterpillar study - questions 11 and 12, section II - Appendix O and broken down by American, non American plants, together with some information obtained from the field research of a large number of independent manufacturing firms which will be discussed in chapters 6 and 7. Three factors of behaviour were measured, namely changes in influence, power and relationships.

In this study these factors are defined as follows:-

> Influence is defined as the ability of the inspector operator to have some effect upon the production supervisor and/or the machine tool operator to change some established order or pattern of work.
>
> Power is defined as having the capacity to persuade, to the extent of taking some authority by the inspector operator over the production supervisor and/or machinist.
>
> Relationship is defined as the change in mode or state of working harmony between the inspection operative and the production supervisor.

Results of Survey.

The American plants reported an increased influence at all plants while non American plants showed a wider spread noting a greatly increased influence, increased influence and no change. The overall result by all Caterpillar plants would indicate that the new advanced measuring machine technology has had some degree of impact, to cause the incumbent inspector to be able to demonstrate an increased influence on the performance of his peer and superior level employees in the manufacturing plant. To a lesser degree some increase in power was noted in both American and non American plants, although American plants reported almost half the response showed no change and non American plants a higher response for no change. Overall

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TABLE No: 5.7

BEHAVIOURAL CHANGES SINCE THE INTRODUCTION OF CMM (1)

%	Major Survey:	Caterpillar U.S. Plants:	Caterpillar Other Plants:	Caterpillar Total:
Influence:				
Greatly Increased	6	-	28	10
Increased	44	100	57	85
No Change	50	-	14	5
Reduced	-	-	-	-
	100	100	100	100
Power				
Greatly Increased	1	-	-	-
Increased	22	55	85	38
No Change	77	45	45	61
Reduced	-	-	-	-
	100	100	100	100
Relationship				
Greatly Improved	2	-	28	10
Improved	40	100	28	75
No Change	57	-	42	15
Deteriorated	1	-	-	-
	100	100	100	100

there was a two-thirds majority reporting that the state had not changed between the inspection operator and the production supervisor and/or machinist.

A notable improvement in relationships was evident, all American plants reported some improvement but non American plants indicated both greatly improved and improved but with a much larger proportion showing no change. Does this again suggest a difference in attitude between the average American employee and the non American employee? Why should the new technology apparently bring the production supervisor and the inspector closer together as a team in America and not so in non American plants? Is this a question of maturity on the part of the American employees or a need for the non American production supervisor to maintain some form of authority in the performance of his task? These questions will be discussed in chapter 6 of this research.

5.6 - ATTITUDES TO INTEGRATION OF JOBS AND DISSATISFACTION WITH WORK AMONG INSPECTORS IN THE MULTINATIONAL PLANTS.

The human problems associated with the merging of technologies has already been discussed in chapter 4 of this research, where it was shown that the majority of the inspectors were in total disagreement with the proposal to integrate job tasks. A similar question was put to the 23 quality control managers at the manufacturing plants of Caterpillar worldwide. The question as shown in Appendix O, section II - question 14 was as follows:-

- o If CMMs become an integrated part of in-line machining process and output data takes away human discretions, do you consider that the inspector should eventually become part of the production team?

Each quality control manager was asked to give a response to one of the following variables:-

- o Strongly disagree
- o Mildly disagree
- o Neither agreement nor disagreement
- o Mild agreement
- o Strong agreement

Related to the above question was the subject of job satisfaction, should such a situation arise in the future and directly affect the work of craft inspectors. This question as shown in Appendix O, section II, question 15, was as follows:-

- o If the CMM tends to require less skill to operate, do you think the inspectors of tomorrow will become dissatisfied with their work or not?

The same 5 variables as discussed above were given for response to this question.

<u>Results from Survey - Integration</u>

Table No: 5.8 shows the findings from both questions as received in /....

the responses from American plants, non American plants and the field survey which will be discussed in chapter 6 of the research. The question of integration gave quite a remarkable result in the American survey as almost a 50 percent split decision went to the 2 extreme ends of the variables with a marginal gain by those in strong and mild disagreement with the proposal, the non American plants' responses were equally unconvincing with a similar split between those in favour and those not in favour of integration of the inspection function. It was evident that there are 2 schools of thought on this whole subject, and one may recall that, when the same question was put to the inspector group at the single manufacturing plant of Caterpillar, Glasgow, although the response in the majority was to disagree with integration, at least 20 percent of both the control and operative groups did have mild agreement with the concept, see chapter 4, section 4.5, page 207. The whole future of automatic gauging in process is very uncertain and perhaps requires some degree of specific research to more accurately forecast the future development in the industry. The implications from these findings would suggest that, while the people directly associated with these new technologies are aware of the advances being made, they are undecided or unaware of the human problems which will inevitably arise in manufacturing industries as these technologies develop further in the future.

Dissatisfaction

The problem associated with possible de-skilling of inspection operatives through the advancement of technology, was considered by both American plants and non American plants and again the results are displayed on Table No: 5.8. There was a 60 percent response of strong to mild disagreement by the American plants with the proposal that further de-skilling would lead to dissatisfaction among inspection operatives but 40 percent of the response strongly agree with the proposal. Non American plants were not so undecided and showed by 86 percent that they strongly to mildly disagreed. There were 14 percent undecided which was the balance of the overall non American /...

TABLE No:5.8

BEHAVIOURAL CHANGES SINCE THE INTRODUCTION OF CMM (2)

			Caterpillar		
	%	Major Survey	U.S. Plants	Other Plants	Total
Integration					
Strong Disagreement		38	46	42	45
Mild Disagreement		11	7	-	5
Neither Agree nor Disagree		15	-	14	5
Mild Agree		15	-	28	10
Strongly Agree		21	46	14	35
		100	100	100	100
Dissatisfaction					
Strong Disagreement		31	53	57	55
Mild Disagreement		27	7	28	15
Neither Agree nor Disagree		20	-	14	5
Mild Agree		16	-	-	-
Strongly Agree		6	40	-	25
		100	100	100	100

plants' response.

Despite the split in the American plants' response, it would seem evident that there is no real concern that the craft inspector will become dissatisfied with his work tasks due to possible de-skilling. This outcome is supported in the single manufacturing plant study chapter 4, section 4.4, where the attitude study among CMM inspection operators revealed that they had experienced an increase in job satisfaction.

5.7 - THE EFFECTS ON NEW MEASURING MACHINE TECHNOLOGY ON STATUS AND JOB INTEREST IN THE MULTI-NATIONAL PLANTS.

The subject of job status has been discussed in several sections of this research and in particular in chapter 4, section 4.4, where as a result of an attitude survey it was revealed that craft inspectors had experienced an improvement in their personal status since their assignment to the new measuring machine technologies. The question of job interest was not requested in the aforementioned attitude survey but it was implied from the findings in this survey that job interest had also improved in line with status. The question put to 23 quality control managers at the manufacturing plants of Caterpillar related to status and job interest is given in appendix O, section II, question 17, and was as follows:-

- What effect has the introduction of CMM technology had on your inspection staff both CMM operators and other inspectors?

Each quality control manager was asked to respond to one or more of the following conditions for both CMM operators and for other inspectors -

- Feeling of increased status.
- Feeling of less status.
- Greater interest in work.
- Less interest in work.
- No change.

Results of survey - Status and job interest. Table No: 5.9.

The overall results from both the American and non American plants was clear cut indicating that between 70 and 80 percent of the responses were aware of increased status among the CMM operatives and approximately 40 percent response for the other inspectors not operating co-ordinate measuring machines, but close enough to know the technology. It was noted that there was almost twice the amount of greater interest shown by non American plants to American plants'

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inspection operatives at 15 and 28 percent response respectively. Of particular note is the fact that the American plants' other inspectors showed an almost double response again over the non American plants on the same factor of greater interest at 46 to 28 percent response respectively. Those inspectors not operating CMMs may tend to try harder and show greater interest with the view that they could gain promotion or increased status by moving onto a measuring machine. The aforementioned age groupings showed that in America a much more senior inspector tended to be on the new technology which probably further increases the element of status, while by contrast the non American plants' CMM operatives tended to be younger employees and perhaps the desire to achieve such a position is not so high among the typical non American employee. There was an almost identical response of 15 to 14 percent by both American and non American plants to the factor of no change among other inspectors, indicating that some of these inspectors had had no effects due to the introduction of the new technology.

Clearly this above analysis has an important bearing on this research project because it does demonstrate that the new technology had a measured effect on those inspectors who were assigned to operate the equipment. It was also interesting as it had the effect of pulling up the status of other inspectors in the group not assigned to new technology.

TABLE No: 5.9

EFFECT ON CMM OPERATORS AND OTHER TABLE INSPECTORS

Effect on CMM Operators	Major Survey	Caterpillar U.S. Plants:	Caterpillar Other Plants:	Caterpillar TOTAL:
Increased Self Status	50	84	71	80
Less Status	0	0	0	0
Greater Interest	26	15	28	15
Less Interest	0	0	0	0
No Change	23	0	0	0
	100	100	100	100
Effect on Other Inspectors.				
Increased Self Status	13	38	42	45
Less Status	3	0	0	0
Greater Interest	20	46	28	40
Less Interest	1	0	0	0
No Change	62	15	14	15
	100	100	100	100

N.B.
Figures shown are percentage values from survey.

5.9 - OBSERVED EFFECTS OF NEW TECHNOLOGY ON THE MULTINATIONAL PLANTS.

The objective of chapter 5 was to study the results of a field study on a multinational organisation concerning the impact and problem of new measuring machine technology. The purpose of this final section of this chapter is to attempt to draw together the findings and relate them to the 6 major factors of the enterprise namely, organisation structure, management, strategies, machine shop environment, control systems and people.

Similar to the pattern developed in chapters 3 and 4, a Table No: 5.10 has been completed with the findings and will be discussed under each heading as follows:-

Organisation Structure.

Due to vertical pressures created by the new measuring machine technology the largest Caterpillar Plant was forced to establish a new sub division within the quality assurance group. This change was also executed by a second American based plant. The remaining 14 plants did not change their spans of control nor add sub divisions or sections mainly as a result of getting good back-up service from the largest plant.

The standard organisation structure for quality control is flat rather than tall, even with the introduction of additional sub divisions at 2 plants, the structure remains shallow. The maximum width of span was 7 at the top and varied from 7 to 16 for the first line supervisor. Strong functional lines of authority were developed between the largest plant and all other Caterpillar plants but the direct lines of authority remained within the line management structure of each plant. New information flow lines and communication systems were developed both inter and intraplant.

Management.

During the early development of the new measuring machine technology, all Caterpillar manufacturing plants worldwide were encouraged to purchase equipment in order that further improvements in quality could be realised. This support came from the director of quality control at the headquarters group in Peoria, Illinois. See Figure No: 5.1.

Middle management in the form of quality control managers at each individual plant also gave strong support almost on a competitive basis in order not to be left behind technologically. Each project had /....

of course to be justified by a return on investment analysis as described in chapter 3, section 3.9. The acceptance of responsibility for making this new equipment operate was found to vary between the manager responsible for using the measuring machine and the manager responsible for planning its use and correlated to the reliability of the equipment. If a measuring machine had high downtime due to electronic faults then the user manager reverted back to first principle measuring techniques, and ignored the new technology. On the other hand, if the equipment was reliable and infrequently out of commission, then the user manager took total responsibility. Almost all of the requests for new measuring equipment came from the management most closely associated with it.

Strategies.

Each multinational plant was given objectives to maximise utilisation of the measuring machine technologies. Utilisation was measured by loading each machine with sufficient programmed tapes which could keep it in use for 8-hour segments. This process was not completely accurate as it depended upon the machine shop producing components in a particular sequence. Therefore the measuring machines had to be overburdened with programmed tapes of selected operations such that the operator could call upon a tape as each component was run through the shop. The discipline on utilisation then fell on the inspection management in each plant to ensure by observation that each machine was being fully utilised.

The most common long term plan reported by the multinational plants was concerned with the study of in-process gauging which would be a technology of the future which could eventually minimise the use for co-ordinate measuring machines. The strategy adopted by each plant for education and training was to have one or two weekly paid staff go to the equipment supplier for initial training. These staff employees would return to the plant and train other staff and operatives. The purpose of the training programme was to minimise the learning curve and maximise the efficient use of the equipment. The gradual build up of measuring machine technology saw the creation of small teams generally with a staff employee as team leader.

Machine Shop Environment.

There has been substantial growth of measuring machine quantities within the worldwide organisation, but selection of equipment has been left to each plant with minimum interference or guidance from the headquarters group. The only criteria placed on each plant was the need for common software so that the American plant at East Peoria could assist with master tape production.

Co-ordinate measuring machines (CMM) were reported to be located near the point of production if large components were to be measured and at the end of the machining line where small parts were to be measured. Most plants had located the CMMs in air controlled

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rooms. Maintenance had been established with a contract to the supplier of the equipment, but some in-house maintenance was carried out by electronic electricians.

Control Systems.

Return on investment analyses were prepared by each plant for all new measuring machines. The major contribution by the CMM technology claimed by all plants was increased productivity. Utilisation was as already discussed, more haphazard in all plants. 2 particular studies on efficiency gave an average of 72 percent improvement over conventional systems.

People:

All plants reported shifts in employment mainly concerned with the displacement of hourly paid blue collar craft inspectors to other tasks and the increase of white collar weekly paid planning staff.

The evidence given in the survey indicates that inspection operators of CMMs have increased their skills since their assignment to the new technology. It was shown that inspectors in the multinational organisation would tend to resist the new technology for 3 major reasons namely, fear of change, protection of status and the avoidance of changing other systems. There was no evidence presented which would show that any resistance was observed at any of the 25 plants surveyed.

The majority of plants disagreed with the proposal that inspection and production tasks would or could be integrated in the future, due to the further advance of measuring machine technology and machine tool technologies. The problems associated with de-skilling of inspectors leading towards job dissatisfaction was totally refuted.

It was observed in most plants that inspectors assigned to CMMs were aware of increased status and higher job interest. The majority of the plants reported that the influence of the inspector over the machine tool operator and the production supervisor had increased. Equally the power to persuade the production supervisor to follow the inspector's instructions was also increased in some plants, while no changes were noted in others. The overall working relationships between the craft inspection operator of the CMM and the production supervisor had improved.

Table No: 5.10

OBSERVED EFFECTS OF NEW TECHNOLOGY

MULTINATIONAL MANUFACTURING PLANTS - CO-ORDINATE MEASURING MACHINES.

Factor	Element	Change Type:	Effect
Organisation Structure.	Horizontal Pressures	A	Wider Span
	Vertical Pressures	A	Increase Levels
	Direct Authority Lines	D	None
	Functional -do-	B	Interplant Incr.
	Information flow lines	B	Interplant Incr.
	Work flow disciplines	D	None
	Informal - Formal	D	None
Management	Support-Top Manager	A	Strong
	Support-Middle Manager	A	Strong
	Involvement	D	Not Observed
	Acceptance-Responsibilities	B	Task Related
	Innovators.	C	Increasing
Strategies	Objectives	A	Related
	Long Term Plans	C	Developed
	Education-Training	C	Haphazard
	Teams-Teamwork	A	Improving
Machine Shop Environment.	Growth	B	Substantial
	Selection	B	Plant Controlled
	Location	B	Plant Controlled
	Maintenance	B	Contract & in-house
Control Systems	R. O. I. Contribution	B	High
	Utilisation	D	Not Observed
	Efficiency	D	Not Observed
People	Employment Shifts	B	Blue collar down.
	Skills	B	Increased
	Resistance	D	None
	Integration	A	Resisted
	Satisfaction	C	No Change
	Manning	B	Seniority
	Status	B	Increased
	Influence	B	Increased

Change Type - A-One step Change, B-Cumulative Change. C-Continuous Change, D-Nil or Not Observed.

CONNECTING SUMMARY

- Chapter 5 provided evidence on the effects of new co-ordinate measuring machines on the multinational enterprise. Details were given on the technology used and how this technology forced changes in the organisation structure. Shifts in employment were observed and changes in systems of communication became necessary. Specific investigation was made of certain behavioural changes among employees closely associated with the new measuring machine technology. These behavioural effects were concerned with attitudes of resistance to change, inter-personal relationships, dissatisfaction and concern for status and job interest.

- Chapter 6 opens the study to a field survey of a large number of firms, some using and some not using co-ordinate measuring machines. The key purpose of this chapter is to attempt to differentiate between these user and non-user firms. Are there particular differences between the organisation structures, management attitudes, strategies for long term planning and other factors? The findings will suggest that there are differences which may form a pattern or mould for firms which intend developing further their activities in the general field of new technologies.

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CHAPTER 6 - New technology in various manufacturing industries.

6.1 - THE OBJECTIVE OF THIS CHAPTER.

The objective of chapter 6 is to develop additional information and further understanding of advances in new technology in manufacturing industry. The specific aims of this chapter will be to analyse the findings from a large survey of manufacturing plants in Europe and America, comparing companies using and not using new measuring technology by examination of the following:-

- o Organisation structures.
- o Divisions of labour.
- o Hierarchy of levels and span of control.
- o Manpower ratios.
- o New technology and production type.
- o Major technical changes made in firms.
- o Effect on production systems from major technical changes.
- o Disposition of people displaced by new technology.
- o Resistance to new technology

Supportive material is provided in the Appendices in terms of -

- o The survey questionnaire. (see Appendix T).
- o The overall results from the above questionnaire. (see Appendix R).
- o Manpower ratios by business activity and employee size. (see Appendix R).

Highlights of Aims and Findings.

Organisation structures are of particular interest to this research project as the central argument is that these structures will be subjected to some form of change due to the impact of new technology. In this section of the study, 100 organisation charts are studied and compared in order that differences or similarities can be established

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between those firms using new measuring machine technology and those firms not using new measuring technology. The organisation structures are examined in some depth to ascertain divisions of labour, hierarchy of levels and spans of control, for the various levels in the pyramid. Interrelated manpower ratios are computed for firms both by their business activity and employee size characteristics. This study is important in order that shifts in manpower within various payrolls can be ascertained in relationship to the new technology being used by the firms. This section of the study is concluded with the analysis of 18 organisation charts of firms using and not using new measuring machine technology. Woodward in her research of organisations and technology developed categories of production types found in various firms (19). These categories are used in this research study in order to ascertain if there is any correlation between particular production types and new measuring machine technology, as it will be shown both in this research and in related prior research, that firms using similar technical methods had similar organisational structures. In this research the production types will be examined both within particular business activities and by employee size groupings.

One of the questions featured in the questionnaire of the field survey was related to the extent of major technical changes made by each individual firm, in the last 2-year period. The objective of this question was again to search out evidence which would differentiate the users of new measuring machine technologies from the non-users. Was there something different about firms who were innovative with their production processes compared to those firms who did not appear to be making any major technical changes? The major technical changes reported are broken down into 4 specific broad categories and then further analysed within these 4 groups in an attempt to find specific differences between the firms.

Closely related to the question of major technical changes is the

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extent to which these changes have affected the system of production. These possible effects are categorised in 5 groupings and discussed by firms using and not using new measuring machine technology, again in an attempt to discover if there are any specific differences between these firms. One of the most difficult problems facing firms who wish to introduce new technology that has the effect of reducing manpower, is to solve the question of how best to reduce the manpower after the technology is in operation. Recently Pilkington Brothers Ltd., Britain, introduced a new computer controlled glass cutting machine, which when associated with other new systems of production process, almost immediately made 400 people redundant. This study suggests that there are 6 possible alternatives available to firms facing this dilemma, and again an attempt is made to determine if there are any differences in the approach by firms using and those not using new measuring machine technologies.

The question concerning resistance to automation and new technologies is asked in this section of the study based on the re-interpreted theories of James R. Bright (38). It was considered that the responses from a large population of firms on this question, would provide some interesting conclusions to the whole subject of resistance to technological change in manufacturing industry.

The final section of this study is the integration of the observed effects of new measuring machine technology, as it is seen by a large number of firms in various business activities and of various employee size groupings within these firms. The 6 key factors of the enterprise are discussed namely, organisation structure, management, strategies, machine shop environment, control systems and people. The Appendix material consists of a copy of the field survey questionnaire together with a summary of the results obtained for each question. Once again all of the information derived from the survey is not used in the text as it was considered not totally central to the key argument on impact of new technology on the firm.

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6.2 - ORGANISATION STRUCTURES.

The objective of this section of the research project is to analyse a number of quality control organisation charts of manufacturing firms using and not using advanced measuring machine technology. The specific aims of this analysis were concerned with a comparison of the following:-

- o Division of labour - the number of different position titles used in each group of firms.
- o Hierarchy of levels and span of control.
- o Divisions and sections within the hierarchy.
- o Administration - interrelated ratios of manpower by size of firm and business activity.

The analysis of the 100 organisation charts is followed by a further detailed examination of 18 quality control organisation charts from firms using and not using advanced measuring technologies selected from the 100 chart total. These 18 charts are paired in 9 specific sets in order that comparisons can be made as related to the following:-

- o Business activity.
- o Number of employees.
- o Number of inspection employees.
- o Expense budgets for inspection.

The pairing of the 18 firms was done on a basis of one of the following:

- o Like business activities.
- o Similar size of firms (employees)
- o American to British based firms.

Highlights:
Original Source of Data -

Approximately 210 organisation charts were collected during the survey of the 287 firms. Many of the charts submitted with the

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returned questionnaire were of insufficent quality to provide measurable data and these were set aside leaving 2 groups of 50 from each of the 2 categories, that is, 50 firms using and 50 firms not using computer-assisted measuring machine technology.

Coding of Basic Data:

The data from these charts was coded and this provided the information for the key structural variables that form the core of the analysis namely, division of labour, span of control, hierarchy of levels, number of sections and manpower rating. These major characteristics have been defined and are shown in Table No: 6.1. Structural attributes of organisation, although not necessarily of quality control organisations, have been validated in any number of ways by various researchers and writers in the literature. For this reason it is necessary to clearly state the definitions of each variable and to illustrate them in sufficient detail so that comparative studies are feasible. To further avoid the imposition of preconceived notions by the researcher on the interpretation of the many and varied charts, additional data was drawn from the actual questionnaire results, such as manpower ratios and budget values which proved to be extremely useful as a measure of the depth to the organisation structure. For example, a large organisation chart supporting many positions and people could prove to be a mere veneer if the annual budget was small in relationship,

TABLE No: 6.1

DEFINITIONS

MAJOR CHARACTERISTICS:

1. Parameters

A. Size - number of full time personnel in firm at date of survey.
B. Business activity - 20 differing business types.
C. Firms within the business activity: number of firms using advanced inspection technology and firms not using advanced Inspection technology. Described in the text for the sake of brevity as users and non-users respectively.

2. Instrumental Conditions

A. Division of labour - number of official job titles used in firm title (not counting different grades within same job).
B. Shape of the pyramid -
   i. Levels - number of supervisory strata in firms (excluding assistants to or assistant supervisor).
   ii. Divisions - number of major sub units in firm whose head reports direct to the most senior quality control executive.
   iii. Direct or most senior quality executive's span of control - the sum of all division heads, chief inspectors, supervisors, etc.
   iv. Sections per division - number of sections in the firm divided by number of divisions.
   v. Division head's span of control - sum of all supervisory and non supervisory personnel who report to the division head.
   vi. CMM sections - (user firms only) number of special sections set up to house co-ordinate measuring machines, indicating centralised or de-centralised inspection systems.

3. Administration

A. Hourly inspection ratio -
   i. Sum of all hourly paid inspection personnel divided by total personnel in firm.
   ii. Same but for direct hourly employees.
B. Weekly inspection ratio - sum of all weekly paid inspection personnel divided by total personnel in firms.
C. Monthly inspection ratio - sum of all monthly paid inspection personnel divided by total personnel.
D. Annual budget for inspection as a ratio of total inspection -

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i. e. budget per head of inspection personnel, also budget per head of total personnel in firm.

Division of Labour:

The research found a total of 33 different position titles contained in the 100 organisation charts examined ranging from the most senior executive of quality control down to the last level of supervision, this did not include similar titles within grades. To simplify this exercise without detriment to the accuracy of the results, these position titles were re-grouped where necessary into a total of 14 types as follows:-

TABLE No: 6. 2

As Re-Titled by Researcher:	As taken from Charts:
1. Manager of quality control.	Vice president for quality. Inspection manager Director of quality control Officer in charge of quality control.
2. Assistant quality control manager.	Assistant to Assistant of Deputy to
3. Chief Inspector.	Chief quality inspector Senior inspector
4. Assistant chief inspector.	Assistant chief inspector
5. Technical manager	Technical director.
6. Superintendent of inspection.	Superintendent of inspection.
7. Foreman inspector	Supervisor of inspectors Chargehand of inspectors
8. Assistant foreman	Assistant supervisor of inspectors. Assistant foreman of inspectors. Assistant chargehand of inspectors.

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9.	Quality engineer.	Quality design engineer. Product quality engineer. Reliability engineer. Co-ordinator of quality. Quality planner.
10.	Documentation c-ordinator.	Quality statistician Senior controller
11.	Head of Laboratory.	Chief metallurgist. Chief chemist. Chief radiologist. Non destructive test supervisor.
12.	Test manager.	Test manager.
13.	Reliability manager.	Safety manager.
14.	Quality assurance manager.	Quality audit. Technical audit. Supplier - vender quality co-ordinator. Gauge controller.

Number of Hierarchal Levels:

The concept of supervisory or hierarchial levels refers to the strata in an organisational pyramid and derives from principles stated by Weber (51) "The principles of office hierarchy and of levels of graded authority mean a firmly ordered system of super and sub-ordination in which there is a supervision of the lower offices by the higher ones. Fayol called it the scaler chain principle (52). The number of levels of authority refers to links in the chain of command, not to skill graduations or salary grades. In this analysis the shortest, longest and mean chain of command was measured for each firm. The topmost level was always the most senior quality person before he reported to a higher level such as a general manager or managing director. It should be noted that assistants or deputies were not counted as levels of command.

Span of Control

The "span of control" is defined as the number of subordinates who report to an individual manager or supervisor. There are 2

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measures of "span of control" used in the analysis. One covers the manager of quality control (the most senior person) and the second covers the average span of control of a division. A division in this study is any major sub-unit which is a first order of horizontal structure differentiation in the organisation, that is, the senior person in the division reports directly to the manager of quality control. A division in this research could mean the metallurgical laboratory, quality assurance or product reliability. The span of control of the lowest order in the hierarchical structure namely, the foreman of inspectors, has not been measured with the exception of counting the number of sections contained in each division (most sections are supervised by one foreman).

Number of Divisions and Sections:

The division previously defined as a major sub-unit reporting to the most senior quality person, can consist of 2 or more persons such as quality engineers reporting to a quality assurance manager, who in essence is the division head. The section then is defined as a sub-unit of a division whose chief reports to the head of the division. The section could be controlled by a foreman or any one of the aforementioned equivalent of the foreman or it could consist of professional "staff" men such as quality engineers, service chemists and metallurgists.

Administration-Inspection and other manpower ratios:

5 separate ratios are calculated and analysed namely, the hourly paid inspection as a ratio to the total hourly personnel in each firm; the hourly paid inspectors to the total direct production employee; the weekly paid inspector as a ratio of total hourly personnel; the monthly paid inspection staff as a ratio of total personnel in the firm and finally, the total inspection personnel all payrolls, as a ratio of total personnel. Each of these ratios provide a very accurate barometer of the amphasis given to inspection in any particular firm. The ratios obviously have even greater meaning when examined

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within similar business activities and also comparative sizes of employee firms.

Analysis of 18 Quality Control Organisation Charts.

9 paired organisation structures are examined in detail to seek further information on the aforementioned structural variables and to determine if any patterns have developed with respect to the shape of pyramids, for user or non-user firms of advanced measuring technology. The following aspects are examined in particular -

- What causes the shape of the pyramid - the need of the firm or traditional evolution of quality control as a key function?
- Do differences exist with like and unlike business activities or employee size groups for position titles, hierarchical levels or span of control?
- Is there any correlation between the number of inspectors in each firm and the annual budget for inspection?
- Have users of advanced measuring machines generally increased or reduced their labour force in comparison with non-user firms?

Approach to the analysis of 100 quality control organisation charts.

4 general approaches were developed -

1. A total review of all 50 firms in each category to evaluate 28 specific characteristics about the organisation structure. See Table No: 6.3.
2. A review with the above data organised in employee size groupings. (see Appendix R, index B).
3. A review with the above data organised in 20 business activity groupings. (see Appendix R, index C).
4. A review of American based firms in comparison with British based firms. (see Appendix R, index E).

TABLE No: 6.3

SPECIFIC CHARACTERISTICS EVALUATED IN THE ANALYSIS OF QUALITY CONTROL ORGANISATION CHARTS.

1. Business Activity or Employee Size.
2. Employee Size.
3. Number of Position Titles.
4. Number of Levels.
5. Director Span of Control.
6. Number of Divisions.
7. Division Span of Control.
8. Number of Sections.
9. Number of CMM Secions.
10. Manager Q. C.
11. Assistant Quality Control Manager.
12. Chief Inspector.
13. Assistant Chief.
14. Technical Manager
15. Superintendent
16. Foreman
17. Assistant Foreman.
18. Quality Engineer.
19. Co-ordinator.
20. Head of Laboratory.
21. Test Manager
22. Reliability Manager.
23. Quality Assurance Manager.
24. Ratio Hourly Inspector to total hourly.
25. Ratio Hourly Inspector to total direct production.
26. Ratio Weekly Inspector to total personnel.
27. Ratio Monthly Inspector to total personnel.
28. Ratio all inspection to total personnel.

Details of each item shown above are given in Appendix R.

6.3 - DIVISION OF LABOUR: POSITION TITLES.

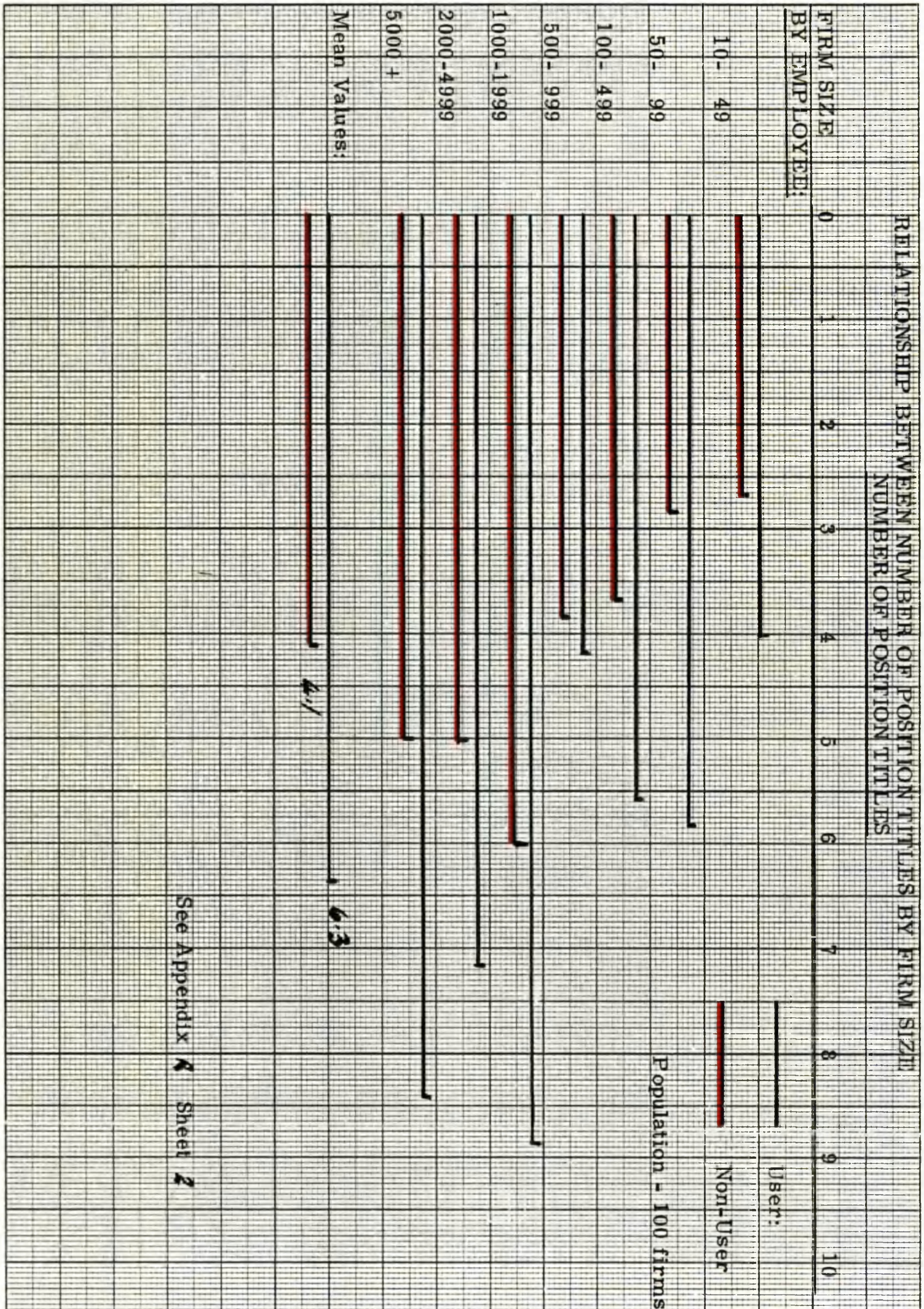
Introduction.

An analysis of the division of labour was important to this research in order that information would be gained with respect to differences and similarities between the organisation patterns of one group of firms to another. An in-depth analysis was made on all position titles to the degree that this was broken down into 14 possible titles known to the researcher to be used commonly in quality control and inspection organisations, both in Britain and America. (see Table No:6.2, page 283). One of the most interesting aspects of this particular part of the research was to examine the position titles used in different business activity groupings and then to make the same examination of that used in American firms in comparison with British firms. This research shows that the average American firm has fewer position titles than its British counterpart and American firms tend to avoid the use of position titles such as assistants either "to" or "of" which were commonly used in British organisation structures in particular the aerospace, defence and motor industries.

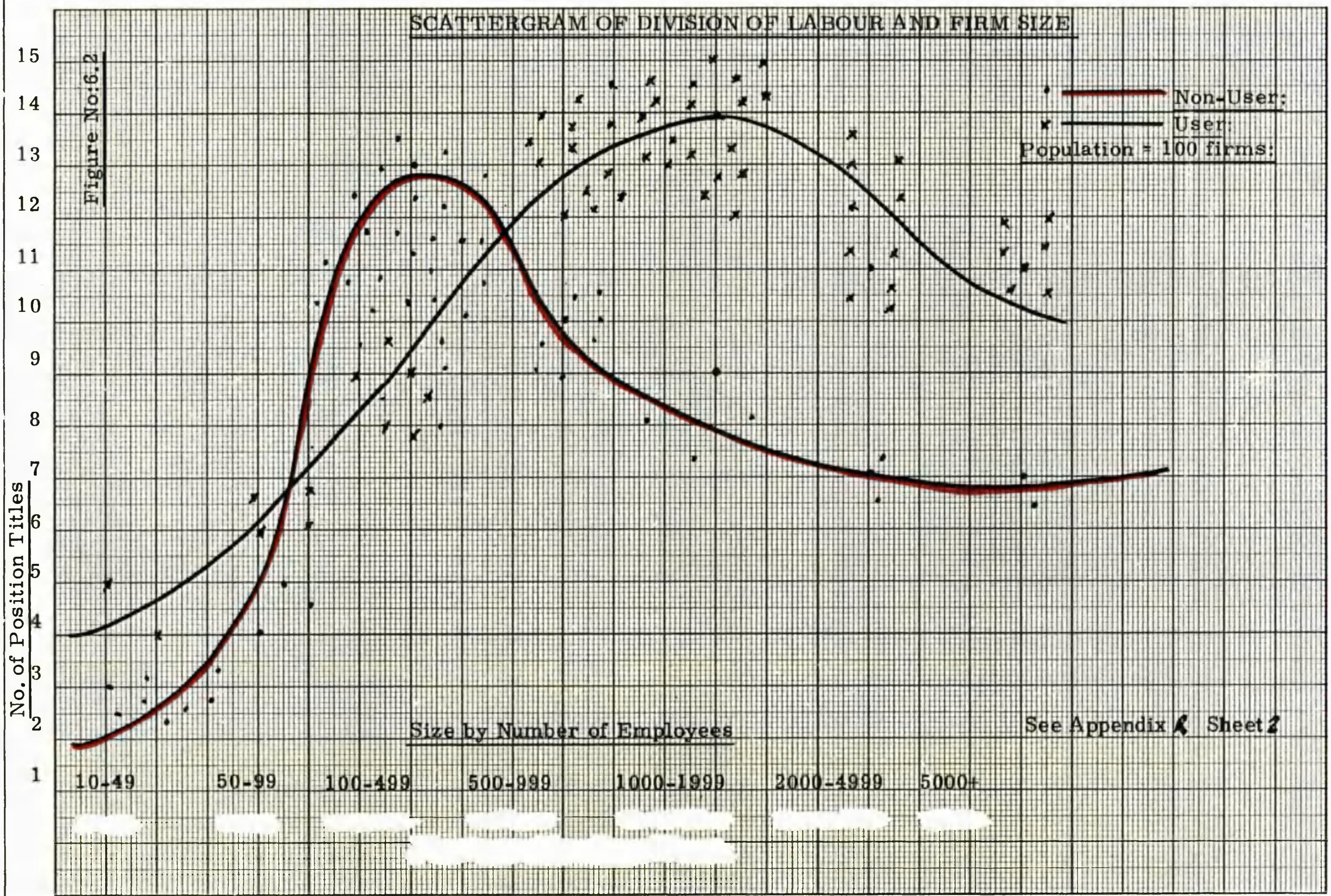
Number of Position Titles - Employee Size Groups.

It is observed as shown in Figure No: 6.1 and Appendix R - Index A that the larger the firm, the more pronounced is the division of labour within it. The correlation between size and number of position titles shows that both user and non-user type firms expand in position titles as size increases but tend to taper off somewhat as the firms reach 2000 and over. This factor is further validated in Figure No: 6.2 which illustrates a scattergram with a curve rather than a straight line. The pattern observed implies that increasing firm size fosters occupational differentiations in the quality control function at a declining rate. In other words, the impact of size on the division of labour declines with increasing size. Although Figure No: 6.2 shows both user and non-user firms following similar curvatures, it

Figure No:6.1



RELATIONSHIP BETWEEN NUMBER OF POSITION TITLES BY FIRM SIZE
NUMBER OF POSITION TITLES
FIRM SIZE BY EMPLOYEE:
10- 49
50- 99
100- 499
500- 999
1000-1999
2000-4999
5000 +
Mean Values:
0
1
2
3
4
5
6
7
8
9
10
4.1
6.3
User:
Non-User
Population - 100 firms.
See Appendix K Sheet 2



SCATTERGRAM OF DIVISION OF LABOUR AND FIRM SIZE
Figure No:6.2
Non-User:
User:
Population = 100 firms:
No. of Position Titles
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Size by Number of Employees
10-49
50-99
100-499
500-999
1000-1999
2000-4999
5000+
See Appendix Sheet

is interesting to note that the non-user group expand more rapidly and decline more rapidly as size increases than that shown for the user group.

Number of Position Titles by Business Activity.

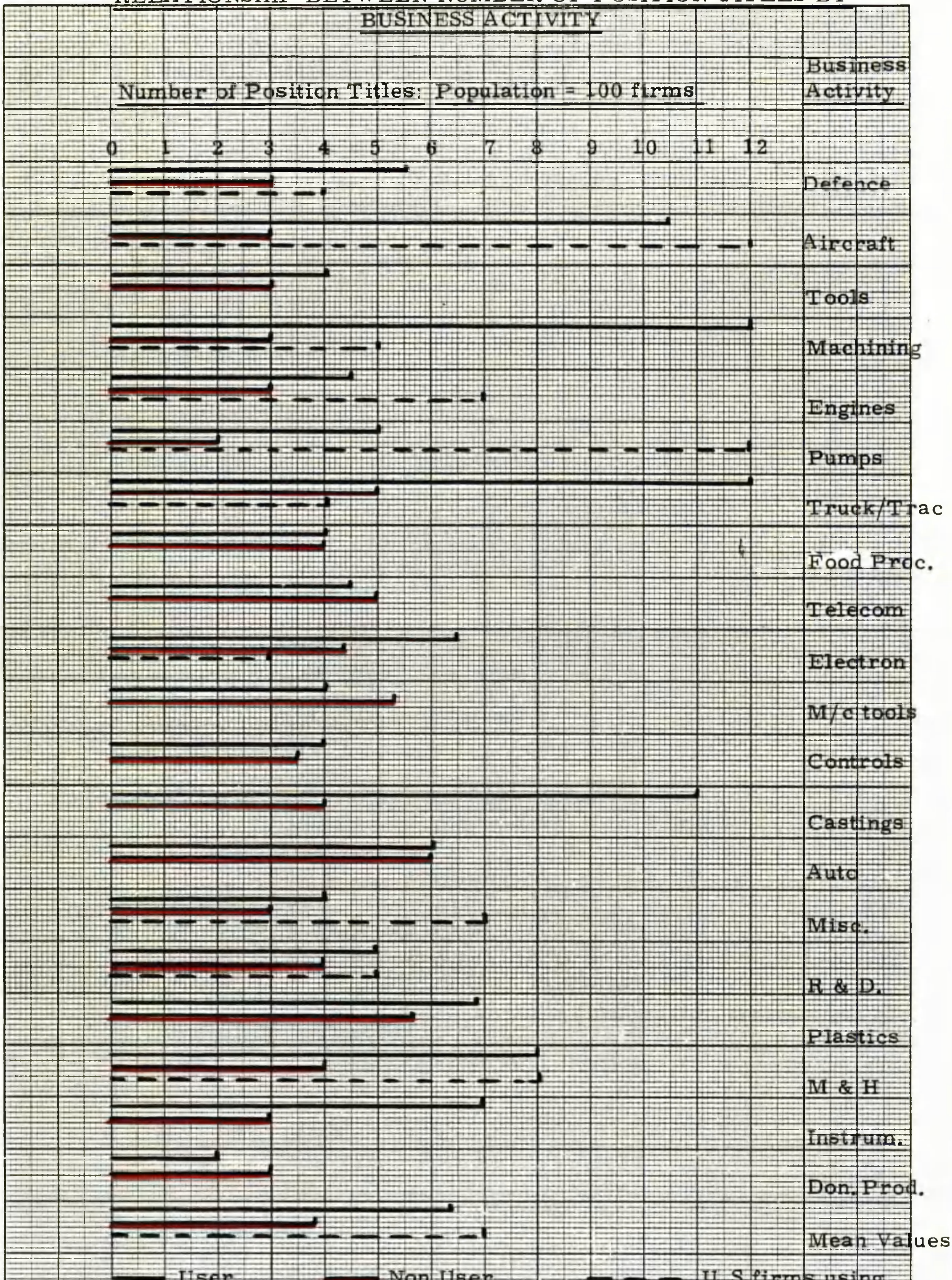
As a further part of the research, the number of position titles by business activity was computed for each of the 20 different activities and again this was calculated for both user and non-user firms. Figure No: 6.3 and Appendix R. Index C/D indicates that position titles are much more numerous in the following business activities namely, aircraft, machining, tractor/truck and castings. These values are not repeated for non-user firms in the same business activity and indeed the non-user firms never exceed 6 and have a mean value of only 3.8 position titles for all 20 business activities against a 6.3 value for user firms. Data was available on 40 American firms in 10 of the 14 business activities using advanced measuring equipment. These figures tend to validate with the total users as the results correlate on the mean values overall, with the exception of electronics, which is less than half the value shown for user firms. (see Appendix R, Index E).

Specific Position Titles by Business Activity.

The above calculations are based on all position titles found in each quality control organisation structure of the 100 firms reviewed. A total of 33 different job titles were found between all firms and they were further reduced to 14 types encompassing the 33 as described previously. Figure No: 6.4 now indicates the relationship between each position title for user and non-user firms. This relationship is also shown numerically in Appendix R, Index C/D. The results in all 3 figures prove very interesting as they indicate a pattern which could be described as a possible model for different concepts of quality control organisation. The first position title, that of quality control manager, validates itself by having almost equal parity between user and non-user.

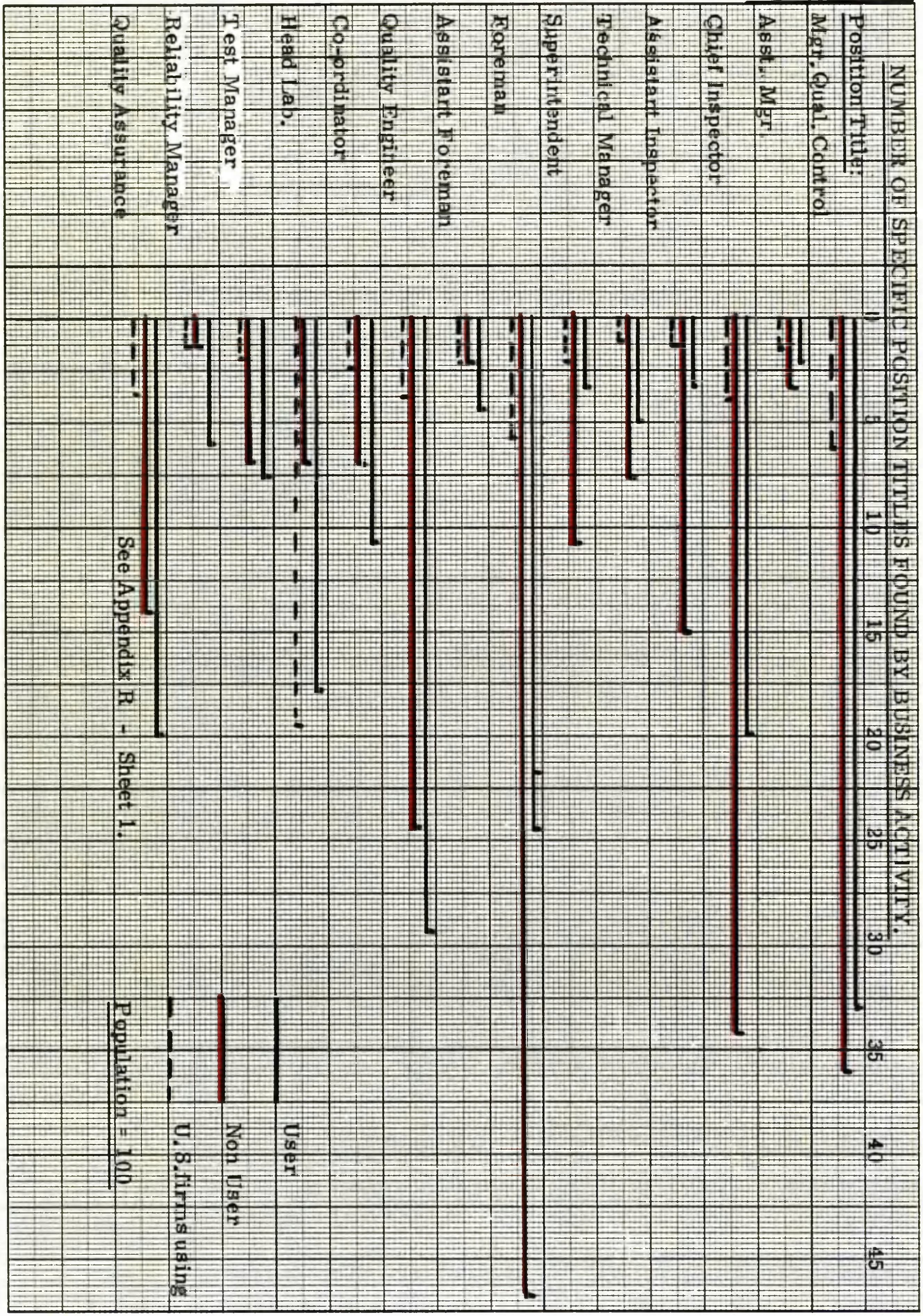
Figure No: 6.3

RELATIONSHIP BETWEEN NUMBER OF POSITION TITLES BY BUSINESS ACTIVITY



See Appendix R - Sheet 1.

Figure No: 6.4


NUMBER OF SPECIFIC POSITION TITLES FOUND BY BUSINESS ACTIVITY.
Position Title:
Mgr. Qual. Control
Asst. Mgr.
Chief Inspector
Assistant Inspector
Technical Manager
Superintendent
Foreman
Assistant Foreman
Quality Engineer
Co-ordinator
Head Lab.
Test Manager
Reliability Manager
Quality Assurance
0
5
10
15
20
25
30
35
40
45
User
Non User
U.S. firms using
See Appendix R - Sheet 1.
Population = 100

Similar Position Titles in all Firms.

The following other position titles have near parity between user and non-user firms; assistant manager of quality control, technical manager, assistant foreman and test manager; and these positions will not be discussed at this point. (see Appendix R, Index C/D).

Position Titles more numerous in user firms.

The following position titles are more numerous in the user group; quality engineer, quality co-ordinator, head of laboratory, reliability manager and quality assurance manager. (see Appendix R, Index C). The reasons why these position titles are more popular with user firms are as follows:-

Quality Engineer:

The quality engineer was defined in Table No: 6.2 as any one of the following; quality design engineer, product quality engineer, reliability engineer, co-ordinator of quality, quality planner. The position description is very much orientated towards prevention of quality problems by improved design, increased reliability, better co-ordination and advanced planning for quality production. The concept of quality engineer originally evolved in the 1940 to 1950 era of quality statisticians to analyse data and provide line management with decision-making information (see Juran Evolution of Quality Control). The reason why this position is more popular with the user firms is related to maximising the return on the asset of the co-ordinate measuring machine (53).

Quality Co-ordinator:

This position covers activities associated with documentation, statistics and control of results. It is more office-based than the quality engineer and is concerned with identifying trends with tolerances within specifications. It is popular with the user from the aspect of knowing what the results from the measuring machines are highlighting, in order that corrective action can be taken. The

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impact of advanced measuring technology on a firm would result in an increase on both these above activities and the results shown in Figure No: 6.4 tend to validate this argument.

Head of Laboratory:

This position was described in Table No: 6.2 as covering - chief metallurgist, chief chemist, chief radiologist, non destructive test supervisor. The reasons why the position should be found more popular with the user firms is again related to the concern for prevention of quality problems in material prior to the machining operations.

Reliability and Quality Assurance Manager.

Both the above positions tend to be synonymous with firms of high reputations for product quality. Rolls Royce for example, describe all their most senior quality managers as quality assurance managers. Boeing Aerospace in America name their senior quality managers as reliability managers. The emphasis given in these words is again directly related to the product and providing the onlooker with a confidence in that firm. Firms who invest in expensive measuring machine technology may want to project a stronger image of quality than the firms who do not invest in these machines.

Position Titles more numerous in non-user firms.

The position titles which are more numerous in the non-user firms are as follows; chief inspector, assistant chief inspector, superintendent of inspection, foreman. (see Appendix R, Index D). The major reasons why these particular position titles are found more popular with non-user firms is discussed as follows:

Chief Inspector and Assistant Chief Inspector.

The title of chief inspector is probably one of the oldest descriptions given to a quality control function. It is commonly used among shipbuilding and very heavy engineering firms. This research has noted that firms in business activities not using advanced measuring

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machines use the title chief inspector more than the user firms. It was observed that non-user firms with some connection to the military made use of the chief inspector title, this was noted in defence business activity firms. It was also noted in some of the user firms such as British Aerospace, but again it was considered that this had some relationship to the military.

Superintendent of Inspection.

It was observed that this position title was used in non-user firms especially where the same title was used for other functions within the firm. For example, superintendent of manufacturing, superintendent of maintenance and so on. The concept adopted by the non-user firms appears to be one of establishing a commonality of titles among peer groups rather than identifying any particular quality emphasis.

Foreman of Inspectors.

The fact that non-user groups have a much greater number of foremen of inspection position title suggests that more supervision is required on conventional type inspection equipment and technology than would be necessary on advanced inspection machines, which are programmed to supervise themselves to some degree. The intelligence level of the inspector operator tends to move him from the typical manual role to one of "knowledge worker". This suggests that user type organisations will tend towards fewer personnel in total within inspection due to the advent of advanced inspection technology; thus some impact is being reflected by fewer people being required to accomplish specific inspection tasks in contrast to the non-user firms who currently set up human barriers of inspection as opposed to technological hardware. Cost benefits can be achieved with lower paid unskilled inspection labour against expensive highly skilled inspection labour required to operate and sometimes programme the advanced measuring machines.

6.4 - HIERARCHY OF MANAGERIAL LEVELS AND SPAN OF CONTROL WITHIN QUALITY CONTROL ORGANISATION STRUCTURES USING AND NOT USING ADVANCED MEASURING TECHNOLOGY.

The larger the size of firm the greater the tendency to generate hierarchical differentiations of authority into many managerial levels. There appears to be a correlation between size of firm in terms of employees and the maximum number of hierarchical levels in any one firm.

Numbers of levels of command by employee size.

Figure No: 6.5 and Appendix R illustrate the relationship between number of levels of command by employee size groupings. It shows that both the user and non-user firms have a steady and consistent growth in numbers of levels up to 2,000 and above, when it tends to plateau then decline slightly. A multi-level hierarchy increases the distance between management and the operating level and creates problems of communication and managerial control, which tend to set limits to hierarchical differentiation. The implications of the plateauing and slight decline are that the impact of size on hierarchical differentiation declines with increasing size; the personnel complement per level as well as the number of levels increases with growth.

Numbers of levels of command by business activity.

This aspect is further validated in Figure No: 6.6 and Appendix R when the number of levels are compared within business activities. With the exception of the large employers namely, aircraft and motor cars, all levels of hierarchy are fairly consistent with a mean value of 4 approximately for both user and non-user; the user type firms if anything have more levels suggesting a longer type pyramid than that of the non-user. The 2 exceptions namely, aircraft and motor car industries, have much greater levels but this maybe due to the large size of employment and the horizontal integration of the firms in terms of production systems. Structural examples of both these

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Figure No: 6.5

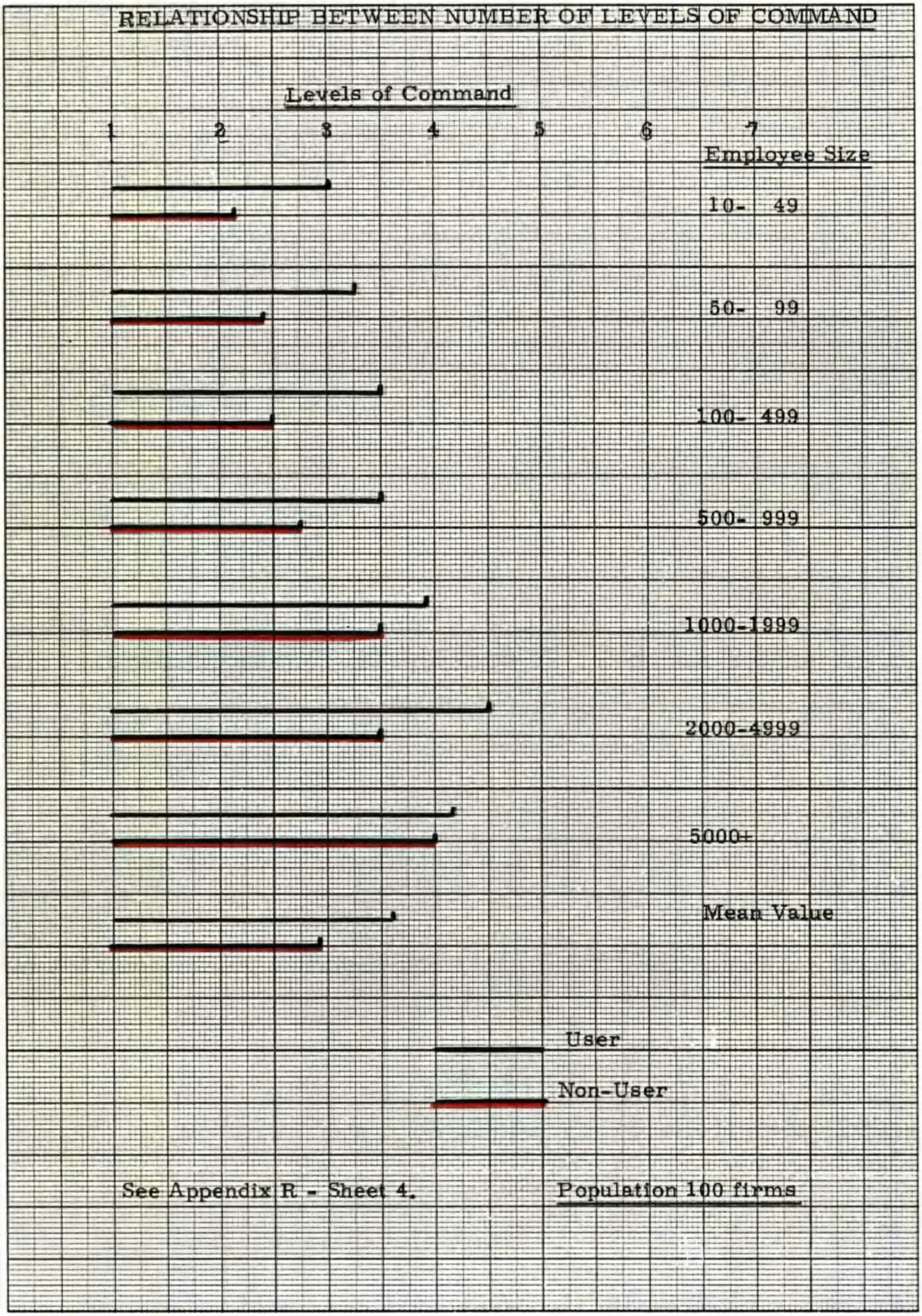
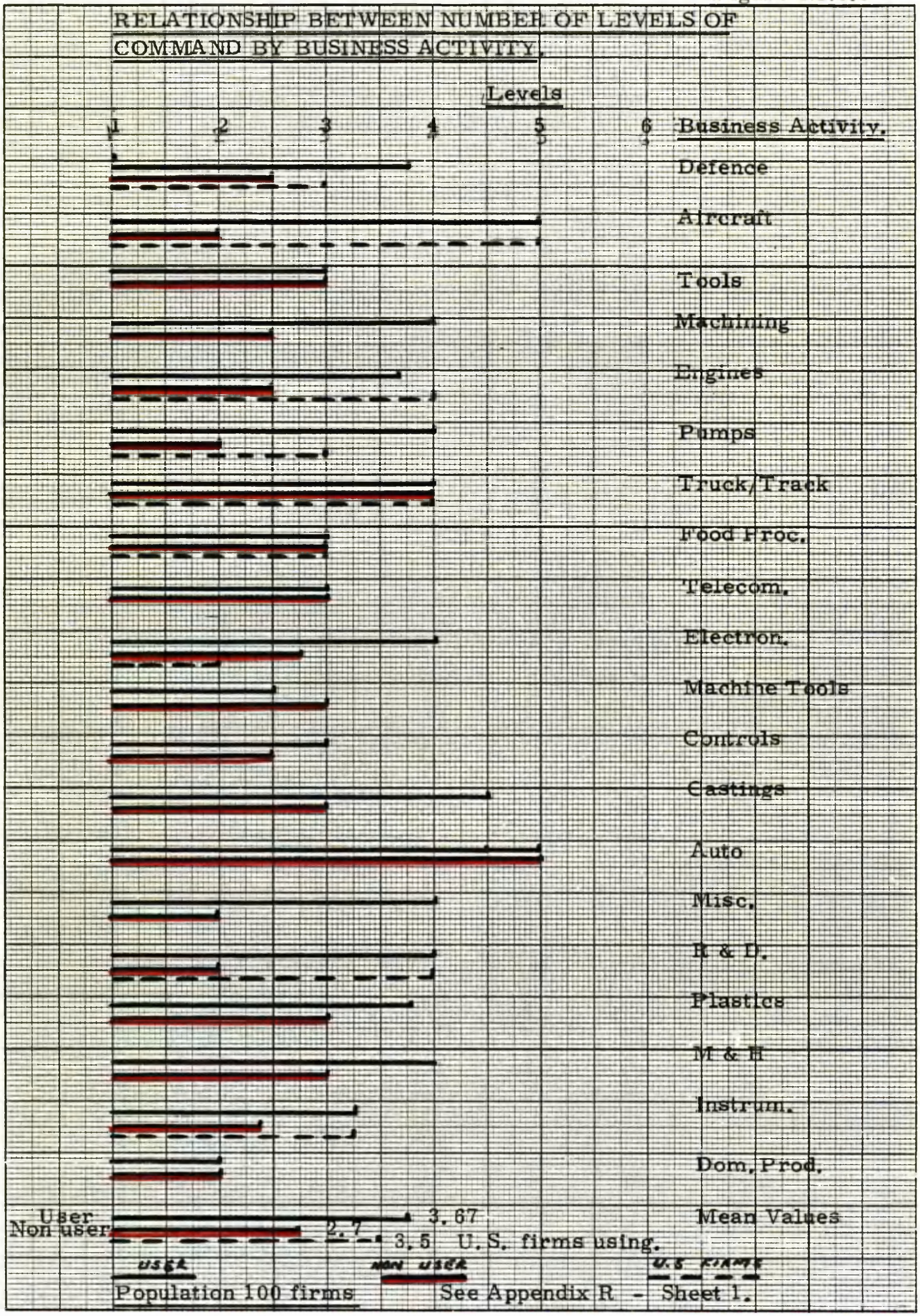

RELATIONSHIP BETWEEN NUMBER OF LEVELS OF COMMAND
Levels of Command
1
2
3
4
5
6
7
Employee Size
10- 49
50- 99
100- 499
500- 999
1000-1999
2000-4999
5000+
Mean Value
User
Non-User
See Appendix R - Sheet 4.
Population 100 firms

Figure No:6.6


RELATIONSHIP BETWEEN NUMBER OF LEVELS OF COMMAND BY BUSINESS ACTIVITY.
Levels
1
2
3
4
5
6
Business Activity.
Defence
Aircraft
Tools
Machining
Engines
Pumps
Truck/Track
Food Proc.
Telecom.
Electron.
Machine Tools
Controls
Castings
Auto
Misc.
R & D.
Plastics
M & H
Instrum.
Dom. Prod.
User
Non user
3.67
2.7
3.5 U.S. firms using.
Mean Values
USER
NON USER
U.S FIRMS
Population 100 firms
See Appendix R - Sheet 1.

industries are shown in Appendix S diagrammatically (ref: 086-009) (076-207). Further validation of user type hierarchy was obtained from 40 American based firms which fell into 10 of the 14 business activities. These American results have strong correlation with British user groups although selected independently, American firms had a mean value of 4 levels of hierarchy; examples of these structures are shown in Appendix S (ref: 096-170).

Points of conclusion on hierarchical levels.

The interpretation advanced so far is that hierarchical differentiation into multiple levels tends to occur in large organisations because it relieves management of excessive supervisory burdens that interfere with its executive responsibilities. Another measure of the supervisory duties of the top quality manager is the number of sub managers or division heads who report to him directly and how many third level managers or perhaps supervisors report to the division head. Figure No: 6.7 and Appendix R show a most interesting set of relationships. First observe the declining span of control by employee size for small size user firms up to the 500 employee range with an increase at the 1,000 to 2,000 range, then a further decline for large user firms. These curves apply to span of control for both director of quality (most senior executive) and the division head reporting to that position. There is close correlation between these spans. The span of control for non-user firms' directors of quality shows a clear curvilinear graph rising in span as size increases. The division head of the non-user firms tend to follow the curve generated by both user spans, although with a reduced average span of control; the implications of these curves suggest that non-user firms in quality control will tend to have wider spans of control as employee size increases, while user firms will decline due to possible deeper concentration and dependence on technology.

Horizontal and vertical pressures.

The inverse association between vertical differentiation into multiple levels and horizontal differentiation into many divisions suggests

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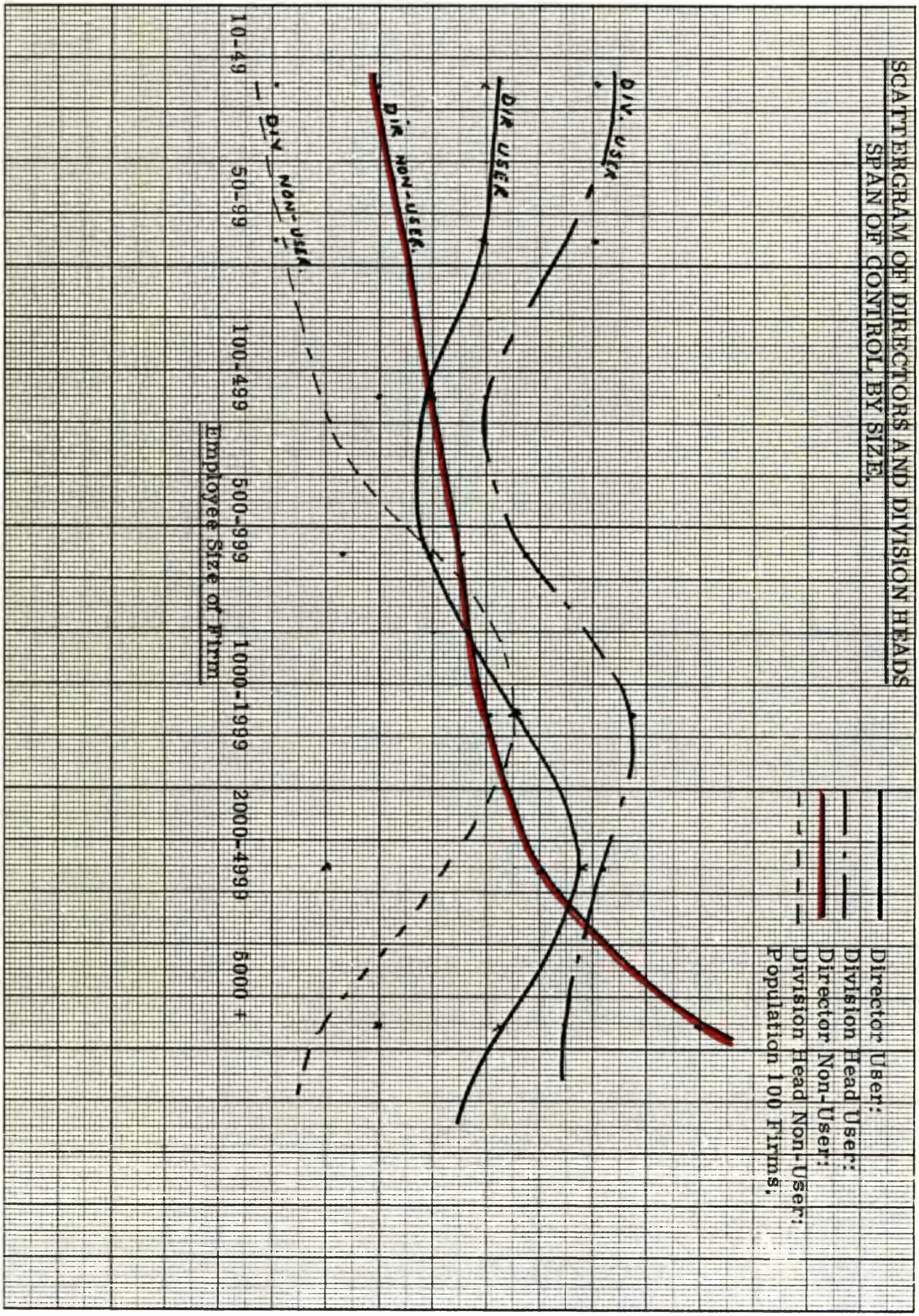
Figure No:6.7


SCATTERGRAM OF DIRECTORS AND DIVISION HEADS
SPAN OF CONTROL BY SIZE.
Director User:
Division Head User:
Director Non-User:
Division Head Non-User:
Population 100 Firms.
DIV. USER
DIR USER
DIR NON-USER.
DIV NON-USER.
1
2
3
4
5
10-49
50-99
100-499
500-999
1000-1999
2000-4999
5000 +
Employee Size of Firm

that organisations have a tendency to develop either a squat pyramid or a tall one, though large organisations are typically both taller and wider at the top than small organisations. One possible condition which could affect in which direction a structure will move is the degree of automation, or in this case, the amount of technology such as computer-aided measuring machines being used in that organisation for control of quality. The use of such technology will tend to make the pyramid taller, mainly because the use of computers and such advanced technology will minimise the disadvantages of the tall pyramid. The tall structure has the advantage of reducing top quality managers' administrative loads, but at the same time, has the disadvantage of increasing its distance from the operating level. How serious the disadvantage is depends upon the form of management, the individual firm and the business activity in which it operates.

Many hierarchical levels engender problems of communication that can seriously impede top quality manager's control over his total function if it is primarily exercised by issuing directives and getting feedback through normal channels as can be observed in the case of EMI, Appendix S (ref: 264-032). This firm has a fairly tall pyramid with many bits and pieces, yet having only 4% of total manpower on inspection activities. This firm is a non-user of advanced measuring technology and perhaps suffers some of the disadvantages previously mentioned for the tall pyramid. This can be compared with another tall pyramid structure shown in Appendix S (ref: 086-009) British Aerospace, which, although much larger in size than EMI, has a 5% of total manpower on inspection activities and is heavily equipped with advanced inspection technology. The research suggests that the more the senior quality executive depends on advanced technology to feed him data then the lesser liability will be a taller hierarchy. This technology, although it tends to de-skill the inspector at the bottom of the pyramid, mechanises many measuring tasks and will routinise others that continue to be performed by operators, thus lessening the need for managerial guidance. Similar to the numerical

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controlled machine tool or indeed the computer, once programmes are designed and set-up this exerts constraints over the performance of employees, who must adapt their work to the requirements of the technology. Since, it is suggested, this technology makes quality management less dependent on hierarchical channels of communication, it reduces the disadvantages of multiple levels and fosters their development. This conclusion is based on the research of 100 firms' organisation structures and the differentiations between users of advanced technology. To some degree the findings can be compared to the evidence shown by Woodward - "Industrial Organisation" pages 51 and 52, where she found that the most automated of 80 British manufacturing firms had the largest number of levels (19). This perhaps is the impact that technology has on structures resulting in a positive relationship between technology and hierarchical levels.

6.5 - DIVISIONS AND SECTIONS WITHIN THE HIERARCHY OF THE ORGANISATION STRUCTURE OF QUALITY CONTROL.

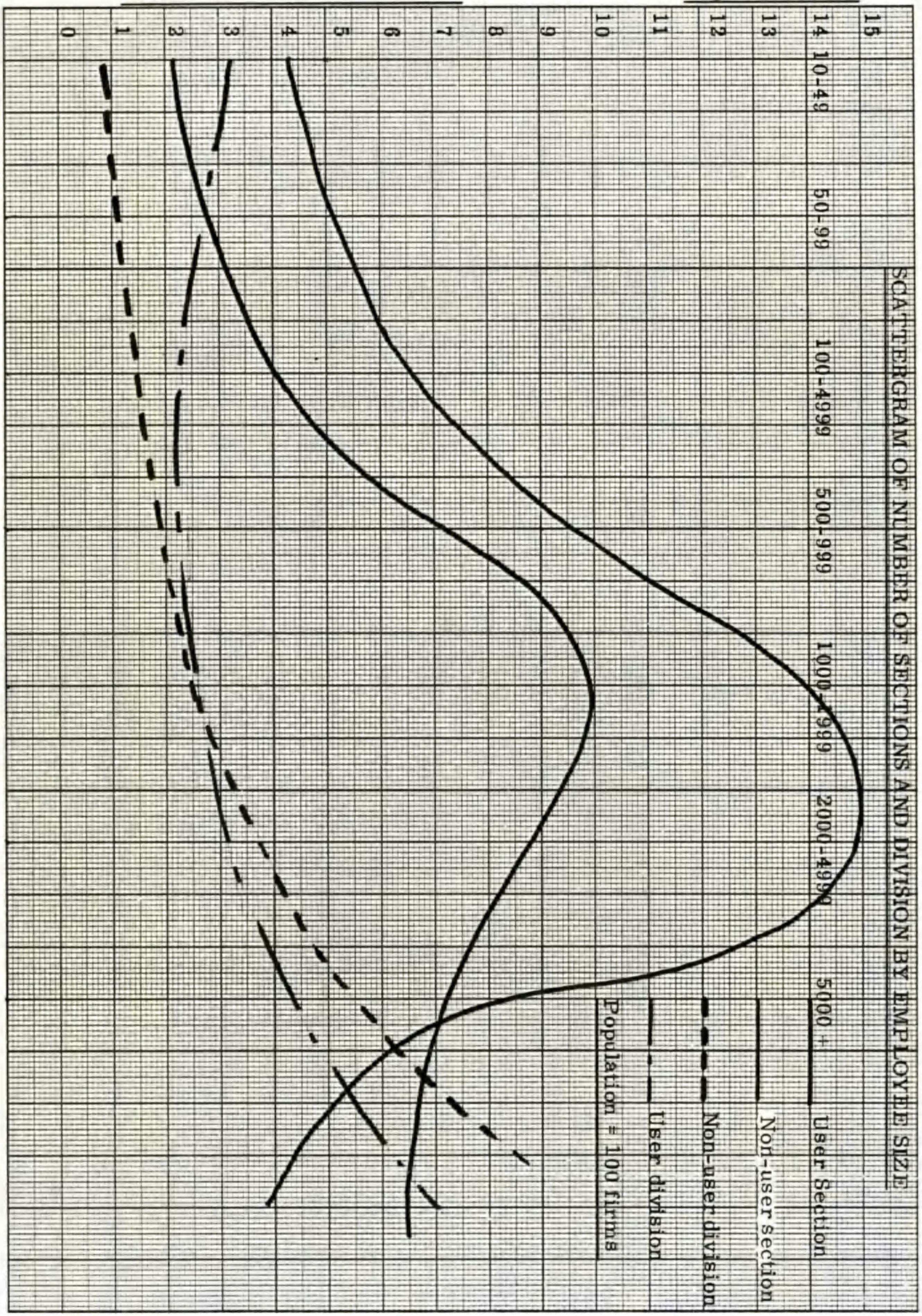
The research now looks at the middle and bottom of the pyramid to determine impact due to the presence of advanced technology.

Divisions and sections by employee size.

Figure No: 6.8 is a scattergram of the number of sections and divisions by employee size. (See also Appendix R). The most pronounced of these curves is that of the number of sections in both the user and non-user firms. The number of sections increase rapidly with size up to a peak of 14 sections on firms between 2,000 and 4,999 employees and then tails off again quite rapidly to averages of 8 sections for firms of 5,000 plus employees. Correspondingly the non-user firm has a similar rapid increase in sections with size, but peaks at 10 for 100 to 2,000 employees and then declines again to an average of 7 sections for 5,000 employees and more. The number of divisions (which in this research are superior in the hierarchy to the section) tend towards a straight line and average 3.25 for all sizes of firms within the user group; while the non-user firms have a curvilinear graph moving from a low level to a high peak and continuing to rise at 6 divisions in the largest firms of 5,000 plus employees. These results imply that the larger the size of firm the greater the number of sections and consequently, as the divisions do not increase in number, then the span of control of the division head increases. This finding supports the earlier conjectures that forestalling the proliferation of divisions requires establishing more functional sub units within them and that reducing the number of divisions once it has become too large, entails establishing a few super divisions that probably contain more sub units than the earlier divisions. The smaller the firm then the more encompassing are the responsibilities given to the division heads under the top quality executive. Figure No: 6.8 and Appendix R further supports the hypothesis concerning the impact of technology on manufacturing industry as the user firms exceed the non-user in section numbers.

No. of Sections and Divisions

Figure No: 6. 8



These sections contain the advanced technology in a practical and physical sense encompassing sections using the data from the technology to assist line management decision-making. Appendix S (ref: 096-170) showing the John Deere Harvester Works is a good example of this relationship. Thus it is suggested that firms with advanced technology will tend to have more sections, therefore the technology exerts some influence on horizontal as well as on vertical differentiation; its influence on horizontal differentiation is reflected in an increase of sections within divisions rather than the addition of more divisions. It has been demonstrated that the multi-level hierarchies in some firms with advanced computer-assisted measuring machines, which reduce the number of divisions, prevent the influence of advanced technology on horizontal differentiation from finding expression and permit it to find expression only on the next level of organisation. An advanced technology seems to be more compatible than a simple one with a complex structure differentiated both vertically into multiple levels and horizontally into many sections though not into a large number of divisions.

Divisions and sections by business activity.

Figure No: 6.9A shows the relationship between number of sections and divisions by business activity. User firms have a mean value of 9.15 sections and 3.51 divisions compared with smaller mean values for non-user firms of 6.43 sections and 2.19 divisions. However despite this higher mean value, user firms are not all more numerous in both sections and divisions. The exceptions for non-user firms having more sections are tools, telecommunication, machine tools, motor cars and domestic products marginally larger; by the very nature of the business activity of all of the above exceptions, one can clearly establish why they may be exceptional, that is, each type produces for wide variety markets, for example, tools could be cutting tools, grinding tools, punching tools, and other tools. Machine tools, perhaps regrettably in Britain, are much too diversified towards standard type conventional machines which seems to appeal

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Figure No:6.9A

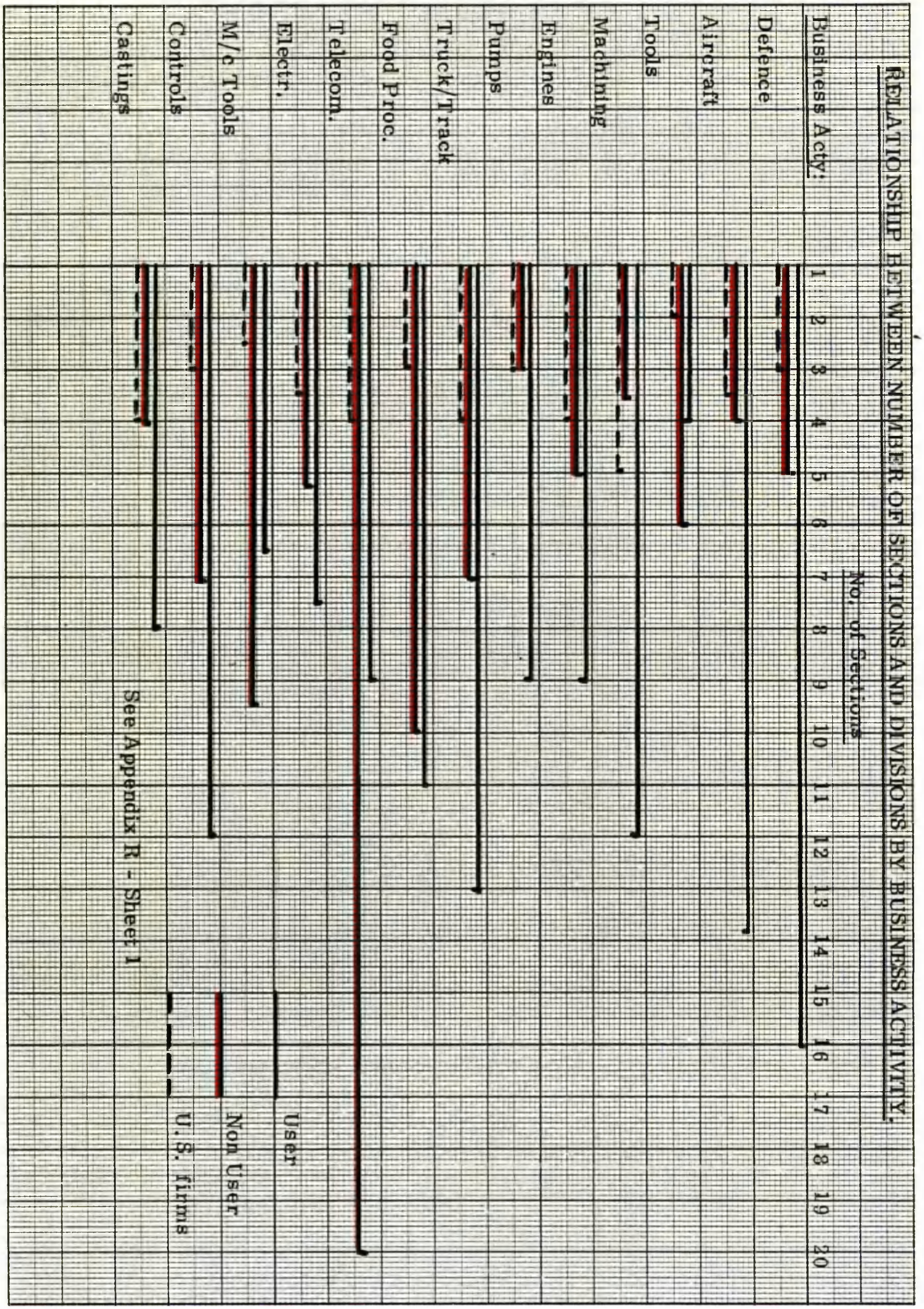
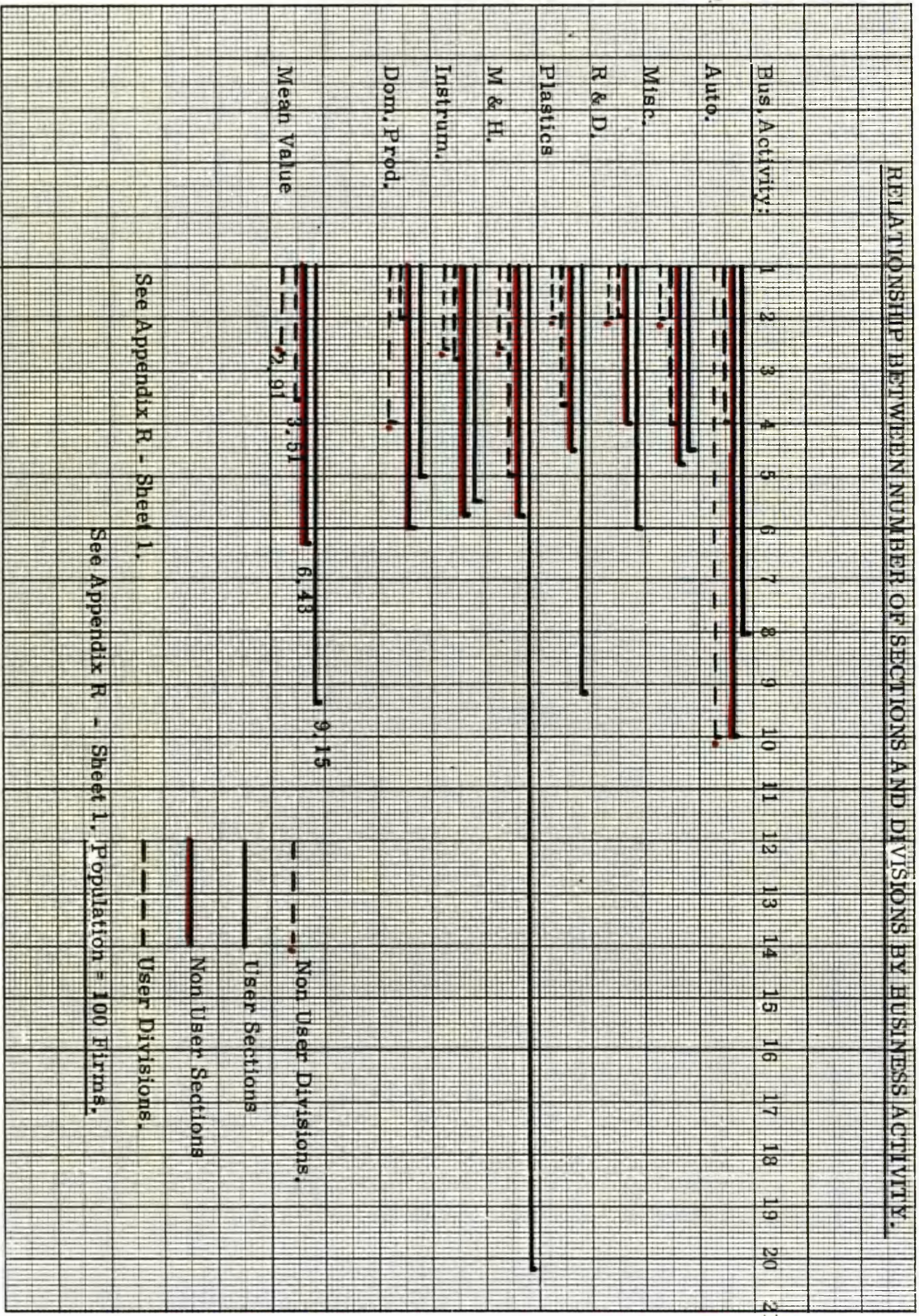


Figure No: 6.9B



to a fast diminishing market, but the firms in this research could have many sections covering each of these machine tool types. Motor cars and domestic products are self-explanatory. With respect to the number of divisions the non-user firms only exceed the user in motor cars and domestic products, the same reasoning applies as before. The fact that this research shows that firms using advanced technology in inspection have more sections and divisions as stated previously, is further validated by the overwhelming results taken from Figure No: 6. 9 but for the 5 sections and 2 divisions the balance of all of the business activities have more sections and divisions in the user type firms.

6.6 - ADMINISTRATION INTER-RELATED RATIOS OF MANPOWER BY EMPLOYEE SIZE GROUPINGS.

Introduction.

This section is concerned with the major characteristics related to administration, in which examination is made in details of the research results of ratios of inspection personnel at various pay levels to the total personnel employed, for firms using and not using advanced measuring machine technology. In addition examination is made of the relationship of annual budget to inspection. This particular study has been included in this section as the researcher correlates this to the base of the structure of organisation. It is interesting to determine if firm size is closely correlated to changes in the ratio of inspection support and does this support vary in terms of inspection pay structure. That is to say, do large size firms have greater or lesser inspection staff as a ratio of total personnel. A further field of interest must be related to the business activity and the relative ratios in each group. This is of special interest as 20 various business activities of different size groups should reflect some degree of difference which has to be investigated. As well as comparing the ratios of all firms, the research looks again at both classifications of users and non-users of advanced technology, then further researches 35 American based firms, all users of advanced equipment and attempts to compare one with another.

Manpower ratios by employee size.

The data on ratios of inspection personnel as related to employee size is contained in Appendix R, Index B-E, and illustrated in Figures Nos: 6.10 to 6.14.

Monthly Payroll ratios.

Examination of the ratio of monthly inspection will basically reflect the managerial, supervisory and senior staff personnel as related to total personnel. One observes in Figure No: 6.10 and Appendix R, sheet 2, column 27, that the larger the size of an organisation then

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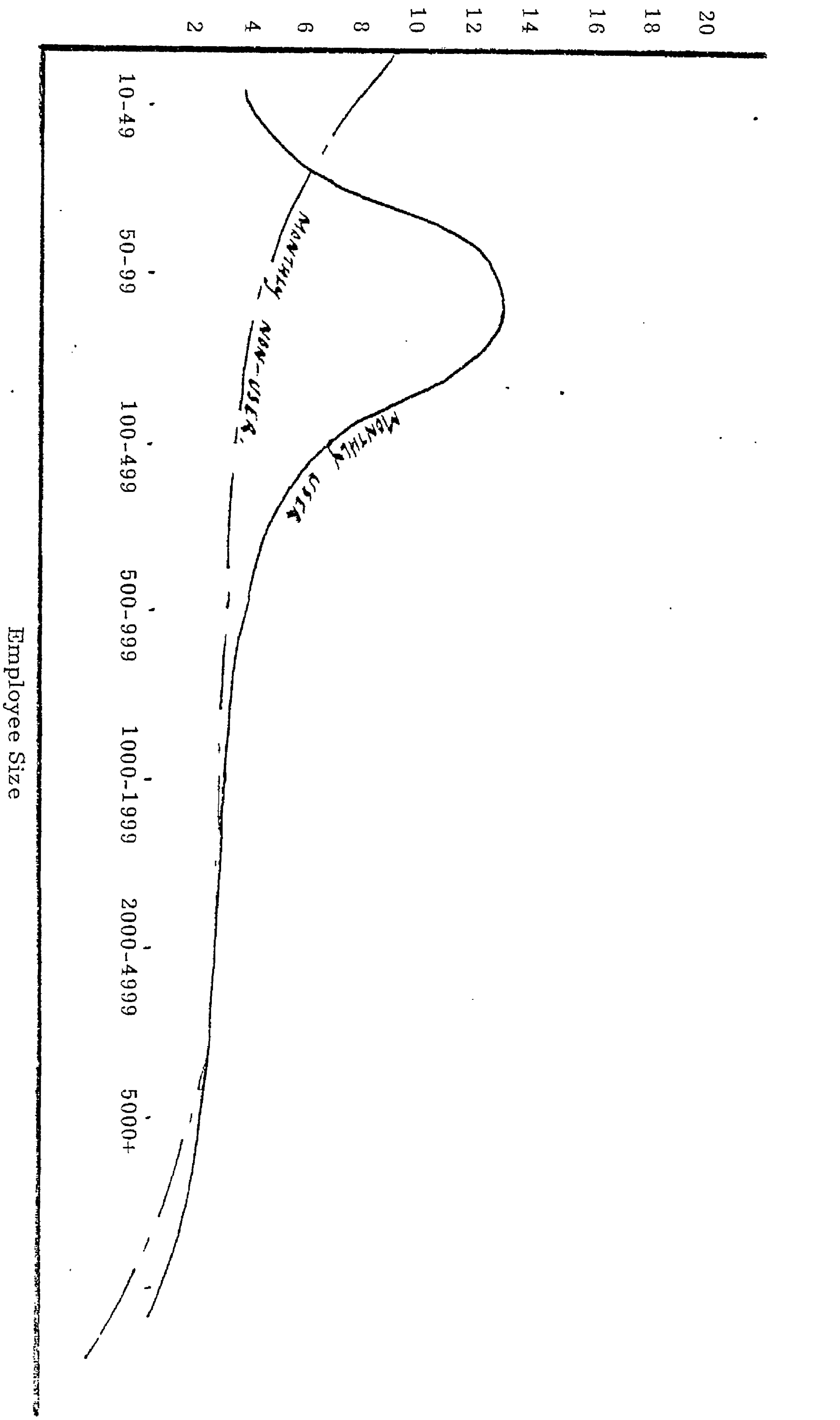
COMPARISON OF NON-USER FIRMS TO USER FIRMS IN TERMS OF INSPECTION MANPOWER TO TOTAL MANPOWER WITHIN EMPLOYEE SIZE OF FIRMS



the lower is this ratio thus confirming the aforementioned studies. From a wide variety of activities and with the exception of a high percentage found in firms of 50 to 99 employees for users of advanced technology, both users and non-users have a steadily declining ratio. This tends to replicate the findings of Starbuck in terms of organisation of less than 100 employees (54). Indeed only in the smallest of organisations reviewed, that is 10-49 employees, non-user firms exceeded user firms in monthly payroll ratio which suggests that lack of technology calls for more administration at higher levels. American based firms although declining in the same manner with increasing size of firm, have in almost all cases of size, even less monthly payroll personnel than all non-user firms in the total study. As all of the 35 American firms are users, this further supports the general theory that increased technology reduces the need for higher level staff.

If, as is suggested, the advanced technology reduces the need for the highest levels of staff and declines with the increase in employee size, where then are the knowledge workers which it is believed will grow as the blue collar worker or manual worker declines with the advancement of technology and automation in industry?

Weekly payroll ratios.

The answer to the above question maybe found in the ratio of weekly paid employees as a percentage of total employees. In this instance and with the exception again of the very small firms, the user groups are consistently larger than the non-user, despite the fact that the mean value for the non-user is higher. (This results because of the influence of the small firms on the total). It is interesting to note that there is hardly any difference in ratio as employee size increases, suggesting that a larger weekly staff is proportionally required to support the needs of the firm. This feature was not however reflected in the Caterpillar case study in chapter 3, which shows a steadily decreasing ratio of weekly personnel against blue

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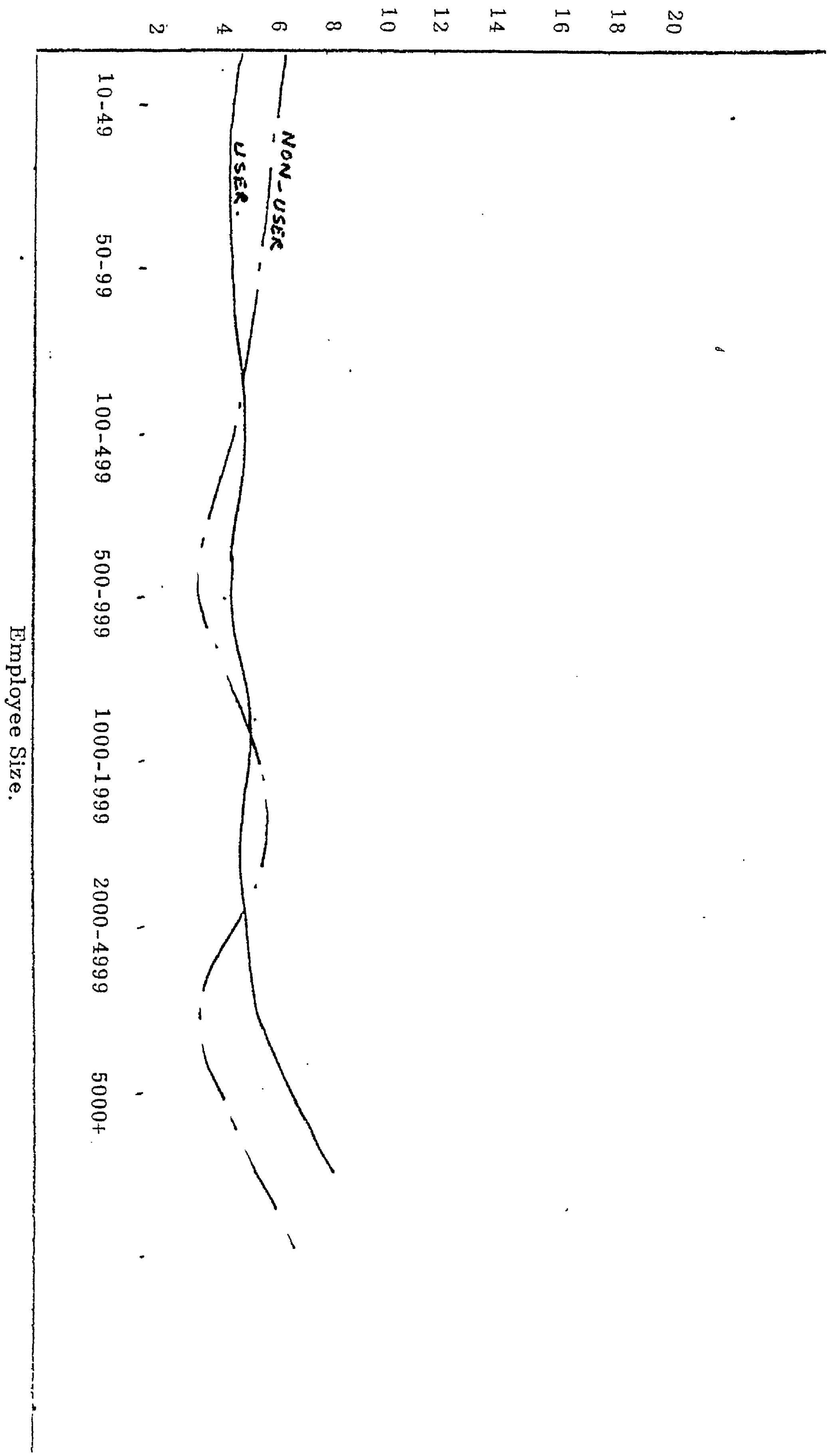
collar employees and this is happening because of severe controls by senior administration on the addition of both monthly and weekly payroll appointments. Again it was observed in the Caterpillar Case Study that, despite reducing numbers, new technology was giving weekly staff in particular more influence and power. Caterpillar have a basic theory that any increase in these payrolls not only affects the overall cost of labour, but tends to create other unseen costs such as more space required in an office, more paper circulating than is necessary, and perhaps worst of all, the formation of further groups trying to solve short term problems. However the inverse of all this care is to ignore the fact that conventional machine tools are being replaced by complex transfer systems, notebooks are being replaced by on-line real time computer print-outs and while it is also true that the cost of computer hardware is dropping dramatically with the advance of cheaper micro-electronics, the cost of software programming is rising just as dramatically; more knowledge workers are required, especially in computer advanced machine tool planning and, as is shown in this study, for advanced measuring machine technology.

From Figure No: 6.11 and Appendix R, it is observed that weekly personnel are neither declining nor increasing with employee size. The economics of scale do not apply in weekly payroll as they apparently do in monthly payroll, that is larger firms require proportionately fewer managers than smaller firms for administering their inspection and quality control functions, however this varies with complexity of technology, especially with the smaller firms. Coming back to the weekly payroll, it is noted from Appendix R, sheet 3, column 26, that 4 out of the 7 non-user employee size groups are larger in percentage than the user group and indeed the mean value is larger in the non-user group. 35 American based user firms have smaller percentages in all employee size groups except 2,000 - 4,999 employee size, where it has a higher percentage than the non-user group. (see Appendix R, sheet 4).



COMPARISON OF NON-USER FIRMS TO USER FIRMS IN TERMS OF INSPECTION MANPOWER TO TOTAL MANPOWER WITHIN EMPLOYEE SIZE OF FIRMS.

It seems apparent from these results that technology has a direct influence on the number of weekly payroll as well as the effect of employee size. This infers that non-user firms require larger forces of planners, analysts, statisticians and other such engineers to perform functions which are carried out by computers and measuring machines in technically advanced firms, in essence it is concluded that weekly payroll inspection may not decrease rapidly with increasing employee size but the more complex the technology results in faster decrease in weekly payroll support. This is further validated by 35 American firms who are all users of advanced measuring technology. (see Appendix R, sheet 4, column 3).

Hourly payroll ratios - direct hourly workers.

In manufacturing industries it is common practice to relate the total hourly payroll to the inspection hourly or indeed any other service function such as maintenance hourly, toolroom hourly, and others, which results in a ratio measure of all services paid by the hour to each other. For finer tuning of true effectiveness, a further ratio is employed and this is concerned with relating these same services to the actual direct hourly payroll. Direct applies to employees engaged in manufacturing or assembling saleable components, that is any item to which value is added as a result of some operation. At the time of the case study in 1978, the direct hourly employee ratio at Caterpillar Tractor plant, Glasgow was running at 1.8 to all other hourly, which means that for each direct employee there are almost 2 hourly service employees assisting him by fixing breakdowns, moving material, preparing tools, issuing at stores and other. Consider for a moment what happens to this ratio when all other payrolls are added, that is weekly and monthly. One is left with a fairly large number of people basicallly supporting the hourly direct employee. Recent research in the American army revealed that for every front line soldier, there are 9 other army personnel behind him organising, supplying, strategising and other activities.

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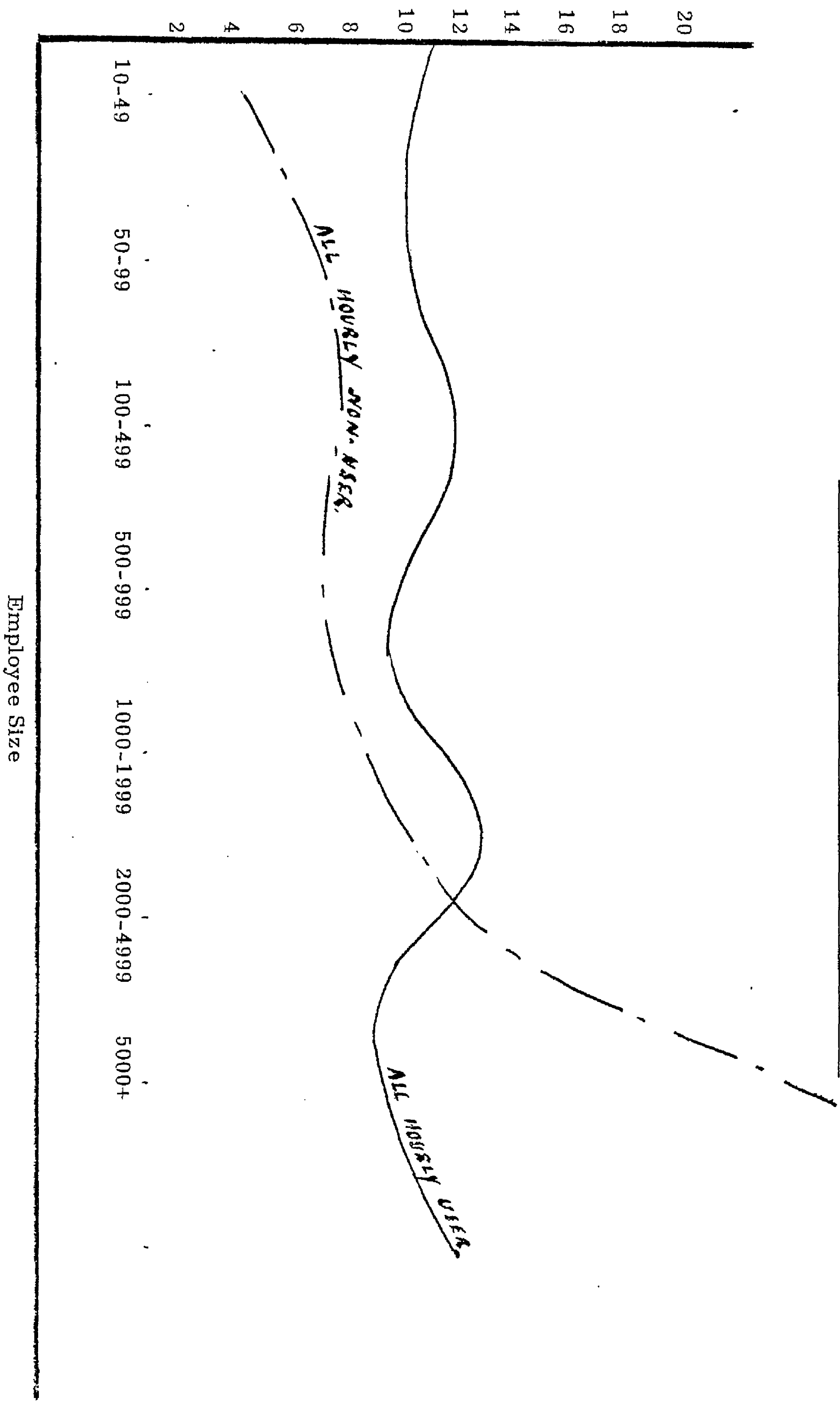
Inspection - Percentage Hourly to total Personnel

Figure No: 6.12



COMPARISON OF NON-USER FIRMS TO USER FIRMS IN TERMS OF INSPECTION MANPOWER TO TOTAL MANPOWER WITHIN EMPLOYEE SIZE OF FIRMS

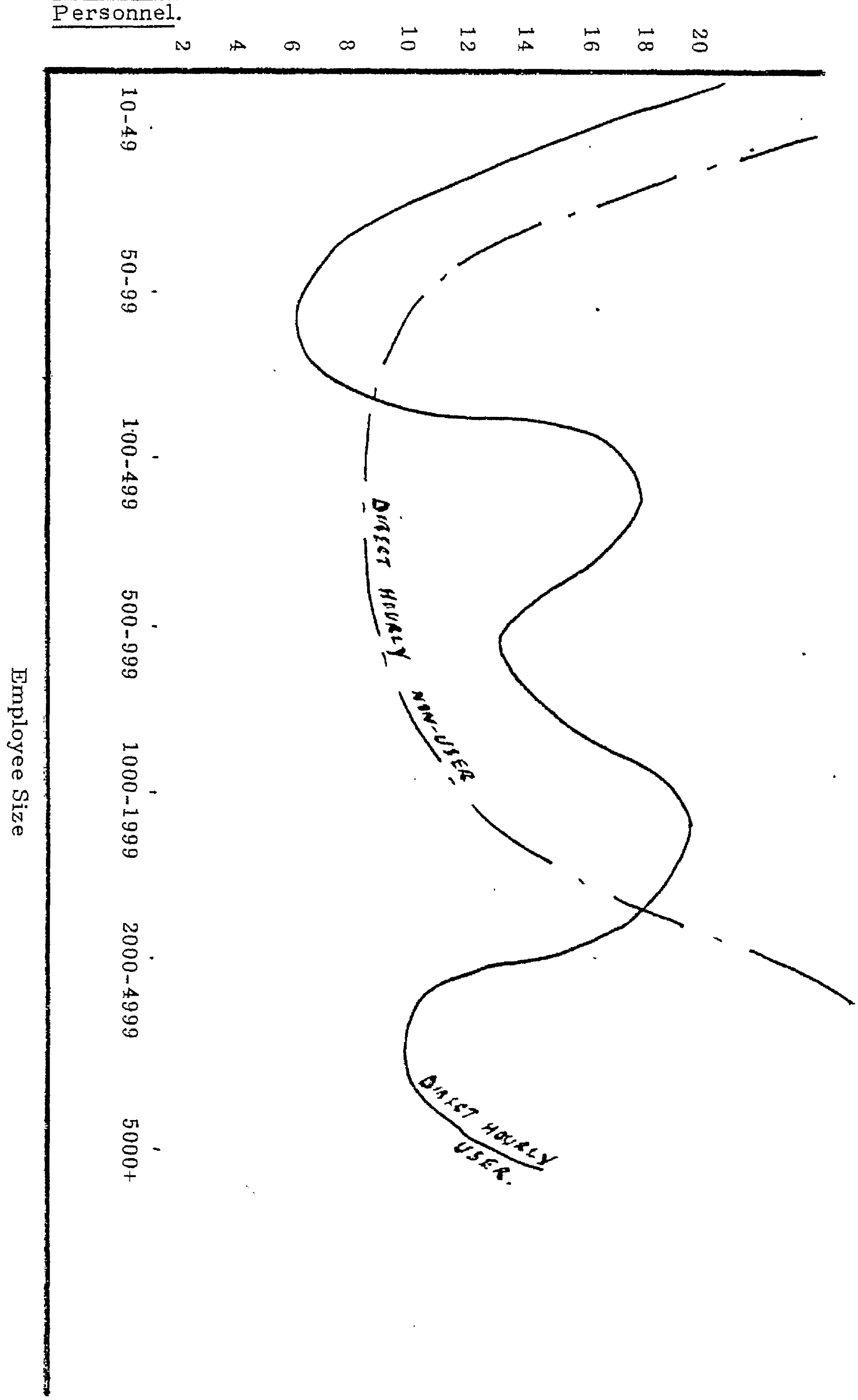
Industry to some degree is moving in the same direction but with some resistance from owners and senior management to control the change.

This research looks at the ratio of hourly inspection to total direct employees and this is shown in Figure No: 6.12 and Appendix R, sheet 3, column 25. In this instance one observes a complete change in inspection percentage from the previous comparisons of weekly and monthly payrolls, in that the user firms exceed the non-user firms in all employee size groups with the exception of the smallest firms and the largest firms, that is 10 - 49 and 2,000 plus employee size, the middle ranges have a much higher dominance of inspection manpower to direct employee and the mean value for all firm groups in the user section is 11.73 against 8.68 for non-users. American based firms also have a higher mean value than the non-user group, although the non-user firms in the 2,000 to 5,000 employee size far exceed the user group both total population and American firms. (see Appendix R, sheet 4, column 1).

There is no particular trend with any of the groups as employee size increases except as previously stated, non-user firms are high at both ends of the scale and form a dish-type curve suggesting that non-users require less inspection personnel in firms of 100 to 2,000 employee size as a percentage of direct employees, while user firms have the exact opposite result, with more inspection personnel as a percentage of direct employee for firms of 100 to 2,000 employee size. By contrast American based firms tend to have an increasing proportion of hourly inspection as the firm increases in size. (Appendix R, sheet 4, column 2).

The results suggest that technology has no particular influence on the relationship between inspection and direct hourly employees and that any differences are a direct function of the needs of the firm in the performance of its activities.

Inspection - Percentage Direct Hourly to total Personnel. Figure No:6-13



COMPARISON OF NON-USER FIRMS TO USER FIRMS IN TERMS OF INSPECTION MANPOWER TO TOTAL MANPOWER WITHIN EMPLOYEE SIZE OF FIRMS

Hourly payroll ratios - all hourly workers.

The next part of the study examined the relationship of all hourly personnel to all hourly inspection to which again referring to the Caterpillar case study in chapter 4, this figure was 16 to 1, that is one hourly inspector to every 16 hourly employees, and indeed, 6.25 if expressed in the same manner as the calculations in Appendix R, sheet 3, column 24. Examination of these details in the above numbered Appendix and as illustrated in Figure No: 6.13, one notes that user firms have greater proportions of hourly inspection except in the employee range of 2,000 to 4,999 where non-user firms exceed both users and American firm users. It is of further interest to note that in general user firms decrease very slightly in hourly inspection personnel as total employee size increases, suggesting economies of scale with increasing size of firm.

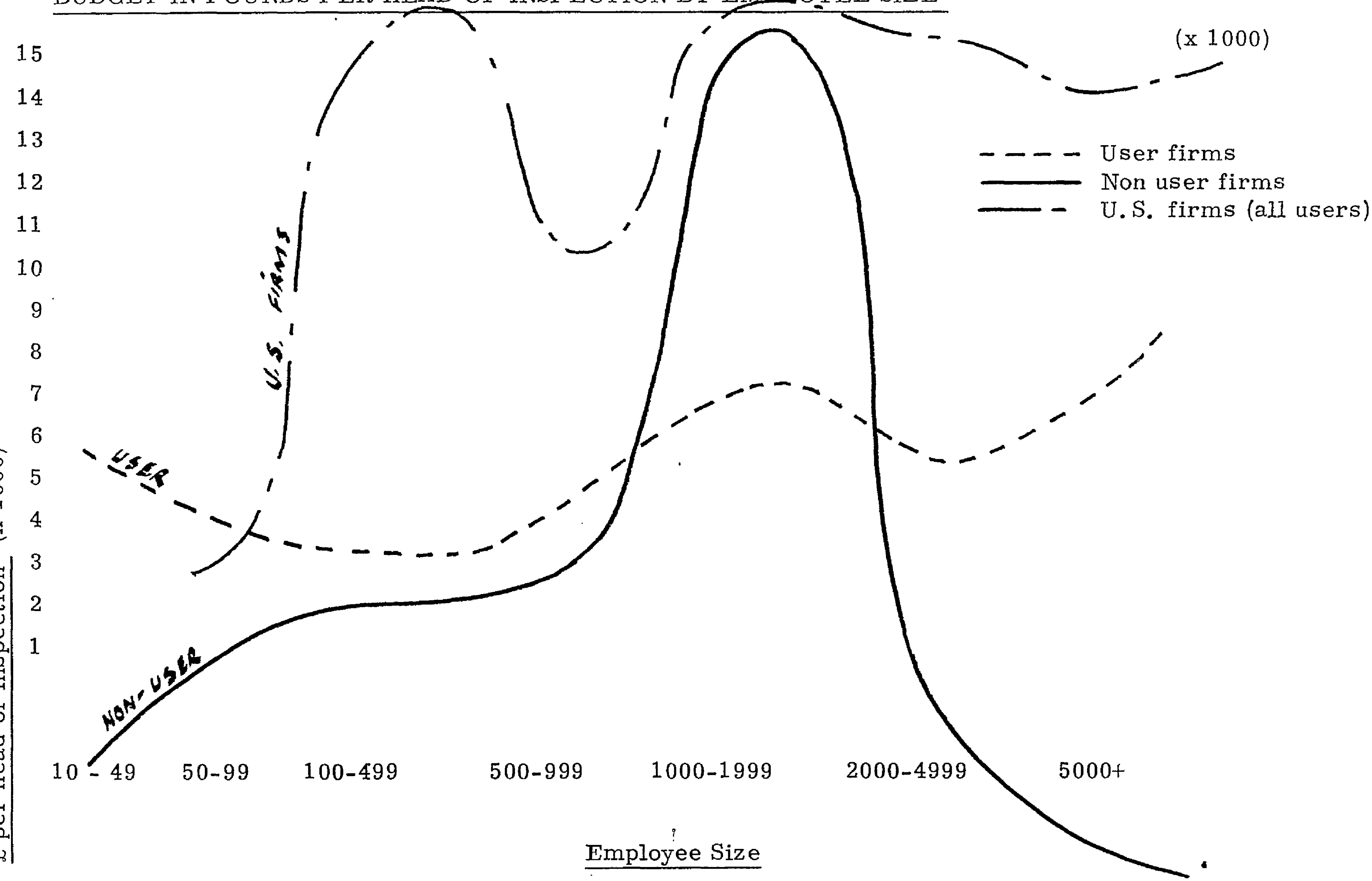
Correspondingly as non-user firms increase in size there is a definite trend of increasing inspection personnel suggesting that as firms increase in size, they need to substitute people in place of advanced inspection technology. Contrasting both these results are the American firms using advanced technology and although they reflect greater percentages of inspectors than the non-user except as stated for the 2,000 to 4,999 size, American firms tend to peak at the middle range of 1,000 - 2,000 employees then begin to decline in inspection hourly manpower as employee size increases. (see Appendix R, sheet 4, column 1).

Budget per head of inspection by employee size.

Figure No: 6.14 shows a graph of budget expenditure by employee size; in this there is a general upward trend of expenditure with all 3 groups indicating that firms have a need to increase their inspection budget per head of inspector with increase in firms size. The user group have a very steady growth which again supports the argument that the new technology is minimising the need to increase labour support in the indirect area of inspection as the firms increase in employee size. (see Appendix R, Index B and Index E).

Figure No: 6.14

BUDGET IN POUNDS PER HEAD OF INSPECTION BY EMPLOYEE SIZE



6.7 - ADMINISTRATION INTER-RELATED RATIOS OF MANPOWER BY BUSINESS ACTIVITY.

Having reviewed ratios as related to employee size firm by firm in section No: 6.5, it is interesting to carry out a similar analysis only this time relate the ratios to business activities, in an attempt to determine the impact of ratios due to advanced measuring technology. The same overall statistics of mean values will result for the totals of all 20 business activities as it did for the total of all employee groups and these have already been expressed under each payroll group in the previous pages. It is necessary therefore to isolate any major differences not reflected in the mean values by individual business activities.

Monthly payroll rating.

It was already established for example that the ratio of monthly inspection to total personnel was greater on average in user firms than in non-user firms, although American based user firms did not follow this rule and were in fact below the mean of non-users. This maybe due to the fact that all business activities were not included in the American results. The user business activities which were less than the non-users in terms of monthly payroll inspection were defence, aircraft, tools, food processing equipment, telecommunications, controls, castings, miscellaneous, R & D., and domestic products; all other activities were either greater or equal to in the user group; this is shown in Appendix R, sheet 3, column 27. The implication from this analysis would suggest that firms at 2 ends of a spectrum of magnitude, namely large components, aircraft, heavy vehicles, etc., at one end, and light engineering such as tools, telecommunications and other miscellaneous items at the other, have a greater requirement for managers and the highest paid staff to administer their firms, if they do not have the support at their elbow of advanced inspection technology. This hypothesis is supported by what was already found with monthly payroll staff related to employee size, that is, users of advanced technology have a

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decreasing need for monthly inspection payroll personnel with increase in size of firm.

Weekly payroll ratios.

There is a similar result for weekly payroll employees in inspection where only 7 of the 20 business activities in the user group exceed the non-user activities in terms of employees in weekly payrolls. These users are defence, machining, electronics, machine tools, miscellaneous, R & D., and medium to heavy engineering. With the exception of perhaps defence, all of these particular business activities despite inclusion in the user group, are not intensive users of advanced measuring equipment and therefore may tend to continue with over-manning practices irrespective of the time saving advantages of the equipment. All of the American firms reviewed by business activity had fewer weekly inspection personnel than non-user firms with the exception of engines,- which was marginally larger than the non-user engines. (see Appendix R, sheet 3, column 26).

Hourly payroll ratios.

Turning to the hourly inspection payroll, one first compares it to direct hourly employees, which has already been defined in section No: 6.5 and notes immediately that only 4 business activities have smaller ratios in the user group as compared to the non-user group, these are motor cars, miscellaneous, instruments and domestic products. (see Appendice R, index C, sheets 3, column 25). What this means is that a greater number of inspectors support direct operations in 80% of business activities using advanced inspection technology. This result is further validated with the total hourly to hourly inspection ratio where 3 business activites only have less hourly inspection support in the user group namely, tools, food processing equipment and domestic products. (All of these business activities are described as light manufacturing and have been identified as not being intensive users of advanced technology. (see

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column 24 of same Appendix). Again with the exception of the aforementioned activities the American user group exceed the non-user group in terms of hourly inspection support. (see Appendix R, sheet 3, column 24).

Employee ratios by rank order.

It is required to establish at this point the relative position not only between users and non-users of advanced equipment in each business activity grouping, but also the relationship activity to activity. This is best shown in Table No: 6.4 containing ratios by rank order for user and non-user business activities. The left hand side of each column has the user rank order and the right hand side displays the non-user firms in that particular business activity. One observes for example, that the business activity with the largest percentage of hourly inspection to total hourly personnel is medium to heavy engineering, second in largest rank order is telecommunications and third, machining. The non-user firms in business activities have domestic products as first, engine manufacture as second and instruments third. Several observations are of immediate interest. Comparing the top 3 rankings between user and non-user shows an almost opposite condition in that domestic products is first for the non-user yet last for the user. Firms making domestic products and utilising advanced measuring technology have least need for hourly inspection manpower while firms making domestic products without utilising advanced measuring technology have greatest need for hourly inspection manpower. A similar observation applies to telecommunication equipment manufacturers where the relationship between users and non-users of advanced measuring technology was found to be 2 to 19 in rank order respectively. Others in the middle ranges of the rank order were not so acute but implications can be established, for example, machine tools have a low ratio of hourly inspector to total personnel as users yet as non-users they are not much different. This result is not unexpected as the performance of British machine tool industry tends to be somewhat erratic (55). This research indicates that, despite the advantages of advanced

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TABLE No: 6.4

RATIOS BY RANK ORDER FOR USER AND NON-USER

Business Activity:	1 Hourly Insp. to Total Hourly: User:	Non U:	2 Hourly Insp. to Direct Hourly: User:	Non U:	3 Weekly Insp. to Total Personnel: User:	Non U:	4 Monthly to Total Personnel User:	Non U:	5 Budget per head of Inspection: User:	Non U:
1. Defence	14	9	12	8	2	8	14	7	3	6
2. Aircraft	13	18	10	18	5	1	5	2	10	12
3. Tools	16	7	18	15	17	7	12	6	11	9
4. Machining	3	10	16	12	1	13	4	12	19	11
5. Engines	9	2	6	7	15	14	7	20	1	16
6. Pumps	4	17	8	6	10	5	2	11	15	3
7. Trucks	15	13	13	5	16	10	8	16	2	1
8. Food Processing	19	8	19	9	20	9	11	5	9	5
9. Telecommunication	2	19	4	19	19	15	17	3	6	14
10. Electronics	7	5	9	10	13	16	6	9	8	2
11. Machine Tools	18	14	15	13	12	17	18	19	13	13
12. Controls	17	16	1	16	7	3	9	8	16	10
13. Castings	5	6	5	11	4	4	20	10	12	17
14. Motor	12	2	11	4	3	2	10	15	14	20
15. Miscellaneous	6	4	14	1	6	12	13	4	7	18
16. R & D.	11	20	3	20	8	19	16	1	20	4
17. Plastics	8	15	7	17	14	6	19	18	18	8
18. Medium/Heavy	1	11	2	14	9	20	3	14	4	7
19. Instruments	10	3	17	2	11	11	1	17	5	15
20. Domestic Prod.	20	1	20	3	18	18	15	13	17	19

technology, they continue to use heavy inspection manpower.

Reviewing the order of the user column only, one notes that the top 3 - medium to heavy engineering, telecommunications and machining, are perhaps the poorest users of advanced measuring equipment as reflected in the survey. (The firms in these business activities tended to have only one measuring machine irrespective of employee size). This point is further clarified with firms in the business activities having the least hourly inspection ratios in the user column namely, tractor/trucks, aircraft, defence and motor, which have all been identified as intensive users of advanced measuring equipment.

Turning to column 2, one reviews the ratio of hourly inspector to the direct hourly employee, and recalls that the direct hourly employee is classified as one who adds value to a product. The relative rank order between column 1 and 2 users has a similar placing with the exception of machining, which jumps from rank order 3 to 16; this suggests that there are many other indirect hourly personnel in the firm as well as inspection personnel making the hourly direct to total hourly look inefficient; this would be difficult to prove between different business activities. The other exceptional difference was in controls, which was the inverse of the previous example, ranked at one for column 3 and 17 for column 1, indicating a good ratio of direct hourly to total hourly, that is more people making things to those assisting. This applies to the controls-type business activity which encompasses hydraulics, flow-meters and the like, and indicates good utilisation. User firms in business activities in column 2 are almost identical to column 1 for rank order and it is not necessary to discuss this further at this stage.

Weekly payroll ratios.

This research showed earlier the differences between hourly inspection manpower to weekly and monthly inspection manpower when compared in user and non-user groups within employee size. It

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indicated that users had more hourly inspection both related to total hourly and direct hourly than non-user firms, yet for weekly and monthly inspection personnel the reverse was true, more numerous in the non-user firms. There were some exceptions to this in the various employee size sections but the abovementioned pattern was of a general rule. How does this apply to weekly inspection as reviewed by business activity rank order? It is noted for example, from Table No: 6.4 and Appendix R, column 3 that machining has the highest percentage weekly inspection and this correlates with the ratio for hourly to total hourly in column 1.

However this is one of the few exceptions, rank order 2 in column 3 is defence against 14 and 12 in columns 1 and 2 respectively, equally rank order 3 is motor car manufacture, while this same business activity is ranked 12 and 11 in columns 1 and 2 respectively. Recalling that the higher the rank order rating, 1 being highest, the greater the number of weekly inspectors as a percentage of total employees. This result shows that with advanced measuring equipment the following business activities have the greatest number of inspectors, viz:- machining, defence and motor. At the other end of the table the following business activities using advance technology have the least weekly inspectors, viz:- food processing equipment, telecommunications and domestic products. The non-user firms in business activities for column 3 again show where the highest number of weekly inspectors are found and these are viz:- aircraft, motor and controls, indicating a need to replace the lack of technology with human support.

Monthly staff payroll.

Column 4 in Table No: 6.4 looks at the monthly staff ratio and the user firms again have some commonality with the weekly and hourly, although exceptions are observed even in rank order 1, instruments, where the comparable rank orders are much lower for weekly and hourly.

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Budget per head of inspection.

Column 5 of Table No: 6.4 ranks the budget per head of inspection personnel by business activity. It seeks to reflect the firms in business activities who are spending the greatest amount of money per annum on their functions, rank order one being the highest. Firms spending least money are shown at the bottom end of the scale. The top 3 in the user group are engines, trucks/tractors and defence, suggesting that firms in these types of activities, having already invested in capital projects for advanced measuring machines, are continuing to support the use of this equipment with highly skilled and expensive manpower. Plastics, machining and R & D., appear at the other end of the scale tending to spend least money per head of inspection personnel despite using advanced inspection technology.

Non-user firms in business activities such as trucks/tractors, electronics and pumps were found to be spending most in support of their inspection functions, perhaps as a replacement for technology. Miscellaneous, domestic products and motor cars in the non-user group tended to spend least money in support of their inspection function. It is interesting to observe at this point that all 3 of these business activities appear more than twice in the upper section of Table No: 6.5 indicating poor effectiveness in terms of manpower.

Rank order of business activities.

Table No: 6.5 shows the best and worst ratio conditions by rank order in each business activity. The upper section of Table No: 6.5 shows the top 4 business activities for firms using and not using advanced inspection technology. Where a business activity appears in more than one column it has been underlined, this tends to reflect a pattern that indicates a fairly consistent result as only 6 activities do not appear twice in the top group, that is user group, and only 4 appear one time only for the non-user group.

As these activities have the highest rank order then they correspondingly have the greatest inspection manning in each category. For the

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Table No: 6.5

RANK ORDER PLACINGS FOR TOP AND BOTTOM BUSINESS ACTIVITIES IN TERMS OF INSPECTION MANPOWER.

		Hourly Insp. to all hourly personnel:	Hourly Insp. to Direct personnel:	Weekly Insp. to total personnel:	Monthly Insp. to total personnel:	Comments:
Rank Order	1	Med./Heavy	Controls	Machining	Instruments	These firms in the business activities shown have the greatest number of inspection personnel related to hourly, hourly direct and total personnel.
Top Four	2	Telecom.	Med/Heavy	Defence	Pumps	
Business activity	3	Machining	R & D	Motor	Med/Heavy	
By User.	4	Pumps	Telecom	Castings	Machining	
Rank Order	1	Dom. Prods.	Misc.	Aircraft	R & D	The "user" group are making least use of their advanced technology in terms of reducing manpower.
Top Four	2	Motor Cars	Instrum'ts	Motor Cars	Aircraft	
Business Activity	3	Instrum'ts	Dom. Prod.	Controls	Telecom.	
By Non-User	4	Misc.	Motor Cars	Castings	Misc.	
Rank Order	17	Controls	Instrum'ts	Tools	Telecom.	Firms in these business activities are making maximum use of advanced technology in terms of lower inspection manpower.
Bottom Four	18	M/c. tools	Tools	Dom. Prod.	M/c. tools	
Business activity	19	Food. Proc.	Food Proc.	Telecom.	Plastics	
By User	20	Dom. Prod.	Dom Prod.	Food Proc.	Castings.	
Rank Order	17	Pumps	Plastics	M/c. Tools	Instrum'ts	Firms in these business activities have lowest number of inspection personnel yet have no advanced inspection technology to support or fill the vacuum. Could be to the detriment of quality.
Bottom Four	18	Aircraft	Aircraft	Dom. Prod.	Plastics	
Business activity	19	Telecom.	Telecom.	R & D	M/c. tools	
By non-user	20	R & D	R & D	Med/Heavy	Engines	

user group it suggests that they are the least effective at reducing their manpower of all 20 user business activities despite the advantages of advanced measuring equipment. The non-user group in this upper section again have the greatest number of inspection personnel of all 20 non-users business activities. The lower section of Table No: 6.5 identifies the bottom 4 business activities in each of the 2 groups, user and non-user; again the activities have been underlined if they appear more than once, note that only 4 activities appear in the user group and 5 appear once only in the non-user group. This indicates a similar consistency at the bottom to that which is observed at the top, that is, the same business activities are appearing throughout. Both groups have the inverse result to the top section in that the firms within these business activities have the smallest number of inspection personnel as a percentage of other totals. This suggests that the user group of activities are really using their advanced technology by minimising their labour force; it also suggests that the non-user firms in the bottom grouping have the lowest number of inspection personnel but without the support of advanced technology. This could lead to a lowering of the quality standards within these firms.

6.8 - ANALYSIS OF 18 QUALITY CONTROL ORGANISATION CHARTS.

Introduction.

The research now selects and displays 18 organisation structure lay-outs from the 100 firms examined in this section of the study with the objective of testing theory and developing further conclusions and implications on the impact and problem of advanced measuring machines on organisation structures. These displays have been grouped in 9 pairs in order that comparisons can be made of users and non-users of advanced inspection technology and also comparisons can be made of American firms against British based firms both in user and non-user classification. (see Table No: 6.6).

Evolution of the quality control function.

Prior research by Juran (53) has shown that, with the evolution of organisation structures for quality control, changes in the structures came about in a series of eras, not because of the firm's internal needs but more so because of new technology, new systems, new fashions, new control methods and so on. Observations were made of the growth of statistical quality control and the introduction of the concept of the reliability engineer and the subsequent growth of staff functions analysing data from which information could be derived to permit line management to make better decisions. It is very interesting to review 18 current organisation structures to determine if possible, what causes the shape of this structure to be what it is; what proportion belongs to the "evolution" as described, and what proportion to that of the needs of the firm for basic control of its quality. In many instances there is a need for the firm to keep all of its different functions in the same hierarchical structure and nomenclator. This research seeks to determine if the user of advanced technology has to have a different type of structure be it related to pyramid shape, position titles, hierarchical levels or span of control. In the previous section it was shown that there is a distinct correlation between the size of the firm in terms of employees and

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Table No: 6.6

ORGANISATION CHARTS ILLUSTRATED

(K=000's)

1	2	3		4	5	6	7	8	9
Ref No:	Firm Name:	User or Non-user of advanced Technology:		Business Activity:	Total Empl's:	Total Insp. Empl's:	% of Total:	Total Budget for Inspection: (£)	Per Head of Employee: (£)
075	Ferranti Ltd.	User	(UK)	Electronics	454	45	10	--	--
216	GEC Measurements	Non user	(UK)	Electronics	1600	111	7	N.A.	--
026	Fairbanks Morse	User	(US)	Engines	1300	69	5	502K	386
106	Cummins Engine	User	(UK)	Engines	2200	N.A.	-	N.A.	-
270	Anderson Strathclyde	Non user	(UK)	Med/hvy Engr.	2000	89	4	N.A.	-
108	Doncaster Monk Bridge	User	(UK)	Cast/F'ging	1000	250	25	600K	600
066	Rolls Royce	User	(UK)	Aero Engines	1200	316	26	757K	630
044	Westinghouse	User	(US)	Med/hvy Engr.	1000	175	17	N.A.	-
032	Litton Microwave	User	(US)	Food Proc.	600	22	4	250K	416
264	EMI	Non user	(UK)	Electronics	700	26	4	300K	428
001	Alvis Ltd	User	(UK)	Defence	2000	153	8	850K	425
167	Robophone	Non user	(UK)	Telecom.	106	7	7	16K	151
096	John Deere	User	(US)	Truck/track.	4500	164	4	N.A.	-
170	Sperry New Holland	Non user	(UK)	Truck/track.	930	32	3	191-6K	206
086	British Aerospace	User	(UK)	Aircraft	3373	153	5	N.A.	-
009	Boeing (Washington)	User	(US)	Aircraft	8500	180	2	N.A.	-
076	B.L. Cars	User	(UK)	Motor	7500	866	12	46K	6
207	Alfred Herbert	Non user	(UK)	Machine Tool	1830	48	3	N.A.	-

the number of inspection personnel employed. Table No: 6.6, column 7, shows the difference in percentages of inspection personnel against total employees. The user firms tend to be greater in all cases of the comparison. This fact could suggest that user firms have a much greater overall concern for quality and are prepared to support this with a substantial number of inspection personnel, which suggestion is re-enforced by the larger amount of finance placed on the annual budget of these firms in contrast to the non-user firms. This point is shown in Table No: 6.6, column 9, despite the fact that data was not available for all 18 firms showing the pounds sterling per employee. One exception to the results was E.M.I., who spent £428.00 per employee on inspection, this being a comparable amount to user firms. (It is worth noting that E.M.I., intimated in their returned questionnaire from the field survey, their intention to buy a co-ordinate measuring machine in the course of 1978).

An other avenue may suggest that new technology introduced does not reduce people as some advocates of automation would indicate, but indeed it adds more people and in effect higher skilled people at that. Again is this not the direction of all manufacturing industry? The Japanese for example, despite their own unemployment problems, are pushing very much ahead with their M.U.M., projects (Methodology for Unmanned Metalworking), but the stage prior to fully automated factories must, it seems in essence, see a decided drop in blue collar workers with a corresponding increase in white collar workers although not to the same proportion. In short, the firms examined in this research who have invested in fringe technology such as computer-aided co-ordinate measuring machines to back up their already established metal cutting advanced technology such as CNC machine tools, could be the pioneers of change from manual to knowledge workers in an increasing and accelerating rate (56).

Results from survey of 9 pairs of organisation structures.

Pair No: 1.

Ferranti, Appendix S (ref: 075-216) for example, are not only a user of computer-aided co-ordinate measuring machines, CMM, but they also manufacture them at their Dalkeith factory near Edinburgh, with a 10% inspection force to total manpower, and undisclosed budget. Ferranti have a structure with 4 levels not including the functional relationship with the overall quality manager for Scotland, and the peer relationship with the central services group, which probably tends to hide some services which another organisation may include in its pyramid. The span of control for the quality manager is 3 thus producing a 3 by 4 pyramid for a ten percent share of the total group manpower making a squat type structure. It is interesting to note about Ferranti their preference for the position title of "engineer"; this is in keeping with the nature of their overall business which tends to be orientated towards research development and innovation of product as compared to the typical manufacturing organisation which is primarily concerned with manufacturing.

G. E. C., Measurements Ltd., Appendix S, (ref: 21-075), are a non-user of advanced measuring equipment. They have a seven percent inspection manpower to total manpower and an undisclosed expense budget. The pyramid in this case is very squat, consequently giving the inspection manager a wide span of control and only 3 levels of management hierarchy. This then seems typical of a non-user structure as the introduction of advanced technology would have created a further division reducing the span of control and making the pyramid slightly taller yet perhaps more effective. The Ferranti structure illustrates this very point.

Pair No: 2.

Comparison is made between 2 user firms, one American based and the other British based, both making industrial engines. Fairbanks Morse, Appendix S, (ref: 026-106), is an American firm employing

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1,300 people with a five percent inspection manpower. They allocate £386 per head per annum per employee towards inspection. The structure has a 4 by 3 pyramid not unlike Ferranti with clear and definite lines of command. One notes the position title for the most senior quality man as manager quality assurance. The emphasis is on assurance and has a fashionable approach to the whole concept of quality control; Fairbanks Morse make intensive use of computer-aided co-ordinated measuring machines. Cummins Engines, Appendix S, (ref: 106-026), although based in Britain are in effect an American owned company. Neither the number of inspection employees not the annual budget were available, therefore direct comparisons cannot be derived, except to say that Cummins is roughly twice as large as Fairbanks Morse, taken plant to plant. Cummins have a fairly regular shaped structure with a 2 by 3 pyramid, that is 2 divisions of span and 3 levels of hierarchy. The Cummins quality organisation, like Fairbanks Morse, make extensive use of measuring technology. Note once again the position title given to the top quality executive, reliability manager. The emphasis is on the product and not the business of controlling internal activities of the firm.

<u>Pair No: 3.</u>

The next pair of companies are not in the same business activity but they are users and non-users of advanced technology. Anderson Strathclyde, Appendix S, (ref: 270-108), for example is a very old firm having merged several times with other firms and consequently changed their name. The basic business interest is mining equipment with one major customer namely, the National Coal Board. They employ 2,000 people and this includes 89 inspection personnel or four percent. Their expense budget was not available. The structure is simple to say the least but is in keeping with the low percentage of inspection manpower covering the product. The one positive aspect of the organisation is probably the position title given to the most senior quality manager which reads quality control and test manager, the word test has a connotation related to safety which

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would be of prime concern for mining equipment. Anderson Strathclyde is a company which has come through some very difficult financial crises in its long years of business, mainly due to their dependence on the National Coal Board and fluctuations by various governments on energy policies. This maybe one of the reasons why there have been so many mergers with other firms in order to survive these periods of high risk. Thus it maybe that under such dilemmas, firms like Anderson Strathclyde have not invested in advanced inspection equipment despite the possible advantages to improve quality and efficiency. Doncaster Monk Bridge Ltd., Appendix S, (ref:108-270), are located at Leeds, England and are in the business of casting high precision forgings. This firm with 1,000 employees and a twenty-five percent inspection together with a £600 per head of employee per annum budget for inspection, makes heavy use of computer-aided measuring equipment and other advanced technology which is in keeping with the high precision requirements put on their products. The top quality manager position is called technical manager, and in addition to the responsibilities of quality, his span of control includes new process development. Other companies may have related him to the chief engineer. Here again one detects the influence of technology by the wide span of control of the top man in comparison with other firms. In a previous section of this chapter it was concluded that technology has an influence on both vertical and horizontal differentiation. (Example, Doncaster Monk Bridge Ltd).

Pair No: 4.

Rolls Royce, Appendix S (ref: 066-044), has a high reputation for quality, and one of its organisation structures from its many factories should show some interesting conclusions. In their aero engine plant at Loughborough, Rolls Royce have a total manpower of 1,200 people twenty-six percent of whom are involved directly on inspection work. The budget for inspection per head of employee per annum is £630, the highest figure yet recorded for the 18 firms under review in this section. The organisation structure is almost a model for quality control, in that the most senior quality manager namely, the quality /....

control manager, has a span of control of 4 and a hierarchical level of 3. This structure ensures close communication with the shop but in addition has the added benefit of advanced inspection technology which is used extensively by Rolls Royce. The plant quality control manager has a functional relationship with an overall head of quality for the Midlands of England who is named, director of quality assurance. This suggests once again that certain services are hidden from the plant as they are readily available from some central source or other plants, these might include special testing, proving grounds, laboratories and others. Westinghouse N. F. D., Appendix S, (ref: 044-066), is an American firm based in America. It was grouped with Rolls Royce merely to compare 2 user firms of equivalent employee size. Westinghouse have 1000 employees, seventeen percent of whom are inspection type personnel; the budget figures were not available. The nature of business is the manufacture of nuclear fuel equipment such as large boilers and the classification in this research is therefore medium to heavy engineering. Westinghouse have a 5 by 4 structure which makes it well balanced in terms of its hierarchical levels to span of control. It is worth noting again the emphasis given to product assurance; it tends to support the very critical and hazardous nature of the final usage given to the product. This structure almost fits the model user type by its incorporation of the position responsibilities of quality engineering, quality records documentation and quality development.

Pair No: 5.

Litton Microwave, Appendix S, (ref: 032-264) is an American based food processing equipment manufacturer with a total employee group of 600 and a four percent inspection force totalling 22 people. They budget £416 per annum per head of employee for the purpose of quality inspection and make use of advanced inspection technology in their organisation. The structure is naturally small due to the small numbers involved, but it produced a 3 by 2 pyramid and logically demonstrates a flow from supplier control through fabrication to finished assembly.

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E. M. I., Appendix S, (ref: 264-032) contrasts the above firm despite its different business activity, in terms of electronics. It is comparable in size to Litton Microwave and in fact the budget per head for inspection at £428 per annum is marginally higher. However E. M. I., is a non-user of advanced measuring equipment at this location and it is interesting to note the 4 by 4 structure for the same number of personnel as Litton Microwave - indeed the variety of position titles are quite remarkable. The most senior quality executive is quality assurance manager, the assurance aspect reflects well for the customer, but below this there are chief engineers, senior quality engineers and various deputies, which makes the overall organisation unusual. Whether the addition of advanced technology such as co-ordinated measuring machines would assist is another question, but it could result in a smaller span for the director without necessarily any further increase in hierarchical levels.

Pair No: 6.

Alvis Ltd., Appendix S, (ref: 001-167) is a British firm whose business interests are concerned with military vehicle manufacture and for this research, has been classified as defence. It is noteworthy that the position title of chief inspector is commonly used in the organisation and as previously stated, this is not unusual in older companies with some affiliation to the military. The pyramid is 6 by 4, a fairly wide span of control for the top quality executive but basically he has 3 main divisions, one of which will house the advanced inspection technology, without which the span of control may have been even wider. They have a fairly low inspection manpower at eight percent of total personnel but support this generously with a £425 per head of employee per annum. The overall structure of the organisation would suggest that they cover most of the "key" quality techniques such as recognising supplier control, gauge control, documentation, metallurgy and others. It is interesting to note the span of control given to the chief inspector, it covers a total of 8 sections. It seems somewhat excessive for one individual to

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adequately cover so many technical functions. Alvis, being a user of advanced measuring technology, will undoubtedly use this equipment in several of these sections. Robophone Ltd., Appendix S, (ref: 167-001), is a non-user of advanced measuring equipment. It is a small organisation, 106 employees and a seven percent inspection manpower, spending approximately £151 per employee per annum on inspection. The structure is somewhat clumsy for such a small organisation, yet on close examination, it identifies the key activities of today's model organisation for quality control i.e., supplier surveillance, production surveillance and customer surveillance.

Pair No: 7

The research now moves to an American based firm, extensively using advanced measuring equipment namely, John Deere Harvester Works, Appendix S, (ref: 096-170). The most senior quality executive uses the expression "reliability" and indeed through the organisation structure, reliability or assurance appears. This terminology tends to underline the American approach to the quality of a product, in that some attempt is made to convey the business objective within the position title, for example, "we build reliable tractors". The structure is a squat pyramid with a 6 by 3 span and hierarchical configuration. The one weakness in the John Deere quality organisation is the very low percentage of inspection personnel to total personnel at four percent. This maybe explained by the fact that this John Deere plant is one of several in the mid-west of America so they may benefit from central services or other such systems which tends to conceal the true inspection manpower required for a unit employing 4,500 people. Sperry New Holland, Appendix S, (ref: 170-096), is a British subsidiary of an American company. Unlike John Deere it is a non-user of advanced measuring equipment, but like John Deere, it is in the same type of business activity, that is, agricultural equipment manufacture, only in a much smaller scale of output. They have 930 employees at the Aylesbury plant but only three percent of these are involved directly with quality and inspection, with

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£206 per employee per annum devoted to the business of quality control. The pyramid has a 3 by 3 structure and appears well balanced for the specific needs of this subsidiary.

Pair No: 8.

British Aerospace, Appendix S, (ref: 086-009), have many establishments throughout the whole of Britain and several are part of this research. One unit, located at Hatfield, has been extracted to review and compare with Boeing of America. All of the British Aerospace plants who responded to the survey included a similar type of organisation chart as the one shown in the Appendix. It goes without saying that inspection must be of top priority for an aircraft manufacturer but British Aero are not over-generous with the overall percentage, which lies at five percent and their structures tend to be too tall with excessive use of "deputy" and "assistant", very often in a one to one relationship indicating a possible over-manning condition with weekly and monthly staff positions. The pyramid is a 3 by 7, providing a very small span for the most senior manager but a good distance between him and his first line supervisors. One recalls that earlier it was concluded that users of advanced technology could overcome the disadvantages of tall pyramids by the very benefits derived from that technology, British Aerospace is a good example of this condition. Boeing, Appendix S, (ref: 009-086), similar to British Aero, have many plants throughout America therefore they will benefit from central services and thus the two percent inspection manpower to total personnel at their Washington plant tends to be misleading, despite their intensive use of computer-aided measuring equipment. The 4 by 4 pyramid structure is neat and all embracing covering internal quality control and supplier quality, but no evidence of customer liaison, unless the only customer is another Boeing assembly plant which is highly probable. Like British Aero no budget values were given, therefore it was impossible to calculate a value per head for quality expenditure.

Pair No: 9.

The final pair of firms to be reviewed are both British and while one is a user and the other a non-user of advanced inspection technology, they are not in the same business activity. B. L. Cars, Birmingham Appendix S, (ref: 076-207), make great use of large computer-assisted co-ordinate measuring machines and have a twelve percent inspection manpower to total manpower at this plant, yet only £6 per head of employee is expended per annum on quality in terms of expense. This makes one consider once again that assistance is provided by B. L., from other central sources in terms of costly services. The B. L., structure of 4 by 4 is of a standard type pyramid covering the normal activities of the quality function. Alfred Herbert, Appendix S, (ref: 207-076), is the largest machine tool manufacturer in Britain, and like many machine tool manufacturers included in this research, are not users of advanced measuring equipment. Only three percent of the total manpower of 1,830 employees are attached to quality control, the budget figures were unavailable and total analysis could not be made. The pyramid of 3 by 4 is not excessive and is in fact in keeping with the low overall percentage of inspection manpower provided at Alfred Herbert.

6.9 - CONCLUSIVE POINTS OBSERVED IN THE DIFFERENCES AND SIMILARITIES IN QUALITY CONTROL ORGANISATION STRUCTURES OF FIRMS USING AND NOT USING ADVANCED MEASURING MACHINE TECHNOLOGIES.

Division of Labour.

- The average American firm was found to have fewer position titles than its British counterpart and did not use titles such as "assistant to" or "assistant of". This latter phenomenon of assistants was found to be common in British firms especially those associated with aerospace, defence and the motor car industries. It was not determined if the British firms had a problem of over-manning but as the organisation charts tended to show one to one relationships for these assistants to their immediate superiors, then the question of over-manning is implied.

- It was observed that the larger the firm the more pronounced is the division of labour within it.

- Position titles were found to be much more numerous in user than non-user firms.

- Specific position titles were found common to both user and non-user firms while other titles were common to either one or the other. It was of particular interest to note that those titles common to user firms tended to find association with the product such as reliability and assurance. By contrast, some non-user firms used somewhat dated titles such as chief inspector or other titles not directly associated with inspection such as superintendent.

- It was noted that non-user firms had a greater number of first line supervisors than user firms.

Hierarchy of levels and span of control.

- It was found that the larger the firm the greater the tendency to generate hierarchical differentiation of authority into many managerial levels.

- There appears to be a correlation between the size of firm in terms of employees and the maximum number of hierarchical levels in any one firm.

- Firms using advanced measuring machine technology were found to have taller pyramids, that is more hierarhical levels than non-user firms. It was considered that the reason for this was due to the use of computers and measuring machine technologies

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thus minimising the disadvantages of communications common with tall pyramids. The technology appears to foster multiple levels rather than reduce them numerically.

- It was noted that horizontal differentiation into multiple levels tends to occur in large organisations because it relieves the management of excessive supervisory burdens that interfere with its executive responsibilities.

- It was found that non-user firms tended to have wider spans of control as employee size increased while user firms tended to decline as employee size increased, perhaps due to deeper concentration and dependence on technology.

Divisions and sections within the hierarchy.

- Results imply that the larger the firm the greater the number of sections and consequently as the division does not increase in number, then the span of control of the division head increases, forestalling the proliferation of divisions requires establishing more sub-units of divisions namely, sections.

- User firms have more sections than non-users to handle new technology, due to horizontal differentiation but expression of new technologies finds itself in the lowest levels, that is sections and not at division levels.

- Exceptions to non-user firms being in general smaller than user firms were found in 5 business activities, tools, telecommunications, machine tools, motor cars and domestic products. The assumption is that these business activities tend to have wider diversification of business interests and require more independent sections.

Administration - interrelated ratios of manpower.

- Non-user firms had more monthly personnel than user firms suggesting that lack of technology calls for more managerial administration at high levels.

- Non-user firms appear to need larger forces of weekly paid employees (planners, statisticians and other engineers), to perform functions carried out by computers and advanced measuring machines in user firms.

- Weekly staff ratios do not decrease with increasing employee size but the more complex the technology results in faster decrease in weekly payroll support in user firms.

- User firms have a greater number of hourly paid inspectors except at large size firms in excess of 2,000 employees when the non-user exceeds the user, suggesting that as firms increase in size, they have to substitute people in place of technologies.

Manpower Ratios and Business Activities.

- Implications are that firms at 2 ends of a spectrum of magnitude of components namely, very large and very small, have a greater requirement for managers and the highest paid staffs to administer their firms if they do not have the support of advanced inspection technology.

- Only 33 percent of users in business activities exceed the non-user for weekly staff but these user activities tend to be the least active users of advanced measuring machine technologies and may be over-manned despite having the technology.

- Hourly inspection ratios are higher in all user business activities except tools, food processing equipment and domestic equipment. These 4 business activities however are not extensive users of CMM equipment.

Rank order correlations.

- Rank order correlations indicate that firms in specific business activities are not using advanced measuring machines but are supporting themselves with more people at weekly staff level.

- Certain user firms in business activities, that is engines, trucks/tractors, and defence are spending more on inspection than others thus supporting their initial capital investments. Contrasted by non-user firms in business activities, tractor/truck, electronics and pumps, spending heavily on budget perhaps to replace not having CMM equipment.

- User firms in certain business activities with heavy ratios, that is large numbers of inspection people, are making least use of their invested capital of advanced measuring machines. They are as follows viz:- medium to heavy engineering, machining and pumps.

- User firms in certain business activities with low ratios, that is fewest number of inspection people, are making greatest use of their invested capital of advanced measuring machines. They are viz:- machine tools, food processing equipment and domestic products.

- Non-user firms with highest ratios that is greatest numbers of inspectors, are very inefficient with lots of people to replace the need for having any advanced measuring technology. They are viz:- domestic products, motor cars, instruments and miscell-aneous.

- Non-user firms with lowest ratios, that is lowest numbers of inspectors in this manpower measurement, appear to be efficient but what is happening to the level of quality because no techno-logical barrier or screen has been erected, to make up for the lack of inspection manpower?

Organisation structures paired in 9 groups.

The following factors were observed with the 18 structures, viz:-

- Non-user structures were much shorter than users, that is fewer levels of management within common business activities and for employee size.

- User firms use different position titles from that of non-user firms.

- User firms had larger percentages of inspection personnel and greater expense budgets to support the CMM technology.

- The advanced measuring machine technology does not appear to have reduced people but more so increased higher skilled requirements.

- Multi-plant organisations appear to share resources with their sister plants or some central source thus minimising the dup-lication of inspection services. This activity tends to mislead the outsider on first observation of inspection ratios.

- User firms tend to emphasise their attitude to the product by description given to quality control positions, such as reliability test, assurance and so on.

- The quality control organisation structure at Rolls Royce, Derby has a 4 span by a 3 level hierarchy. This is supported by a twenty-six percent inspection to total manpower ratio and provides a £630 per employee budget support. It could be de-scribed as a model for quality control.

6.10 - NEW TECHNOLOGY AND PRODUCTION TYPE.

The 287 firms who responded to the field survey were classified into 8 production groups to form a scale of technical complexity. These firms were further divided into those using and not using CMM equipment and shown by 7 employee size groupings and 20 different business activities. The aims of this section of the research were to -

- Classify the types of production being used by the firms in this survey.
- Determine if there are any specific production type differences between firms using and not using CMM equipment.
- Identify what employee size groups and business activites are evident if any differences are apparent between the use and non-use of CMM equipment.
- Establish any overall points of significance from the results obtained.

Classification of firms into production types.

The 287 firms were classified into production types adapted from the scale originally developed by Woodward (19). The definition of these production types for this research is given as follows:-

TABLE No: 6.7

Type:	Definition for this research:
1. Single simple articles.	Production of simple units to customers' orders.
2. Prototypes.	Production of technically complex units.
3. Large equipment.	Fabrication of large equipment in stages.
4. Jobbing.	Production of special products or components in a variety of quantities generally as one-time only orders.
5. Small batches.	Production of small batches of products or components 50 to 100 per run.
6. Large batches.	Production of large batches of products or components above 100 per run.
7. Mass production.	Production of high volumes of products or components.
8. Continuous flow.	Production of material such as liquids, gases or solid shapes.

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Table No: 6.9 shows the total responses given by each firm and classified into one of 8 production types. The firms are broken down by user and non-user of CMM equipment. Several firms gave multiple responses to this question to cover a range of product or processes used in their facilities. The total number of responses was 499 with 255 or 51 percent by user firms and 244 or 49 percent by non-user firms. The most significant feature about this data is that 50 percent of all firms are in small or large batch production type. The next largest production type is for mass production and prototype production, both of which have approximately 11 percent of the total responses.

Difference between user and non-user firms.

Table No: 6.9 shows that there is only marginal differences between the production types used by both user and non-user firms. The single most significant difference is in mass production where the user firms had 41 responses or 8.2 percent of the total against the non-user firms who had 17 responses or 3.4 percent of the total.

Differences in employee size groups and business activities.

The matrix shown in Table No: 6.8 indicates that there are large cells of responses between small and large batch production types and specific employee size groups. These cells are shown as follows:-

TABLE No: 6.8

Employee Size:	Proto-type:	Small Batch:	Large Batch:
100- 499	(16)	23 (43)	13 (23)
500- 999		14	
1000-1999		13	
2000-4999			18

( ) non-user firm response.

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Table No: 6.9

FIRMS IDENTIFIED BY PRODUCTION TYPE

(Multiple responses were given where a firm had more than one yes)

Production Type:	User:	%	Non-User:	%	Total:	%
Single Art	7	(1.4)	17	(3.4)	24	(4.8)
Proto	27	(5.4)	78	(5.6)	55	(11)
Large	23	(4.6)	20	(4)	43	(8.6)
Job	16	(3.2)	20	(4.8)	36	(8)
Small	71	(14.8)	81	(16.2)	152	(30)
Large	55	(11)	45	(9)	100	(20)
Mass	41	(8.2)	17	(3.4)	58	(11.6)
Continuous	15	(3)	16	(3.2)	31	(6.2)
	255	(51)	244	(49)	499	(100)

The implications of the above are that non-user firms in this research appear to have extensive small and large batch type production at 100 to 499 employee size groups, while the user firms are also in the same type of production, but spread over 4 different employee size group categories.

The business activities for user firms which are significant in the small and large batch production types are tractor/truck, electronic and aircraft. The non-user firms for the same analysis are shown to be significant in miscellaneous, machining and electronic business activities.

Points of overall significance from the results obtained.

- o The majority of firms both user and non-user in this research are clustered with the small and large batch type production systems. These results correlate with the recent report on Automated Small Batch Production which clearly shows that the majority of today's manufacturing industries in Britain have a small to large batch production system (57).
- o The majority of firms in the survey have more than one production type system - this indicates some degree of diversification of product range.
- o There are no significant differences between the production types of firms using and firms not using CMM equipment.
- o Firms in the small employee size groups feature strongest in the small and large batch production type systems.
- o Firms in business activities such as tractor/truck, electronics, aircraft, miscellaneous and machining feature strongest in the small and large batch production type systems.

(Supportive detailed analysis of production type by employee size and by business activity is given in Appendix U).

6.11 - MAJOR TECHNICAL CHANGES.

The field survey has shown that in a total sample of 287 firms in the manufacturing industry, 52 percent have invested in advanced co-ordinate measuring machine technology while the balance of 48 per cent have not made this investment. The aims of this section of the research are as follows:-

- To identify major technical changes made by all of the firms in the survey over the last two years.
- To classify these major changes by a technological analysis and arrange them in user or non-user of CMM equipment groups.
- To determine if there are any significant differences between user and non-user firms.
- To establish any overall points of significance from the results obtained.

Definition of major technical changes.

Major technical changes are defined for this research as those changes which include, as an example, the introduction of numerical control machine tools, the introduction of transfer machine systems, computers, robotics, automation and new processes, that did not exist previously.

Major Technical Changes.

Table No: 6.10 is a summary of major technical changes as reported in the survey. This shows that out of a total of 335 major changes, 260 or 77 percent were made by firms already using CMM equipment and 75 or 23 percent by firms not using CMM equipment. The number of firms in the user and non-user groups were divided into the changes made to show that on average, all firms made 2.6 major technical changes over 2 years (1.3 per annum), users of CMM made 3.4 changes over the 2 years (or 1.7 per annum), while the non-user firms made only 1.4 changes per firm over 2 years (or 0.7 per annum).

TABLE No; 6.10

SUMMARY OF MAJOR TECHNICAL CHANGES

	User:			Non-User:			Total:	
	%		%	%		%	%	
1. Computer Based	48	126	(75)	56	42	(25)	50	168
2. Process Based	14	34	(72)	17	13	(28)	14	47
3. Technical Systems	6	16	(55)	17	13	(45)	8	29
4. Inspection Measurement	32	84	(92)	9	7	(8)	27	91
TOTAL CHANGES:	100	260		100	75		100	335
	(77%)			(23%)			(100%)	
Average Major Change per Firm	3.4			1.4			2.6	

Classification of major technical changes.

All of the major technical changes reported were classified into 4 broad groups to best describe the change. These groups were titled computer, process, technical or inspection based technical changes. Table No: 6.10 shows that 168 of the major changes were in effect computer based, this was 50 percent of all the changes reported. The next highest group of changes were related to inspection measurement where 91 changes were reported or 27 percent of the overall total.

Comparison between firms using and not using CMM technology.

Table No: 6.11 provides a detail analysis of all the major technical changes reported and separates them into 4 groups, which have been further broken down to show the type of changes within each group. The differences between the user and non-user firms are evident at 4 points namely,

NC/CNC user firms are 3 times more active.
Transfer/robotics user firms are 8 times more active.
Co-ordinate measuring user firms are 68 times more active.
Automation non-user firms are 2 times more active.

One other interesting aspect from Table No: 6.11 is the number of firms in both the user and non-user groups who reported no major technical changes over the last 2-year period. This represents 33 percent of the total survey, 51 percent for all non-user firms and 16 percent of all user firms.

Overall points of significance.

- Many manufacturing firms in Britain are by and large investing in some major technical change at the rate of 1.3 changes per annum.

- Over 50 percent of these changes have some relationship to a computer or numerical control system.

- Firms already using CMM equipment are much more active in making major technical changes than those firms not using CMM equipment, the only exception to this is with automation where non user firms are twice as active as user firms.

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TABLE No: 6.11

DETAIL OF MAJOR TECHNICAL CHANGES

Technical Change:	User Firms:	Non-User Firms:	Total All Firms:
1. Computer Based.			
Machining Centres	18	4	22
*NC/CNC	98	31	129
DRO	3	5	8
CAD/CAM	7	2	9
2. Process Based.			
Welding	2	2	4
Soldering	2	4	6
Heat Treat	0	1	1
Spark Erosion	2	0	2
New conventional m/c tools	9	2	11
New assembly systems	1	2	3
Transfer systems/robotics	16	2	18
Material Handling	2	0	2
3. Technical Systems			
Automation	5	10	15
Group Technology	2	1	3
Data Collection	8	2	10
Adaptive Control	1	0	1
4. Inspection Measurement.			
Testing/Gauging	16	7	23
Co-ordinate Measuring	68	0	68
TOTAL Changes	260	75	335
Total firms reporting	101	123	224
No. firms not doing anything	25	70	95
Balance with technical changes	76	53	129
Average major changes per firm	3.4	1.4	2.6

* N.C. Numerical Control Machine Tools
CNC Computer Controlled Numerical Control Machine Tools
DRO Digital Readout Systems
CAD Computer Aided Design
CAM Computer Aided Manufacture.

- Over a third of all the firms in the total survey have not made any major technical changes over the last 2-year period.

6.12 - EFFECTS ON PRODUCTION SYSTEMS FROM MAJOR TECHNICAL CHANGES.

Having established in the last section that each firm in the survey who reported having made a major technical change were on average making changes at the rate of 1.3 per annum per firm, how did these changes affect the nature of the existing production system?

Table No: 6.12 shows a summary of the effects reported by firms in the survey. In total 203 effects were noted in a total of 77 firms or 1.16 effects per firm. These effects were broken down into 5 categories as follows:-

- Effects on people.
- Effects on the performance of the firm.
- Effects on the control systems.
- Effects on the technology.
- No effects observed.

While it is noted that 39 percent of the firms reported no effects, the balance of 61 percent indicated that 77 firms had been affected with the introduction of the previously described major technical changes. Table No: 6.12 further shows that user firms had 123 effects or 60 percent and non-user firms 80 effects or 40 percent of the total. This represented on average 1.05 effects per firm for user firms and 1.4 effects per firm for the non-user firms. (There were fewer affected firms in the non-user group therefore the ratio per firm is higher). User firms appear to be more affected with systems control and people than non-user firms but there are only marginal differences with performance and technology systems.

Table No: 6.13 shows the details of effects on the production systems and indicates the effects on each of the 4 categories discounting the fifth category of no effect. Effects on people, show that user firms have introduced double shifting and reduced labour. Differences in performance show that more non-user firms have observed

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TABLE No: 6.12

EFFECT ON THE PRODUCTION SYSTEM

Effect	User %		%	Non-User %		%	TOTAL %	
1 Effect on People	8	10	(71)	5	4	(29)	(7)	14
2 System Performance	22	28	(53)	30	24	(47)	(25)	52
3 System Control	13	16	(66)	10	8	(33)	(12)	24
4 System Technology	15	19	(55)	18	15	(45)	(16)	34
5 No Effect	41	50	(63)	36	29	(37)	(39)	79
Total Effects:	100%	123	(60)	100%	80	(40)		203

	User	Non-User	TOTAL
A. Total Firms	152	137	289
B. Firms No Technical Changes	27	74	101
C. Total Firms with Changes	125	63	188
D. Firms with technical changes but no effects	48	29	77
E. Effected Firms	77	34	111
Average effects per firm:	1.05	1.4	1.16.

TABLE No: 6.13

DETAIL OF EFFECT ON THE PRODUCTION SYSTEMS

Effect:	User:	Non-User:	Total:
1. **Effect on People**			
Reduce Labour	5	2	7
Operator Skill Reduced	2	2	4
Double Shifting	3	0	3
TOTAL:	10	4	14
2. **System Performance**			
Increase Output	12	10	22
Improve Quality	4	7	11
Reduce Costs	3	2	5
Increase Capacity	5	2	7
Increase Versatility	1	1	2
Increase Batch Size	3	2	5
TOTAL:	28	24	52
3. **System Control**			
Added Planners	4	1	5
Data Collection	7	3	10
Change Inspection Procedures	5	4	9
TOTAL:	16	8	24
4. **System Technology**			
Improve Material Handling	1	1	2
Change Plant Layout	0	1	1
Instal Group Technology	4	3	7
Add Transfer Systems	4	3	7
Automate	8	2	10
Change or/add process	2	5	7
TOTAL:	19	15	34
5. No Change or Effect (despite Major Technical Changes)	50	29	79
TOTAL:	123	80	203

improvements in quality than user firms. Control systems indicate that more white collar planners have been added to user firms and data collection systems have been increased. With the fourth category of technology, user firms appear to have automated to a higher degree than non-user firms. User firms report more no change or no effects than non-user firms. The 12th American Machinist Inventory of Metalworking Equipment 1976-78 (ref: 58) shows a dramatic growth of N. C., equipment over the last 15 years, the total number of N. C., machines has doubled in America over the last 5 years alone with multifunction machines (machining centers) increasing by 37 percent and the number of way-type and transfer machines has increased by 26 percent. There is a definite drop in total machine tools, in fact the number of machine tools installed in the last 5 years is half that of the previous 5 years, in that there are fewer machines but greater output. A similar pattern is shown with British manufacturing industry as reported in Metalworking Production's Fourth Survey of Machine Tools published in 1977. (ref. 59). They report a flattening off with the growth of machine tools in total but an increasing percentage of N. C., machine tools. In 1971 N. C., machines represented 0. 65 percent of all metalcutting machine tools, in 1976 the proportion had increased to 1. 32 percent. These results from America and Britain correlate with this research for major changes in technical items especially related to computer based changes. The difference reflected in this research shows that although many firms are pushing on with metalcutting and metalforming technology, almost 48 percent of all the firms in this research are not supporting their front line technology with new fringe technology such as advanced measuring equipment.

Remarkably there is a very small percentage of firms reporting any changes in their production system as related to people. One would consider with a reduction on total machine tools, an increase in machining centers with subsequent higher output, then fewer people would be required, yet only 7 firms reported a labour reduction, indeed only 4 firms reported a skill reduction which tends to raise more questions on how firms are implementing these changes.

6.13 - PROBLEMS CONCERNING THE DISPOSITION OF EMPLOYEES WHO ARE OR WILL BE DISPLACED BY AUTOMATION.

One of the most difficult problems which faces firms who are moving from labour intensive to capital intensive environments within their organisations, must be the question on what to do with displaced employees. The survey questionnaire posed the following question -

- o How would you plan to take care of your people as you move more towards more automation and less labour intensive equipment? (see Appendix T, question 21).

6 multi choice responses were given for each possible alternative or alternatives if more than one plan was available, these choices were -

- o By normal wastage.
- o By re-training to other remaining skills.
- o By a phased redundancy policy.
- o No particular plan - let it happen.
- o Shorter working week.
- o Other.

Results of the survey - by business activity.

Tables Nos: 6.14 and 6.15 show the details of both user and non-user firms by business activity for the 6 alternatives recalling that some firms responded to more than one choice. The results from the users indicate a preference in their plans for 2 major avenues; first a policy of re-training followed by a second alternative of normal wastage. The firms in business activities strongest for both of these plans were tractor/trucks, electronic and aircraft. The third largest response came from other, meaning an alternative not listed such as increasing output or productivity so that the displaced personnel maybe absorbed into this higher throughput activity. Only a very small number of firms responded to the other alternatives such as phased redundancy, no plan or shorter week, although it is evident from reported cases that many firms practice one of these 3

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Table No: 6.14

AUTOMATION AND PEOPLE BY BUSINESS ACTIVITY
USERS OF ADVANCED MEASURING TECHNOLOGY.

Business Activity:	Normal Wastage		Re-Training		Phased Redundancy		No Plan		Shorter Week:		Other		Total	
	No.	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes		%
Defence	5	3	4	4	8	0	7	1	8	0	7	1	8	5.3
Aircraft	2	11	3	10	13	0	13	0	12	1	13	0	13	8.7
Tools	2	2	3	1	4	0	3	1	4	0	4	0	4	2.7
Machining	2	3	1	4	4	1	5	0	5	0	5	0	5	3.3
Engines	8	3	3	8	11	0	10	1	11	0	10	1	11	7.3
Pumps	5	3	2	6	8	0	7	1	8	0	7	1	8	5.3
Tractors	6	13	6	13	18	1	18	1	18	1	19	0	19	12.7
Food Proc.	3	1	2	2	4	0	4	0	3	1	4	0	4	2.7
Telecom.	1	3	1	3	4	0	4	0	4	0	3	1	4	2.7
Electron	8	9	5	12	17	0	15	2	17	0	15	2	17	11.3
M/c Tools	3	6	3	6	8	1	9	0	9	0	9	0	9	6.0
Controls	0	5	2	3	5	0	5	0	5	0	5	0	5	3.3
Castings	1	3	2	2	2	2	4	0	4	0	4	0	4	2.7
Motor	3	7	3	7	9	1	10	0	10	0	9	1	10	6.7
Misc.	7	4	3	8	11	0	10	1	11	0	10	1	11	7.3
R & D	1	2	3	0	3	0	1	2	3	0	2	1	3	2.0
Plastics	2	1	1	2	3	0	3	0	3	0	3	0	3	2.0
M & H	0	3	1	2	3	0	3	0	3	0	3	0	3	2.0
Instrum.	5	2	3	4	7	0	6	1	7	0	4	3	7	4.7
Dom.Prod.	0	2	0	2	2	0	2	0	2	0	2	0	2	1.3
TOTAL:	64	86	51	99	144	6	139	11	147	3	138	12	150	100
Percentage	42	58	34	66	96	4	93	7	98	2	92	8		

Table No: 6.15

AUTOMATION AND PEOPLE BY BUSINESS ACTIVITY
NON-USERS OF ADVANCED MEASURING TECHNOLOGY

Business Activity:	Normal Wastage		Re-Training		Phased Redundancy		No Plan		Shorter Week		Other		Total	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes		%
Defence	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aircraft	1	1	1	1	2	0	2	0	2	0	1	1	2	1.5
Tools	3	2	1	4	5	0	5	0	5	0	4	1	5	3.7
Machining	12	7	11	8	19	0	18	1	19	0	16	3	19	19.1
Engines	2	1	2	1	3	0	3	0	3	0	2	1	3	2.2
Pumps	2	2	2	2	4	0	4	0	4	0	3	1	4	3.0
Tractors	5	3	1	7	3	0	7	1	8	0	8	0	8	5.9
Food Proc.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telecom.	2	1	2	1	2	1	2	1	3	0	3	0	3	2.2
Electron.	5	11	9	7	16	0	15	1	16	0	13	3	16	11.9
M/c Tools	5	6	3	8	9	2	11	0	11	0	9	2	11	8.1
Controls	3	1	2	2	4	0	4	0	4	0	3	1	4	3.0
Castings	2	5	6	1	6	1	6	1	6	1	7	0	7	5.2
Motor	3	1	1	3	4	0	4	0	4	0	4	0	4	3.0
Misc.	11	14	12	13	22	3	22	3	25	0	23	2	25	18.5
R & D	5	1	6	0	6	0	5	1	6	0	2	4	6	4.4
Plastics	1	2	2	1	3	0	3	0	3	0	3	0	3	2.2
M & H	3	3	2	4	5	1	6	0	6	0	5	1	6	4.4
Instrum.	5	3	3	5	8	0	7	1	8	0	7	1	8	5.9
Dom. Prod.	0	1	0	1	1	0	1	0	1	0	1	0	1	0.7
TOTAL	70	65	66	69	127	8	125	10	134	1	114	21	135	100
Percentage	52	48	49	51	94	6	93	7	99	1	84	16		

measures in the shorter term but may not necessarily plan for these approaches. The non-user firms indicated in Table No: 6.15 a similar approach to the user firms with the largest percentage of their responses going for re-training and normal wastage. Some response was given to other and shown to represent a body of thinking for increasing output, gaining more sales and thus absorbing the manpower so displaced by automation. The business activities of firms in the non-user group with the highest responses for the 2 above alternatives were again those in miscellaneous, electronics and machining.

The results of the survey - by employee size.

With the overall total percentages being identical to those shown and discussed in the tables for business activities, it remains only necessary to review and discuss the detail, of which employee size group is strongest for each given alternative. The highest number of firms in the user group of firms in Table No: 6.16 for re-training as an alternative was in the 5,000 plus size, followed closely by firms in the 500 to 999 and 1,000 to 1,999 employee size. The largest number of firms for a normal wastage approach was in the 1,000 to 1,999 employee size group. The earlier discussion on the other alternative was shown to be most popular with firms at 100 to 499 and 500 to 999 employee size groups, that is, these firms considered going out for more sales to increase workload as the best alternative. Table No: 6.17 provides the same data for non-user firms and shows these firms were very evenly divided in their plans or lack of plans for automation. Only at 1,000 to 1,999 employee size group was there any significance for a policy of normal wastage, although most firms chose normal wastage and/or re-training as the most acceptable alternatives. The firms who chose other as an alternative, such as increasing output, were all in the smallest size of firms in the survey from 10 up to 500 employees.

The major significance from these results is that firms in general seek and plan for the most acceptable alternatives for disposition of

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Table No: 6.16

AUTOMATION AND PEOPLE BY EMPLOYEE SIZE
USERS OF ADVANCED MEASURING TECHNOLOGY.

Employee Size:	Normal Wastage		Re-Training		Phased Redundancy		No Plan		Shorter Week		Other		Total	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes		%
10- 49	0	1	1	0	1	0	0	1	1	0	1	0	1	0.7
50- 99	4	1	2	3	5	0	3	2	5	0	4	1	5	3.6
100- 499	16	16	15	17	31	1	30	2	31	1	27	5	32	23.2
500- 999	9	14	6	17	22	1	22	1	25	0	20	3	23	16.7
1000- 1999	7	16	6	17	23	0	22	1	23	0	22	1	23	16.7
2000- 4999	15	19	12	22	32	2	32	2	32	2	33	1	34	24.6
5000-80000	8	12	3	17	19	1	19	1	20	0	19	1	20	14.5
TOTAL:	59	79	45	93	133	5	128	10	135	3	126	12	138	100
Percentage:	42	58	33	67	96	4	92	8	98	2	91	9		

Table No: 6.17

AUTOMATION AND PEOPLE BY EMPLOYEE SIZE
NON-USERS OF ADVANCED MEASURING TECHNOLOGY

Employee Size:	Normal Wastage		Re-Training		Phased Redundancy		No Plan		Shorter Week		Other		Total	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes		%
10- 49	10	2	8	4	12	0	12	0	12	0	6	6	12	9.2
50- 99	8	8	7	9	16	0	16	0	16	0	12	4	16	12.3
100- 499	36	32	32	36	65	3	64	4	67	1	60	8	68	52.0
500- 999	3	7	7	8	13	2	11	4	15	0	14	1	15	11.0
1000- 1999	3	10	6	7	11	2	12	1	13	0	13	0	13	10.0
2000- 4999	2	2	2	2	4	0	3	1	4	0	4	0	4	3.0
5000-80000	1	1	0	2	1	1	2	0	2	0	2	0	2	1.5
TOTAL	68	82	62	68	122	8	120	10	129	1	111	19	130	100.0%
Percentage	52	48	48	52	94	6	92	8	99	1	85	15		

people due to automation. Acceptable in terms of better control by the firm and acceptable to the employees at large, displaced by the automation. Except in some extreme cases, automation has an evolutionary effect on firms' employee size and generally phases in slowly enough to permit minimum disruption among the labour force. One recent extreme case was the introduction of a very large computer controlled glass cutting machine by Pilkington Brothers in England, the result of this new innovation was the displacement of 400 employees. Pilkington declared a phased redundancy approach but the local and national trade union representatives wanted a shorter working week. The case continues unresolved but it does indicate that the impact or problem of automation can in the short term force alternatives which both employers and employees find unacceptable.

It appears reasonable to assume that firms do not want to lose their skilled employees and would, if possible, seek re-training as the best solution, but this approach may have to be accelerated with a normal wastage plan which is assisted by early retirements and permanent leave for the medically unfit. In all instances, co-operation and a degree of flexibility is required of employees and trade unions if the exercise is to succeed.

6.14 - RESISTANCE TO AUTOMATION AND ADVANCED TECHNOLOGIES SUCH AS COMPUTER-ASSISTED MEASURING MACHINES.

Prior research reported in the literature suggests that employees will resist changes to their work assignments as a result of automation and other advanced technologies. In order to test this suggestion, firms in the survey were asked the following question -

- It has been suggested that automation and advanced technology of any kind will be resisted for various reasons, some of which are as follows - has this been your experience with inspection equipment in particular? (see Appendix T, question No: 23).

Each respondent was requested to answer yes, no or perhaps to the following 9 reasons. (The various reasons have been shortened here in the text, but are shown in full in the abovementioned Appendix).

- Status and prerogative.
- Existing ways.
- Skills, experience and knowledge.
- Security of employment.
- Avoid scraping assets.
- Avoid altering other systems.
- Fear of change.
- Conflict with organised groups.
- Increases mystique.

Results of Survey - by business activity.

Table No: 6.18 shows the data collected from 147 user firms in the survey. Reviewing the total results, it indicates that fear of change, job security and skills knowledge were the top 3 reasons given for resisting the automation, with 43, 40 and 35 percent of the combined yes and perhaps responses given to these reasons. The 2 most prominent business activities for the reason of fear of change were tractor/trucks and motor, but no significance can be attached to this particular result as most firms would almost naturally indicate a degree of fear of change. It was interesting to observe that the reason for least concern was given to possible conflict with

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Table No: 6.18

RESISTANCE TO AUTOMATION AND ADVANCED TECHNOLOGY
USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY

Y = Yes
P = Perhaps
N = No

Business Activity	Current Status Y.	P.	N.	Existing Ways Y.	P.	N.	Skills know-how Y.	P.	N.	Job Security Y.	P.	N.	Scrap Assets Y.	P.	N.	Change Syst'm Y.	P.	N.	Fear of Change Y.	P.	N.	Conflict Y.	P.	N.	Too Scientific Y.	P.	N.	Total:	%.
Defence	4	0	3	2	2	3	1	3	3	0	5	2	2	0	4	0	2	4	2	3	2	1	2	4	1	3	2	7	4.8
Aircraft	1	1	10	1	2	9	1	3	8	1	4	7	0	5	7	1	4	7	2	2	8	0	1	11	0	3	9	12	8.2
Tools	0	0	4	0	1	3	0	1	3	0	0	4	0	0	4	0	0	4	0	1	3	0	0	4	0	1	3	4	2.7
Machining	1	0	4	1	0	4	1	1	3	0	1	4	0	1	4	0	1	4	1	2	2	0	0	5	0	2	3	5	3.4
Engines	5	3	3	6	3	2	2	6	3	4	4	3	3	3	5	2	6	3	4	1	6	1	5	5	2	2	7	11	7.5
Pumps	0	0	8	0	1	7	1	0	7	0	1	7	0	0	8	0	1	7	0	1	7	0	0	8	1	0	7	8	5.4
Tractors	8	3	8	6	4	9	3	4	12	4	6	9	6	4	9	6	4	9	9	1	9	4	5	10	4	7	8	19	13.0
Food Proc	0	0	3	0	1	2	0	2	1	0	1	2	0	1	2	0	2	1	0	3	0	0	2	1	0	1	2	4	2.7
Telecom	1	0	3	1	0	3	0	0	4	1	0	3	0	0	4	0	0	4	0	2	2	0	1	3	0	0	4	4	2.7
Electron	0	2	15	0	4	13	0	3	13	0	5	12	2	1	14	1	2	14	1	2	14	0	2	15	0	4	13	17	11.6
M/c tools	0	1	8	0	1	8	0	1	8	0	2	7	0	1	8	2	1	6	1	1	7	0	2	7	1	0	8	9	6.1
Controls	0	1	4	0	1	4	1	1	3	2	0	3	0	1	4	0	0	5	0	2	3	0	1	4	0	0	5	5	3.4
Castings	0	2	2	0	1	3	0	1	3	0	2	2	0	2	2	0	1	3	1	2	1	0	2	2	0	2	2	4	2.7
Motor	3	0	7	0	4	6	1	3	6	4	3	3	0	1	9	0	4	6	1	6	3	1	1	8	0	4	6	10	6.8
Misc.	1	1	8	2	2	6	1	2	7	2	2	6	1	2	7	3	0	7	4	1	5	1	2	7	2	0	7	10	6.8
R & D	0	0	3	0	1	2	0	2	1	1	0	2	1	0	2	0	1	2	1	1	1	1	0	2	0	0	2	3	2.0
Plastics	0	1	2	1	0	2	0	2	1	1	0	2	0	1	2	1	0	2	1	0	2	0	1	2	1	0	2	3	2.0
M & H	1	1	1	2	0	1	1	0	2	1	0	2	1	0	2	1	1	1	1	1	1	2	0	1	1	1	1	3	2.0
Instrum.	1	0	6	0	1	6	1	0	6	1	0	6	0	3	4	0	1	6	1	1	5	0	1	6	0	0	7	7	4.8
Dom.Prod	0	0	2	0	0	2	0	2	0	0	1	1	0	0	2	0	0	2	0	1	1	0	1	1	0	0	2	2	1.4
TOTAL:	26	16	104	22	29	95	14	38	94	22	37	87	16	26	103	17	31	97	30	34	82	11	29	106	13	20	100	147	
Percent:	18	11	70	15	20	65	10	26	64	15	25	60	11	18	71	12	21	66	20	23	56	8	20	72	9	20	68		100%

organised bodies, such as trade unions. This maybe as a result of the respondents' own attitudes to trade unions from a managerial aspect or alternatively as a recognition by the trade unions that automation and advanced technologies are an inevitable part of technological progress without which manufacturing industry cannot survive on a competitive basis with other countries. Table No: 6.19 shows the data as collected from 104 non-user firms in the survey. In this instance the top 3 reasons were given as fear or change, avoid altering other systems in harmony with inspection, and skills/knowledge. The reason giving least concern was status and prerogative. The business activities of the non-user group who were strongest in their response to fear of change were miscellaneous and machining; again no major significance is drawn from this as the number of firms in this category were fairly evenly spread and these 2 top activities also had a high percentage of the total population of all firms.

Results of the survey - by employee size.

Table No: 6.20 shows the data collected from 137 user firms arranged by 7 employee size groupings. This time the top 3 reasons given for resistance were job security, skills/knowledge and existing ways at 39, 34 and 32 percent of the combined results for yes and perhaps in each variable. The least concern was given equally to conflict with organised bodies and status/prerogative. The leading employee size groupings for job security as being the number one reason to resist was given by firms of 2,000 to 4,999 and 5,000 plus employee size groupings, that is the largest size of firms. Table No: 6.21 gave the results for 102 non-user firms by employee size groupings, this time the top 3 reasons were given as fear of change, avoid the need to change other systems, and skills/knowledge which was exactly the same order for the same data as shown by business activity. Once again the reason given of least concern was conflict with organised bodies. The strongest employee size grouping responding to these above reasons were all in the 100 to 499

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Table No:6.19

RESISTANCE TO AUTOMATION AND ADVANCED TECHNOLOGY
NON USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY

Y = Yes
P = Perhaps
N = No

Business Activity:	Current Status Y.	P.	N.	Existing Ways Y.	P.	N.	Skills know-how Y.	P.	N.	Job Security Y.	P.	N.	Scrap Assets Y.	P.	N.	Change Syst'm Y.	P.	N.	Fear of Change Y.	P.	N.	Conflict Y.	P.	N.	Too Scientific Y.	P.	N.	Total:	%.
Defence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Aircraft	0	1	1	1	1	0	1	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0	1	1	1.0
Tools	0	0	5	0	2	3	1	2	2	1	2	2	0	1	3	0	3	2	2	1	2	0	2	3	1	1	3	5	4.8
Machining	1	0	14	1	0	14	0	3	12	1	2	12	1	1	13	1	2	11	2	3	10	0	0	14	1	3	10	14	13.5
Engines	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	1	0	1	0	0	2	0	0	2	0	1	1	2	1.9
Pumps	0	1	2	0	0	3	0	0	2	0	1	2	1	0	2	0	1	2	0	1	2	0	1	2	0	1	2	3	2.9
Tractors	2	3	3	2	3	3	1	4	3	1	1	6	3	2	3	4	0	4	3	1	3	1	1	6	1	4	3	8	7.7
Food Proc.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Telecom.	1	0	1	0	2	0	2	0	0	1	1	0	0	1	1	0	1	1	0	1	1	0	0	2	0	2	0	2	1.9
Electron.	0	2	11	2	0	11	1	1	11	0	4	9	0	2	10	1	4	8	0	3	10	0	1	11	0	1	11	12	11.5
M/c tools	0	1	9	0	1	9	0	1	9	0	1	9	2	0	8	1	1	8	0	2	8	0	0	10	0	2	8	10	9.6
Controls	0	1	3	0	0	4	0	2	2	1	0	3	0	0	4	1	0	3	0	1	3	1	1	2	0	0	4	4	3.8
Castings	0	0	3	0	0	3	0	2	1	0	1	2	1	1	1	1	1	1	1	2	1	2	0	1	1	1	1	3	2.9
Motor	2	0	0	2	0	0	2	0	0	0	2	0	1	1	0	3	0	0	0	2	1	1	0	1	0	2	1	3	2.9
Misc.	1	5	15	4	8	9	5	3	8	4	5	11	2	2	17	6	3	12	5	8	9	1	6	13	0	7	13	20	19.2
R & D.	0	1	2	0	1	2	1	1	1	0	1	2	0	2	1	0	1	1	2	0	1	0	1	2	0	2	1	3	2.9
Plastics	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	2	1.9
M & H	0	0	5	0	1	4	0	0	4	0	0	4	1	1	4	2	1	3	0	1	3	0	1	3	0	1	3	4	3.8
Instrum	1	0	6	1	0	6	1	1	5	2	1	4	0	1	6	1	1	5	2	1	4	0	1	6	0	1	6	7	6.7
Dom. Prod	0	0	1	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	1	1.0
TOTAL:	8	15	85	13	19	76	15	26	65	11	23	71	12	16	78	22	20	65	18	27	63	6	16	81	4	29	71	104	
Percent:	7.4	13.9	78	12	18	79	15	25	61	10	22	68	11	15	74	21	19	60	16	25	58	5.8	15	78.6	3	28	68		100%

Table No: 6.20

RESISTANCE TO AUTOMATION AND ADVANCED TECHNOLOGY
USERS OF ADVANCED MEASURING TECHNOLOGY BY EMPLOYEE SIZE

Employee Size:	Current Status			Existing Ways			Skills know-how			Job Security			Scrap Assets			Change Syst'm			Fear of Change			Conflict			Too Scientific			Total:	%.
	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.		
10- 49	0	0	1	0	0	1	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	1	0	0	1	0	0	1	0.7
50- 99	1	0	4	0	0	5	1	0	4	1	0	4	0	1	4	0	1	4	1	0	4	0	1	4	0	0	5	5	3.6
100- 499	2	1	29	3	10	19	2	12	18	1	6	25	1	6	25	3	6	24	2	8	22	0	5	27	3	6	23	32	23.4
500- 999	2	3	18	0	4	19	1	4	18	1	7	15	1	3	19	0	5	18	1	7	15	0	4	19	1	4	18	23	16.8
1000- 1999	5	3	14	4	3	15	4	4	14	6	5	11	1	8	13	3	3	16	4	6	12	2	4	16	0	3	19	23	16.8
2000- 4999	7	6	21	8	5	21	3	9	22	6	8	20	6	1	26	6	6	21	10	7	17	3	9	22	3	9	20	34	24.8
5000-80000	4	3	12	4	3	12	0	6	13	2	10	7	3	5	11	3	5	11	6	4	9	3	4	12	4	4	11	19	13.9
TOTAL:	21	16	99	19	25	92	11	36	89	18	36	82	13	24	98	15	27	93	25	32	79	9	27	100	11	26	96	137	
Percent:	15	12	73	14	18	68	8	26	65	13	26	60	10	18	72	11	20	68	18	23	58	7	20	73	10	20	70		100%

Y = Yes
P = Perhaps
N = No

Table No: 6.21

RESISTANCE TO AUTOMATION AND ADVANCED TECHNOLOGY
NON-USERS OF ADVANCED MEASURING TECHNOLOGY BY EMPLOYEE SIZE

Business Size:	Current Status			Existing Ways			Skills know-how			Job Security			Scrap Assets			Change Syst'm			Fear of Change			Conflict			Too Scientific			Total:	%
	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.	Y.	P.	N.		
10- 49	0	1	10	2	1	8	1	2	8	0	1	10	1	3	8	0	1	9	3	0	8	1	1	9	1	1	9	11	10.8
50- 99	2	1	12	2	1	12	0	6	7	0	4	10	2	0	12	2	1	11	3	2	10	0	1	12	1	3	9	13	12.7
100- 499	3	8	42	3	11	37	10	10	33	9	10	32	5	6	39	12	14	27	11	16	26	3	8	39	1	16	34	51	50.0
500- 999	0	2	10	1	2	9	1	3	8	1	2	9	1	2	9	3	1	8	1	2	9	1	2	9	0	4	8	12	11.8
1000- 1999	2	3	5	2	3	5	2	3	5	1	3	6	3	1	6	3	1	6	0	4	6	0	2	8	0	2	8	10	9.8
2000- 4999	0	0	4	0	1	3	0	1	3	0	1	3	0	1	3	0	1	3	0	1	3	0	1	3	0	2	2	4	3.9
5000-80000	1	0	0	1	0	0	1	0	0	0	1	0	0	2	0	2	0	0	0	1	0	1	0	0	0	1	0	1	1.0
TOTAL;	8	15	83	13	19	74	15	25	64	11	22	70	12	15	77	22	19	64	18	26	62	6	15	80	3	29	70	102	
Percent:	7.5	14	78	12	18	70	15	24	62	11	22	68	12	15	74	21	18	61	17	25	59	6	15	80	3	28	69		100%

Y = Yes
P = Perhaps
N = No

group but this group had the highest population among all the non-user firms and results are heavily weighted in this direction.

Summary of Findings.

Top 3 reasons given by each category.

Business activity - user:	Fear of change, job security, skills/knowledge.
Business activity - non user:	Fear of change, avoid change other systems, skills/knowledge.
Employee size - user:	Job security, skills/knowledge, existing ways.
Employee size - non user:	Fear of change, avoid change other systems, skills/knowledge.

Least concern reason for each category.

Business activity - user:	Conflict with organised groups.
Business activity - non user:	Status and prerogative.
Employee size - user:	Conflict and status.
Employee size - non user:	Conflict with organised groups.

The most common reason variable given by all categories is a resistance due to the need to protect handskills, experience and knowledge, the second most common reason for resistance is a general fear of change. This result is of high importance to this research as it suggests that 287 firms are experiencing some degree of resistance to the introduction of new technologies mainly due to their employees' need to protect their developed handskills in tasks which are becoming obsolete. An experience acquired over years of working life and a knowledge which may become superfluous in time. General fear of change is a common psychological defence and is of no particular significance to this research finding.

It is of interest to observe that the least reason for resistance is given to the need to avoid conflict with organised groups. This again is important because it sums up an attitude of a large number of firms which would be a sample of the overall population of manufacturing industry.

6.15 - OBSERVED EFFECTS OF NEW TECHNOLOGY ON A LARGE NUMBER OF FIRMS IN BRITAIN AND AMERICA.

The objective of chapter 6 was to develop additional information and further understanding of advances in new technology in manufacturing industry. To achieve this a large field survey was made of manufacturing firms located in Britain and America. The survey vehicle used in this field study was a written questionnaire, a copy of which is given in Appendix T. The total of 287 firms responded positively to the field survey and the results were analysed by a computer programme and sorted under the 6 key factors of the enterprise namely, organisation structure, management, strategies, machine shop environment, control systems and people. These factors are discussed as follows:-

Organisation Structure.

It is evident that there are marked differences between firms using new measuring machine technologies and those firms not using these technologies. These differences are related to division of labour. It was apparent that non user firms had a greater number of position titles per firm than the user firms and that there were distinct differences between the names given to these position titles between the 2 subject groups. It was also noted that non user firms had more first line supervisors than user firms. It is implied from this evidence that firms introducing new measuring machine technology either had these types of divisions existing in their labour or made changes in their structures due to the impact of the new technologies. The data previously discussed in the single manufacturing plant, see chapters 3 and 4, together with the evidence from the multinational plants' study, see chapter 5, would support the contention that the firms have changed as a result of the new technology. Other observations were made on the organisation and division of labour not necessarily related to new technology, these observations will be discussed later in chapter 8.

On the question of hierarchical levels, it was observed that firms with new measuring machine technology had taller pyramids, that is more levels of management than the firms not using new measuring machine technology. It was also observed that user firms had smaller spans of control as employee size of firm increased. By contrast it was noted that at the lowest level of the structure, there were more sections in user firms than non-user firms, that is although the span of control at the top level and the middle of the pyramid was smaller for user firms compared to non-user firms, the new technology tended to find its expression at the first line level by horizontal differentiation. It was noted that business activities with wide diversification of product were larger in non-user firms than in user firms, examples of this were in tools, machine tools, telecommunications and domestic products. In all other business activities the user firms had larger organisation structures.

Management.

It was observed that non user firms tended to have more managerial and senior administrative staff than user firms. Equally these non user firms had larger weekly paid staff positions. The implications from these 2 above observations are that user firms gain advantages in less staff due to the greater efficiencies derived from measuring machine technologies. It was noted that weekly payroll staff did not decrease as a ratio to hourly paid blue collar as the firm increased in employee size, except in the case of firms using new measuring machine technology, where it was noted that there was a faster decrease in weekly payroll support.

Strategies.

It was observed that specific business activities using new measuring machine technologies are spending more on their annual inspection budgets supporting their capital investment on the new measuring machine technologies. Equally certain business activities not using new measuring machines are also investing heavily on annual inspection expense budgets. It is implied from this that the former user

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group recognise a need to maximise on their investment while the latter non user group have to make the budget expenditure in order to maintain standards of quality through manual inspection systems. A further observation on strategy was that multi-plant firms tended to have smaller inspection manpowers as related to single entity firms, indicating a pooling of services to minimise duplication of labour and unnecessary costs.

Machine Shop Environment.

The majority of firms in the survey in both user and non user groups were found to have small or large batch type production systems. It was also observed that the majority of firms had more than one type of system indicating diversification of product. There was no particular significance drawn from the production system and the type of technology used. It was noted that user firms were much more active than non user firms on the whole question of making major technical changes such as introducing numerical controlled machine tools. The effect of these technical changes on the production systems of the user firms was greater than the non-user firms, in that there were more changes in people, improvements in performance and systems of control with the user firms. Effects on the system of technology such as changing plant layout, installing group technology was about equal for user and non user firms.

Control Systems.

The evidence from the field survey would suggest that firms using new measuring machines had installed more data processing systems and added more planning staff than the non user firms.

People.

In the event of having to displace people due to the introduction of automation or similar labour saving technologies, it was shown that both user and non user firms would prefer a policy of re-training to other skills or using normal wastage such as retirement and attrition. It was observed that the largest size of firms preferred a /...

re-training policy while the smallest size firms tended to seek other alternatives such as increasing output, seeking more sales and larger markets, than attempting to reduce their labour force.

On the subject of resistance to change, it was observed that user firms found that people were inclined to resist technological change for 3 major reasons namely, general fear of change, job security and to protect their current skills and knowledge, while the non user firms listed general fear of change, avoiding the need to change other systems, and to protect acquired skills and knowledge. There is therefore no great difference between firms using and not using new measuring machine technologies on the subject of what reasons are given for resisting new technology, it is however of some significance to discover the above denoted reasons as given by a large number of manufacturing firms in industry.

It was noted earlier in the question concerning major technical changes that firms using new technology were much more active than non user firms in the reduction of people, increasing of shift working and increasing of white collar planner support groups. It was observed in this study that on the question of manpower ratios, user firms had on average a large number of hourly paid staff than non user firms up to firm size of 2,000 employees, after which the non user firms exceed the user firms in hourly inspection numbers, implying that as firms increase in size, they have to substitute people in place of technology in order to maintain quality levels.

Table No: 6.22

OBSERVED EFFECTS OF NEW TECHNOLOGY

MULTIPLEX MANUFACTURING PLANTS - USERS OF CO-ORDINATE MEASURING MACHINES AS A COMPARISON TO NON-USERS OF CO-ORDINATE MEASURING MACHINES.

Factor	Element	Change Type:	Effect
Organisation Structure	Horizontal Pressures	C	Narrow Span
	Vertical Pressures	C	More Levels
	Direct Authority Lines	B	More Defined
	Functional -do-	C	Stronger
	Information flow lines	C	Stronger
	Work flow disciplines	C	Stronger
	Informal - Formal	D	Not Observed
Management	Support-Top Manager	A	Stronger
	Support-Middle Manager	B	Stronger
	Involvement	D	Not Observed
	Acceptance-Responsibilities	B	More Direct
	Innovators.	C	More Active
Strategies	Objectives	A	Identified & related
	Long Term Plans	B	Higher integration
	Education-Training	D	Not Observed
	Teams-Teamwork	C	More Apparent
Machine Shop Environment.	Growth	B	Higher
	Selection	D	Not Observed
	Location	C	More Emphasis
	Maintenance	C	Integrated Plan.
Control Systems	R.O.I. Contribution	B	Better Control
	Utilisation	D	Not Observed
	Efficiency	D	Not Observed
People	Employment Shifts	A	Variable to firm size
	Skills	B	Increasing
	Resistance	D	None
	Integration	C	Evolutionary
	Satisfaction	C	Moderate
	Manning	B	Better pre planning
	Status	B	Increased
	Influence	B	Increased

Change Type - A-One step Change, B-Cumulative Change.
C-Continuous Change, D-Nil or Not Observed.

CONNECTING SUMMARY.

- The analysis of organisation structure was the major objective of chapter 6. This investigation was made to ascertain any differences or similarities between firms using and firms not using co-ordinate measuring machines. The evidence from the research showed that many differences existed between user and non-user firms in terms of span of control, hierarchical levels and manpower ratios. It was also observed that position titles were different for managers in the 2 groups studied. Further analysis showed that user firms had a greater propensity to invest in all types of new technologies and were therefore subject to greater effects on the system of production.

- Chapter 7 completes this research project by a study of 150 firms using new measuring machine technology. The principal aims of this final section are to study (1) the technology, (2) how it was established, finally (3) how the new technology affected people directly associated with its use in the plants. The outcome of this research will be compared to previous findings, the implications for manufacturing industry will be highlighted and discussed in the concluding chapter.

Chapter 7 - New Measuring Machine Technology in various manufacturing industries.

7.1 - THE OBJECTIVE OF THIS CHAPTER.

The objective of chapter 7 is to analyse the findings from the large field survey of firms who are using new measuring machine technology. The specific aims of this analysis will concern the following:-

- The source and types of measuring machines in use.
- The concepts and policies on how new technology was established in these firms.
- The problems and attitudes concerned with integration of inspection with production due to technological change.
- The changes in influence and power of the craft inspector.
- The relationship between craft inspector operators and production supervisors.
- The dissatisfaction as a result of de-skilling.
- The effect of new technology on status and job interest.

Highlights of aims and findings.

Out of a total of 150 firms in the field survey using new measuring machines, it was reported that there were 330 machines. This total is analysed by firms within specific business activities and by firms within specific employee size groupings. The major manufacturers of measuring machine technology are shown by their percentage share of the firms in the survey. A detailed survey of the worldwide market of measuring machine suppliers has already been given in Appendix D. The reasons why particular measuring machine technology was selected is further analysed both on a firm to firm basis and as a comparison between American and British based firms. Finally in this first section there is a discussion on the period when measuring machines were purchased, the purpose being to establish market growth trends and to determine any correlation in time lag between knowing about the new technology, making the decision to

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acquire it, then finally installing it within the firm's premises.

The next section of this research study examines the question of how new technology started within firms. As a relater to the previous section of this chapter, when was the first year that firms knew about the new technology? Was there one particular champion for the new technology and if so, what was that person's basic discipline, that is production, engineering, quality control or other? The time lag on getting the new technology as previously discussed, will be examined in this section then finally, the degree of analysis which firms made as pre investigation on the new technology before finally making an investment decision.

The concern for integration of tasks has been discussed earlier in this study and once again the same question is posed of 150 firms using new measuring machine technology. This thesis argues that this single problem will result in much disruption in the future within manufacturing industry, much more than it has done in the past. The importance of this study is therefore deeply concerned with recognising that such problems will arise and ascertaining the attitudes of people most closely associated with these particular changes brought about by new technologies.

The next section of this chapter is concerned with interpersonal changes brought about by the introduction of new measuring machine technologies. Has the presence of a much more accurate measuring system resulted in the craft inspector operator having increased his influence of persuasion over the machine operator and others? Equally what has the new technology done to the location of authority in the work group? Has the craft inspector found a new role in his communication with production line supervisors, which places the inspector in a more powerful functional position of authority within the framework of line authority?

Following on from the above argument, what is happening to the inter-personal relationships between the craft inspector and the production line supervisor? Has this relationship improved or deteriorated with the introduction and use of new measuring machine technology? Previously in this research, investigations were made on the problems of de-skilling as a result of new technology. This was studied in the single manufacturing plant with numerical controlled machine tools and with new measuring machines. The same theme is continued in this section with an investigation into the findings of 150 firms on whether the craft inspector would become dissatisfied or not with his task or job in the event of new technology causing de-skilling of that job.

The next section of this chapter examines the question of status and job interest. These subjects have been explored previously in this research project with the result that the status of the craft inspector appeared to increase as a result of the new technology. Equally his job interest had a similar lift after his assignment to the measuring machine technology. This section now examines the response by 150 firms to the same question on whether status and job interest has been seen to increase due to the introduction of new technology. In addition in attempting to ascertain changes in status and job interest among the craft inspectors who were assigned to the new equipment, a secondary measure is made of craft inspectors who remained on conventional measuring systems, to determine if they had experienced changes in status or job interest due to their indirect relationship with the new measuring machine technology.

The final section of this chapter is concerned with integrating the overall findings of this section and discussing these under the heading of observed effects of new technology. Once again the 6 key factors of the enterprise are identified namely, organisation structure, management, strategies, machine shop environment, control systems and people.

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7.2 - THE SOURCE AND USERS OF MEASURING MACHINE TECHNOLOGY.

Chapter 2 provided a detailed description of all the known types of measuring machines manufactured on a worldwide basis. This description was further supported by a review of measuring machine manufacturers which is given in Appendix D. In this section of the research the following factors are analysed based on the findings from the survey questionnaire responded to by 150 firms using co-ordinated measuring machines (CMM).

- Percentage share of CMM sold by manufacturers to the 150 firms within business activities.
- Percentage share of CMM sold by manufacturers to 150 firms within specific employee size groups.
- Reasons given by CMM users for choice of specific measuring machine.
- Comparison of reasons for choice of CMM between British and American users.
- Comparison on the year of purchase of measuring machine by British and American users.
- Percentage share of CMM sold by manufacturers to 150 firms within 20 business activities.

The overall results of the field survey of firms using co-ordinated measuring machines (CMM) showed that out of the 150 firms who responded, a total of 330 CMMs were owned between all of these firms. (Approximately 2 machines per firm). When this data is further analysed as shown in Table No: 7.1, it shows that the market for co-ordinate measuring machines is dominated by 4 manufacturers who between them covered almost 70 percent of the sales to the 150 users. The 4 suppliers were Ferranti Limited (41%), L.K. Notsa Limited (13%), D.E.A., Italy (11.5%) Johanson, Sweden (4.5%) all other suppliers (29.7%).

With the data analysed by business activity, it shows that the following 6 business activities have 65 percent of the total users of the CMM

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equipment namely, tractors (16%), aircraft (13%), engines (12.7%), electronics (10.9%), autos (6.6%) and machine tools (5.7%). Reviewing each individual manufacturer's sales, it is noted that the following comparison reflects the percentage share by business activity against each major supplier of CMM equipment:-

TABLE No: 7.1

Ranking in Sales by Manufacture.

% Share:	B'ness Activity.	Manuf. 41 Ferranti	13 L.K.	4.5 Johanson	11.5 DEA	70% Others
16	Tractors	2	4	0	1	1
13	Aircraft	3	1	3	2	3
12.7	Engines	5	5	3	3	2
10.9	Electronics	1	5	1	4	5
6.6	Autos	7	3	0	5	4
5.7	M/c tools	4	2	0	6	8

4 CMM manufacturers dominate the market.

It would appear from information contained in Appendix D - Worldwide Review of manufacturers of CMMs, that these 4 manufacturers dominate the British and American markets as shown by this research, for the following major reasons:-

1. Ferranti - first known company in the market, established a lead and took out a licence agreement with Bendix in America.

2. L.K. Tools - first British company to exclusively manufacture co-ordinate measuring machines. Usefully located in the industrial midlands in England.

3. Johanson - Swedish based metrology organisation with a long established reputation in the worldwide gauging field. Have apparently used their name to gain entry into the CMM market.

4. D.E.A. - Italian firm exclusively manufacturing measuring machines since mid 1960s. Assisted initially by Fiat in Turin to supply measuring machines to the automobile and machine tool industries. D.E.A., are now reputed to be the world's largest producers of CMM equipment.

Most other CMM manufacturers appear to either specialise in specific fields thus restricting their volume, or have other more important products in their range. For example, Brown and Sharpe manufacture CMMs but their major activities are concerned with machine tools.

Top 6 Business Activities using the CMM Equipment.

This data would indicate that certain types of business activities make greater use of CMM equipment than others. These activities tend to have the following common features:-

1. Products tend to be large (aircraft, tractors, engines).
2. Production type is either large equipment or small batch.
3. There is a correlation between the growth of numerical controlled machine tools in these business activities and that of CMM growth (59).

Other interesting implications from the data show that the top suppliers of the CMM equipment have particular relationships with their major customers.

Ferranti	-	Electronics (Ferranti's major expertise).
L.K.	-	Aircraft (near locality of Rolls Royce).
Johanson	-	Electronics (small type CMM applicable to small high accurate products).
D.E.A.	-	Tractors (D.E.A., offer standard models of very large size).

Percentage share of CMM sold by manufacturers to 150 firms within specific employee size groups.

Results from this field survey would indicate firms employing upwards of 2,000 people have the largest ownership of CMM equipment. Table No: 7.2 shows that in the 7 employee size categories, the firms with 2,000 and above employees have 53.9 percent of the CMMs. The middle range employee size groupings from 100 to 1,999 employees have a combined share of 44.1 percent. Firms with less than a 100 employees had a very small percentage of the CMM share.

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The implications of the above would suggest that there is a correlation between the size of the firm in terms of employees and the increased ownership of the CMM technology up to and including 4,999 employees. Above this size of group does not cause further CMM ownership. Analysis of the 4 major suppliers shows that both Ferranti and L.K., have had major success with firms in the 2,000 to 4,999 employee size group while Johanson have concentrated in the 100 to 499 employee size. Finally D.E.A., with the widest and largest range of CMM products, have had greatest penetration at the 5,000 and above employee size groups.

Reasons given by users for choice of measuring machine.

In order to accurately determine why each of the 150 firms choose a particular measuring machine, an open ended question was asked in the CMM section of the field questionnaire. This question resulted in 264 responses with 14 different possible reasons on why the equipment was acquired and the details of this are given in Table No: 7.3 by business activity. There were 5 major reasons given and these are summarised as follows:-

TABLE No: 7.2

Reason:	% of all reasons:	Business activities preference:
Accuracy	15.9	Electronics, tractors, engines.
Cost and accuracy	14.4	Aircraft.
Cost	11.7	Defence.
Availability	10.9	Electronics.
Cost & table size	10.6	Aircraft
Table size	9.4	Aircraft and tractors.
	73 percent	

When this data is analysed by business activity, it is observed that certain business activities are more evident than others in terms of requirements. This is shown in the above extract from the matrix given in Table No: 7.3.

Comparisons of reasons for choice between American and British users of CMM equipment.

The data given for the acquisition of CMM equipment was further analysed by comparing American and British users for reasons. Tables Nos: 7.5 and 7.6 analyse 11 major reasons for choosing the equipment and show that the British users had 78 percent of the reasons to the American users 22 percent. (This dominance by Britain is due to the larger sample of firms in the survey being from Britain). One of the most interesting results from this data is that British firms appear to be more concerned with cost while American firms are reporting a need for accuracy with cost as a secondary concern. This may indicate a financial constraint on the part of British managements in their rationalisation concerning new technology in comparison with a technological constraint as shown by the American result.

Comparison of year of purchase between American and British users.

Table No: 7.7 identifies the year when firms bought their co-ordinate measuring systems, a grand total of 296 were purchased or forecasted between 1957 and 1980, a period of 23 years which has witnessed the steady growth of this technology within manufacturing industry. The data is divided between British and American firms showing that while a total of 198 were bought by the British firms, some 98 were invested in by American firms. Examination of the totals each year suggests that the market is still growing at approximately 1 to 2 percent per annum but with the most noticeable change taking place at 1965 when sales seem to double then almost double again 5 years later. In the early 1970s a further development of the co-ordinate measuring machine with the introduction of direct computer control has probably increased sales and will continue to increase sales as the pressure for reduction in labour costs continue within manufacturing industry.

TABLE No: 7.3

SURVEY RESULTS OF CMM USERS BY TYPE BY BUSINESS ACTIVITY.

Business Activity:	Ferranti No:	%	L.K/ Notsa No:	%	Johanson No:	%	D.E.A. No:	%	Others No:	%	Total	% Share
Defence	6	(4.4)	4	(9.3)	0	(0)	4	(10.5)	1	(1)	15	4.5
Aircraft	11	(8.0)	12	(27.9)	1	(6.6)	7	(8.4)	12	(12)	43	13.0
Tools	2	(1.5)	1	(2.3)	2	(13)	0	(0)	1	(1)	6	1.8
Machining	6	(4.4)	0	(0)	1	(6.6)	2	(5.3)	2	(2)	11	3.3
Engines	8	(13.2)	1	(2.3)	1	(6.6)	5	(13.1)	17	(17)	42	12.7
Pumps	7	(5.1)	5	(11.6)	1	(6.6)	1	(2.6)	1	(1)	15	4.5
Tractors	12	(8.8)	4	(9.3)	0	(0)	10	(26.3)	27	(27)	53	16.0
Food Proc.	1	(0.7)	0	(0)	1	(6.6)	0	(0)	3	(3)	5	1.5
Telecom.	5	(3.7)	1	(2.3)	0	(0)	0	(0)	0	(0)	6	1.8
Electron.	22	(16.2)	1	(2.3)	3	(20)	2	(5.2)	8	(8)	36	10.9
M/c Tools	10	(7.4)	6	(13.9)	0	(0)	1	(2.6)	2	(2)	19	5.7
Controls	6	(4.4)	0	(0)	1	(6.6)	1	(2.6)	2	(2)	10	3.0
Castings	2	(1.5)	1	(2.3)	0	(0)	1	(2.6)	2	(2)	6	1.8
Auto	5	(3.7)	5	(11.6)	0	(0)	2	(5.2)	10	(10)	22	6.6
Misc.	3	(2.2)	1	(2.3)	2	(13)	0	(0)	5	(5)	11	3.3
R & D	4	(2.9)	0	(0)	1	(6.6)	0	(0)	0	(0)	5	1.5
Plastics	3	(2.2)	0	(0)	1	(6.6)	0	(0)	0	(0)	4	1.2
M & H	5	(3.7)	1	(2.3)	0	(0)	0	(0)	1	(1)	7	2.1
Instru.	7	(5.1)	0	(0)	0	(0)	2	(5.2)	3	(3)	12	3.6
Dom. Prod.	1	(0.7)	0	(0)	0	(0)	0	(0)	1	(1)	2	0.6
TOTAL	136	(100)	43	(100)	15	(100)	38	(100)	98	(100)	330	100%
% Share	41		13		4.5		11.5		29.7		100%	

TABLE No: 7.4

SURVEY RESULTS OF CMM USERS BY TYPE BY EMPLOYEE SIZE.

Employee Size:	Ferranti No:	%	L.K/ Notsa No:	%	Johanson No:	%	D.E.A. No:	%	Others No:	%	Total	% Share
10- 49	1	(0.7)	0	(0)	0	(0)	0	(0)	0	(0)	1	0.3
50- 99	2	(1.4)	0	(0)	0	(0)	1	(2.6)	2	(2)	5	1.5
100- 499	22	(16.2)	5	(11.6)	8	(53)	4	(10.5)	14	(14)	53	16.0
500- 999	19	(13.9)	7	(16.3)	3	(20)	4	(10.5)	13	(13)	46	13.9
1000- 1999	28	(20.6)	5	(11.6)	4	(26.6)	2	(5.3)	8	(8)	47	14.2
2000- 4999	36	(26.5)	17	(39.5)	0	(0)	13	(34.2)	25	(25)	91	27.6
5000-80000	28	(20.6)	9	(20.9)	0	(0)	14	(36.8)	36	(36)	87	26.3
TOTAL:	136	(100)	43	(100)	15	(100)	38	(100)	98	(100)	330	
% Share:	41		13		4.5		11.5		29.7		100	

Table No:7.5

USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY

REASON FOR CHOICE OF MEASURING SYSTEM

Business Activity:	Cost	Accuracy	Travel	Table Size	Availability	Cost and Accuracy	Cost and Availability	Accuracy and Service	Travel and Table Size	Cost and Table Size	Cost and Travel	Component Suitability	Accuracy and Table Size	Other	Total:	%
Defence	5	2	1	3	3	0	0	0	0	2	0	0	1	1	18	6.8
Aircraft	0	2	1	4	3	6	0	1	1	7	0	0	1	0	26	9.8
Tools	0	2	0	1	0	0	1	0	0	1	0	0	1	1	7	2.6
Machining	0	1	0	1	1	1	0	0	0	2	1	1	0	0	8	3.0
Engines	4	7	0	3	2	2	0	0	0	4	0	3	0	0	25	9.4
Pumps	1	1	0	1	1	4	0	0	0	1	0	1	1	2	13	4.9
Tractors	3	(7)	1	4	1	5	3	1	0	1	0	6	4	2	38	14.4
Food Proc.	0	0	0	2	1	1	0	0	0	0	1	3	0	0	8	3.0
Telecom.	0	1	0	0	0	5	0	0	1	1	0	0	0	0	8	3.0
Electron.	3	7	0	1	4	1	1	0	1	0	0	0	1	5	24	9.0
M/c Tools	1	1	1	0	2	6	1	0	0	3	0	0	0	1	16	6.0
Controls	2	0	0	0	2	0	0	0	0	1	1	0	0	1	7	2.7
Castings	2	0	0	1	1	0	0	0	1	0	0	1	0	0	6	2.3
Motor	4	2	1	1	2	1	2	0	0	2	1	0	0	0	16	6.0
Misc	2	2	0	0	2	1	2	1	0	1	0	0	3	0	14	5.3
R & D.	0	0	0	0	0	2	0	2	0	0	0	0	0	1	5	1.9
Plastics	0	1	0	2	0	0	0	0	0	0	0	0	1	0	4	1.5
M & H.	2	4	0	0	0	1	0	0	0	0	0	0	0	0	7	2.6
Instruments	2	2	1	1	3	2	0	0	0	1	0	0	0	0	12	4.5
Domestic Prod.	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2	0.7
TOTAL:	31	42	6	25	29	38	10	5	4	28	4	15	13	14	264	
Percentage:	11.7	15.9	2.3	9.4	10.9	14.4	3.8	1.9	1.5	10.6	1.5	5.7	4.9	5.3		100%

TABLE No: 7.6

MAJOR REASON FOR CHOICE OF MEASURING SYSTEM

Reason:	U.K. No:	U.K. %	U.S. No:	U.S. %	Total No:	Total %
Cost	84	30.7	6	7.8	90	25.7
Accuracy	57	20.9	20	26.0	77	22.0
Travel	16	5.9	2	2.6	18	5.1
Table Size	61	22.3	11	14.3	72	20.5
Availability	42	15.4	10	13.0	52	14.9
Software	1	0.4	5	6.5	6	1.7
Service	0	0	0	0	0	0
Cost and Accuracy	3	1.0	10	13.0	13	3.7
Cost and Travel	2	0.8	4	5.2	6	1.7
Cost and Table Size	1	0.4	4	5.2	5	1.4
Accuracy and Size	6	2.0	5	6.5	11	3.1
Total:	273	100	77	100	350	100
	78%		22%		100%	

TABLE No: 7,7

YEAR OF PURCHASE OF MEASURING SYSTEM.

Year:	U.K. No:	U.K. %	U.S. No:	U.S. %	Total No:	Total %
1957	1	0.5	0	0	1	0.3
1958	0	0	0	0	0	0
1959	1	0.5	0	0	1	0.3
1960	4	2.0	1	1	5	1.7
1961	1	0.5	1	1	2	0.6
1962	3	1.5	0	0	3	1.0
1963	4	2.0	1	1	5	1.7
1964	6	3.0	1	1	7	2.4
1965	10	5.0	3	3	13	4.4
1966	15	7.5	6	6	21	7.1
1967	9	4.5	5	5	14	4.7
1968	9	4.5	4	4	13	4.4
1969	8	4.0	6	6	14	4.7
1970	8	4.0	11	11	19	6.4
1971	10	5.0	13	13	23	7.7
1972	7	3.5	11	11	18	6.1
1973	14	7.0	14	14	28	9.5
1974	13	6.5	5	5	18	6.1
1975	11	5.5	1	1	12	4.1
1976	20	10.0	7	7	27	9.1
1977	18	9.0	1	1	19	6.4
1978	20	10.0	4	4	24	8.1
* 1979	5	2.5	2	2	7	2.4
1980	1	0.5	1	1	2	0.6
TOTALS	198	100	98	100	296	100
	66%		34%		100%	

* Forecasted to Purchase

7.3 - CONCEPTS AND POLICIES ON HOW NEW TECHNOLOGY GOT INTO FIRMS.

This section of the research project examines the data given in the field survey in an attempt to determine how new technology finds its way into the firms. The following specific analysis has been carried out:-

- What was the original source of knowledge?
- What was the first year of knowing about the new technology?
- Who was the person within the firm most in favour of the new technology?
- How long did it take from the first time of knowing to introduce the new technology?
- What degree of analysis was carried out to check what other users or suppliers experienced with the new technology?

Original source of knowledge.

From a total of 5 different possible sources of knowledge on CMM equipment, Table No: 7.8 shows that in a comparison of British and American users, the technical press had the highest percentage of source contacts at 32.7 percent, but this result was largely influenced by the British users where more than a third of all users indicated that this was their original source. The American firms, although a much smaller sample, tend to indicate that the CMM manufacturer was the greatest source of knowledge. This latter result suggests the suppliers of this equipment are more effective in American than in Britain, in terms of advertising their own products. It is interesting to note that the least effective source was the firm's headquarter group in both American and British results.

Most common year of knowing.

Table No: 7.9 shows that the most common year for knowing about the new technology was 1970 but the period of 1965 to 1967 collectively were the years when most firms were first aware of the technology. Again and despite the smaller sample, the American firms appear to be marginally ahead in terms of knowing about the

TABLE No: 7.8

ORIGINAL SOURCE OF KNOWLEDGE ON CO-ORDINATE MEASURING MACHINES.

Source of Knowledge:	U.K. No:	U.K. %	U.S. No:	U.S. %	Total No	Total %
Firm's Headquarters	12	12	0	0	12	9.8
Technical Press	35	35	5	23.8	40	32.7
Conference Exhibition	17	17	2	9.5	19	15.6
CMM Manufacturer	19	19	10	47.0	29	23.8
Other	18	18	4	19.0	22	18.0
TOTAL:	101	100%	21	100%	122	100%
	82%		16%		100	

N.B. All firms did not respond to this question.

TABLE No: 7.9

FIRST YEAR OF LEARNING ABOUT CMM

Year:	U.K. No:	U.K. %	U.S. No:	U.S. %	Total No:	Total %
1957	2	(2.1)	0	(0)	2	(1.4)
1958	1	(1.1)	0	(0)	1	(0.7)
1959	2	(2.1)	0	(0)	2	(1.4)
1960	3	(3.2)	2	(8.5)	5	(3.6)
1961	4	(4.3)	1	(4.2)	5	(3.6)
1962	4	(4.3)	2	(8.5)	6	(4.2)
1963	7	(7.5)	0	(0)	7	(5.0)
1964	6	(6.4)	2	(8.5)	8	(5.7)
1965	9	(9.7)	2	(8.5)	11	(7.8)
1966	3	(3.2)	9	(19.1)	12	(8.6)
1967	4	(4.3)	7	(14.9)	11	(7.8)
1968	5	(5.4)	3	(6.3)	8	(8.6)
1969	2	(2.1)	3	(6.3)	5	(3.6)
1970	9	(9.7)	5	(10.6)	14	(10.0)
1971	3	(3.2)	3	(6.3)	6	(4.2)
1972	4	(4.3)	1	(4.2)	5	(3.6)
1973	5	(5.4)	3	(6.3)	8	(5.7)
1974	4	(4.3)	1	(4.2)	5	(3.6)
1975	10	(10.7)	2	(8.5)	12	(8.6)
1976	5	(5.4)	1	(4.2)	6	(4.2)
1977	0	(0)	0	(0)	0	(0)
1978	1	(1.1)	0	(0)	1	(0.7)
TOTAL	93	100%	47	100%	140	100%
	66%		34%		100	

technology before British firms, irrespective of the fact that Ferranti, Scotland were the originators of the first commercial measuring equipment. If the data given in Table No: 7.7 year of purchase is compared to that of the above Table on year of learning about CMM, it can be seen that there is correlation between both results, in that after 1965 and 1970 there was considerable evidence of growth of the CMM equipment.

Person most in favour of new technology.

In relation to how technology gets into firms, this research tried to identify a person within the firm strongly in favour of new technology. Table No: 7.10 shows that of the 89 people identified as being strongly in favour of new technology, their basic discipline and percentage share were as follows:- quality (58%), production (10%), engineer (5%), and general management (16%). Only 9 percent of the total were of director level with the firms. The average number of years service with the company for these people was 16.5 years which tends to discount the theory that new technology gets into firms by the process of people moving jobs and technological information from one firm to another. There appears to be no great significance between the disciplines of the persons in favour, obviously the quality functions dominate the total number of disciplines and where this function is not prominent,such as in the automobile-motor and R & D business activities, these are pushed by general management function.

Time lag to introduce new technology.

An interesting aspect of new technology is related to the time which elapsed between the time of first knowing about the new technology to the time when it is introduced into the firm. Table No: 7.11 shows that on average it took 2.58 years to get the technology with the domestic products business taking longest at 7.5 years and food processing equipment business activity taking least time at 1.1 years. The reasons why there is a time lag and why it should vary from one business activity to another could be related to one or several

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Table No: 7.10

PERSON STRONGLY IN FAVOUR OF NEW TECHNOLOGY

Bus. Activity.	% in fav.	Aver yrs of serv.	Managers position description most related to - Quality No:	Quality %	Production No:	Production %	Engineering No:	Engineering %	General No:	General %	Grand Totals:	No. of Directors:
Def.	80	17.4	4	66	1	16	0	0	1	16	6	0
A'cft	66	22	4	50	2	25	0	0	2	25	8	1
Tools	60	10.6	1	33	1	33	0	0	1	33	3	0
M/c	100	17.5	5	100	0	0	0	0	0	0	5	1
Engs	85	12	4	66	0	0	1	16	1	16	6	0
P'mps	85	10.8	5	83	0	0	0	0	1	17	6	0
Tract	50	18.3	2	66	0	0	0	0	1	33	3	0
F.Proc	50	17	2	100	0	0	0	0	0	0	2	0
Tele	50	30	2	100	0	0	0	0	0	0	2	0
Elec	82	18.3	11	78	1	7	0	0	2	14	14	0
M/c Tls	90	15.7	4	44	3	33	0	0	2	22	9	2
C'tls	60	4	2	66	0	0	1	33	0	0	3	1
Cast.	50	14	1	50	0	0	0	0	1	50	2	0
M'tr	50	15	1	20	0	0	1	20	3	60	5	2
Misc	57	14	3	75	0	0	1	25	0	0	4	0
R&D	25	20	0	0	0	0	0	0	1	100	1	0
Plast	100	16.6	2	66	0	0	1	33	0	0	3	0
M&H	33	10	1	100	0	0	0	0	0	0	1	0
Instr	50	21	3	75	1	25	0	0	0	0	4	0
D.P.	100	27	1	50	1	50	0	0	0	0	2	1
Total			58	65	10	11	5	5.6	16	18	89	8
Aver	66%	16.56 yrs										

TABLE NO:7.11

TIME LAG TO INTRODUCE TECHNOLOGY
VISIT TO OTHER USERS & SUPPLIERS.

Business Activity:	Time Lag (years)	% of Firms who made visit	Average Visits per firm ( ) total visits	
Defence	1.76	80	(11)	1.5
Aircraft	2.27	91	(27)	2.25
Tools	2.3	75	(5)	1.0
Machining	2.4	80	(8)	1.6
Engines	3.6	71	(12)	1.7
Pumps	2.7	71	(8)	1.14
Tractors	5.8	100	(17)	2.6
Food Proc.	1.1	100	(6)	1.5
Telecom.	1.2	100	(5)	1.25
Electron.	2.2	76	(22)	1.3
M/c Tools	2.8	90	(22)	2.2
Controls	1.8	75	(5)	1.25
Castings	2.0	100	(12)	3.0
Motor	2.7	50	(13)	1.3
Misc.	2.5	85	(7)	1.0
R & D	1.25	33	(2)	0.3
Plastics	1.6	100	(3)	1.0
M & H	1.6	33	(1)	0.3
Instru.	2.6	62	(7)	0.87
Dom. Prod.	7.5	100	(3)	1.5
Average	2.58	78.6%	(196)	1.43

factors namely -

1. Financial constraints.
2. Technological constraints.
3. Managerial constraints.

Degree of analysis by visits to other users.

The extent to which potential owners of CMM equipment verified the experience of other users or indeed suppliers prior to their own decision to make the investment, was considered an important aspect of the whole business of acquiring new technology. Table No: 7.12 showed that 78.6 percent made a visit and a total of 196 visits were accomplished, on average 1.43 visits per firm. The most numerous visits were noted in the castings business activity with the least shown in R & D and medium to heavy (M&H) engineering. Of the total 196 visits made, 31 percent were to suppliers of the CMM equipment and 54 percent to other users, the balance of 15 percent covered both user and supplier combined visits. Significantly 21.4 percent of the potential owners of the CMM equipment made no visits whatsoever.

Table No: 7.12 specifically details the most common visits showing that the equipment suppliers covered the largest share of the visits while user firms like Rolls Royce, Caterpillar, Ford and others were instrumental in hosting other potential users. There was however no one firm which dominated all others in projecting this new technology.

TABLE No: 7.12

VISITS TO OTHER USERS AND SUPPLIERS OF ADVANCED MEASURING TECHNOLOGY.

Total visits made to other users and suppliers	=	196
Visit to suppliers	=	60 (31%)
Visit to other users	=	105 (54%)
Visit to both suppliers and other users	=	30 (15%)
Total percentage of firms who made some type of visit	=	78.6%
Total percentage of firms who made no visits	=	21.4%

Most Common Visits	No. of Visits:	% of Total:
Ferranti or Bendix	25	12.8
Various (not stated)	20	10.0
L.K. Tools Ltd	12	6.0
Exhibitions	7	3.6
Rolls Royce	6	3.0
D.E.A. (Italy)	4	2.0
Caterpillar	3	1.5
Ford (Motor)	3	1.5
Lucas	2	1.0
Smith Industries	2	1.0
British Aero	2	1.0
	86	43.9%
Others (one off only)	110	56.0%
TOTAL:	196	100.0%

7.4 - PROBLEMS AND ATTITUDES CONCERNED WITH INTEGRATION OF INSPECTION WITH PRODUCTION DUE TO TECHNOLOGICAL CHANGE.

Introduction.

Improving technology and growth in the field of N. C., and C. N. C., machine tools especially machining centers, may in the future supersede the need for a significant proportion of current styled co-ordinate measuring machines. This may come about due to in-process gauging systems or revised co-ordinate measuring machine design application to an in-process quality control. With these above advances in technology, there has to be an associated displacement of labour from the current inspection workforce into some other function. These changes will probably be of an evolutionary nature over a long period of time and thus the impact will not be so dramatic on the plant. Normal methods of displacement of labour will be followed by most firms, for example, attrition without re-hire, promotion without replacement and other. This research suggests that some of the technologically redundant labour will follow the course of the new technology and adopt a kind of advisory role within a production team. This new advisory function would investigate and correct through the operator, tolerance band drifts outwith specifications given in the blueprint.

In order to test the attitude of users of current measuring machine equipment on this subject, the 150 users in the field study were asked if through these technological advances they considered that the inspector should eventually become part of the production team? Each respondent was asked to indicate how he felt about the proposal in 5 variables namely,

- Strongly disagree with the inspector moving to production.
- Mildly disagree with the inspector moving to production.
- Neither agree nor disagree with the inspector moving to production.
- Mild agreement with the inspector moving to production.
- Strong agreement with the inspector moving to production.

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Results of Survey.

Table No: 7.13 shows that overall almost 50 percent of the respondents were against and 35 percent for the proposal, with the balance of 15 percent neither agreeing nor disagreeing. Interesting as it is, the 2 largest percentages were reflected at extreme ends of the scale to one another, that is, 37.4 percent strongly disagreeing and 20.4 percent in strong agreement. It was also observed from this table that there were differences in opinion between similar business activities - for example with engines, where 6 firms were against and 5 for the concept, also with tractor/truck, 9 firms were for and 8 against. Table No: 7.14 shows the same basic data arranged in employee size groups, the same percentage integrates are evident but it is interesting to note that the 2 strongest groups against are at 100 to 499 and 2,000 to 4,999 employee size, while the employee groups in favour are strongest at the 100 to 1,999 employee size grouping and evenly distributed about the other size groups, with the exception of the 2 smallest groupings from 10 to 99 employee size firms, where the numbers are zero.

The results given in these charts tend to be inconclusive, since there are 2 schools of thought among the 150 firms who responded to the survey. One group clearly see the consequences of advanced technology and the eventual elimination of "after-the-event" inspection techniques, while the group against the argument for integration may also see the elimination of inspection, but cannot accept the idea of integration or they do not agree with the notion that advancing technology will get to the degree of sophistication where it will ever displace the need for the independent inspector.

Table No:7.13

INTEGRATION OF INSPECTION WITH PRODUCTION
USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY

Business Activity:	Strongly Disagree	Mildly Disagree	Neither agree nor Disagree	Mild Agreement	Strong Agreement	Total	%:
Defence	4	1	1	0	2	8	5.4
Aircraft	7	2	1	1	2	13	8.8
Tools	2	0	1	1	1	5	3.4
Machining	2	1	0	1	1	5	3.4
Engines	4	2	0	2	3	11	7.5
Pumps	5	1	0	1	1	8	5.4
Tractors	9	0	2	3	5	19	12.9
Food Proc.	3	0	0	1	0	4	2.7
Telecom.	2	0	0	0	2	4	2.7
Electron	3	1	6	4	3	17	11.6
M/c tools	3	1	2	1	0	7	4.8
Controls	1	1	1	0	0	4	2.7
Castings	2	1	1	0	0	4	2.7
Motor	0	0	2	3	4	9	6.1
Misc.	2	4	1	1	2	10	6.8
R & D	3	0	0	0	0	3	2.0
Plastics	0	1	1	0	1	3	2.0
M & H	2	0	0	1	0	3	2.0
Instrum	1	1	2	2	1	7	4.8
Dom. Products	0	1	1	0	0	2	1.4
Total:	55	18	22	22	30	147	
Percentage:	37.4	12.2	15.0	15.0	20.4		100%

Table No: 7.14

INTEGRATION OF INSPECTION WITH PRODUCTION
USERS OF ADVANCED MEASURING TECHNOLOGY BY EMPLOYEE SIZE

Integrate	Employee Size 10-49	50-99	100-499	500-999	1000-1999	2000-4999	5000-80000	Total	%
S. D.*	1	4	11	8	6	14	6	50	37.0
M. D.	0	0	5	3	2	5	2	17	12.6
N.	0	0	6	6	2	4	2	20	14.8
M. A.	0	1	4	1	5	4	4	19	14.1
S. A.	0	0	6	4	8	6	5	29	21.5
Total:	1	5	32	22	23	33	19	135	
%:	0.7	3.7	23.7	16.3	17.0	24.4	14.1		100%

* Strong Disagreement
Mild Disagreement
Neither
Mild Agreement
Strong Agreement

7.5 - CHANGES IN INFLUENCE AND POWER.

Introduction.

With the introduction of powerful new technologies such as co-ordinate measuring machines onto the shop floor, what effect does this have on the new operator in terms of his influence and power as related to other members of the workforce? Influence in this instance is defined as the ability to persuade others to follow a particular direction, while power in this context is defined as the ability to exert authority, moving from a capacity as asking to demanding a change in a particular work situation related to inspection of components. Prior to the introduction of CMM equipment, the craft inspector used conventional gauging to check if a component was correct or incorrect to print. This process of measurement was largely dependent upon the skill of the inspector and often the result of his check was calculated on a scrap of paper. With the CMM equipment print-out, data can very quickly indicate out of tolerance conditions, generate graphical plots and thus give the inspector a much greater technological advantage.

This research project attempted to ascertain from 150 users of CMM equipment if the argument that the inspector had gained greater influence and power was valid or not. Table No: 7.19 and Table No: 7.20 show the results obtained from 146 firms who responded to this question.

Change in influence.

Table No: 7.15 shows the change in influence by business activity and suggests that only 11 firms or 7.5 percent observed a great change while 63 firms or 43.2 percent noted an increase. Just less than 50 percent or 72 firms reported no change. The firms in business activities who reported the increased influence were engines, tractor-trucks and miscellaneous. Those observing no change were electronic, motor and pumps. Table No: 7.16 shows the same

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Table No:7.15
Business Acty.

CHANGES IN INFLUENCE AND POWER OF CMM OPERATOR USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY.

	Change in Influence					Change in Power				
	Great Increase	Increase	No Change	Total	%	Great Increase	Increase	No Change	Total	%
Df.	1	3	4	8	5.5	0	1	7	8	5.5
A'c.	1	5	6	12	8.2	0	1	11	12	8.2
Tls.	0	1	3	4	2.7	0	1	3	4	2.7
M.	0	1	4	5	3.4	0	0	5	5	3.4
Eg.	0	8	3	11	7.5	0	2	9	11	7.5
Ps.	0	3	5	8	5.5	0	1	7	8	5.5
Tct.	4	12	3	19	13.0	0	13	6	19	13.0
FP.	0	2	2	4	2.7	0	2	2	4	2.7
Tel.	1	1	2	4	2.7	1	0	3	4	2.7
Elc.	1	4	12	17	11.6	0	2	15	17	11.6
M.T.	1	3	3	7	4.8	0	1	6	7	4.8
Cs.	1	3	1	5	3.4	0	2	3	5	3.4
Cast.	0	1	3	4	2.7	0	0	4	4	2.7
Mtr	0	2	7	9	6.2	0	0	9	9	6.2
Misc.	1	5	5	11	7.5	1	2	8	11	7.5
R&D	0	2	1	3	2.1	0	1	2	3	2.1
Pls.	0	1	2	3	2.1	0	1	2	3	2.1
M&H	0	2	1	3	2.1	0	1	2	3	2.1
Inst.	0	4	3	7	4.8	0	1	6	7	4.8
DP.	0	0	2	2	1.4	0	0	2	2	1.4
T =	11	63	72	146		2	32	112	146	
% =	7.5	43.2	49.2		100%	1.4	21.9	76.7		100%

Table No:7.16

CHANGES IN INFLUENCE AND POWER OF CMM OPERATOR USERS OF ADVANCED MEASURING TECHNOLOGY BY EMPLOYEE SIZE.

Influence:

	Employee Size 10-49	50-99	100-499	500-999	1000-1999	2000-4999	5000-80000	Total	%
G. I.*	0	1	1	0	2	5	1	10	7.5
I.	0	1	14	8	10	15	10	58	43.3
N. C.	1	3	17	14	11	13	7	66	49.3
Total:	1	5	32	22	23	33	18	134	
%.	0.7	3.7	23.9	16.4	17.2	24.6	13.4		100%

Power:

	10-49	50-99	100-499	500-999	1000-1999	2000-4999	5000-80000	Total	%
G. I.	0	0	1	0	0	0	1	2	1.5
I.	0	1	6	5	3	11	4	30	22.4
N. C.	1	4	25	17	20	22	13	102	76.1
Total:	1	5	32	22	23	33	18	134	
%.	0.7	3.7	23.9	16.4	17.2	24.6	13.4		100%

* Greatly Increased
Increased
No Change.

percentage influence by employee size groupings, but it is interesting to note that firms in the larger size groupings tend to note changes in influence predominately while the largest groups of firms who reported no change in influence are in the 100 to 499 employee size group. This last observation appears to be somewhat contrary to expectations as one would consider that changes would be more apparent in a smaller than a larger firm, and from the observations made in the business activity Table No: 7.15, there is again a division of opinion on whether the operator has or has not gained increased influence. Combining the results from both tables would indicate that large size firms of 2,000 plus employees in the engine and tractor/truck types of business activity could be subject to a change in influence of operators on CMM equipment, while small firms in the 100 to 499 employee size in the electronic and motor types of business activities have less probability to observing a change in influence.

Changes in power.

Table No: 7.15 shows that only 2 firms or 1.4 percent observed a great increase in power on the part of the operator but 32 firms or 21.9 percent noted an increase in power. A much larger number of firms totally 112 or 76.7 percent reported no change in power. Only one business activity dominated the firms who noted increase in power and this was in the tractor/truck business, while electronic, aircraft and engine business activities reported no change predominately. Table No: 7.16 shows the largest single group of firms observing increased power were in the 2,000 to 4,999 employee size group although another 11 firms were noted between 100 and 999 employee size groups also observing increased power. It would therefore be wrong to conclude in this instance that specific size groups were more subject to change than others. The firms reporting no change were evenly spread over employee size groups from 100 employees upwards and therefore no significant conclusion is drawn from this category.

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7.6 - RELATIONSHIPS BETWEEN OPERATORS AND PRODUCTION SUPERVISORS.

Introduction.

Almost half of the firms in the field survey indicated that they had observed the CMM equipment inspector operator to have increased his influence and approximately a quarter of the same sample noted an increase in the power of authority in their respective operators. This section of the research investigates whether this observed increase in influence and power has had any effect on the relationship between the operator inspector and the production line supervisor, who is the user of the CMM equipment service?

Each respondent to the question of relationships was asked to indicate the degree of change in the relationship as follows:-

- Greatly improved relationship.
- Improved relationship.
- No change in the relationship.
- Deteriorated relationship.

Results of survey.

Table No: 7.17 shows that from a total of 144 firms, only 5 firms or 3.5 percent indicated greatly improved relationships while 57 firms or 39.6 percent noted improved relationships while 81 firms or 56.2 percent reported no change. One firm reported a deteriorated relationship but this must be discounted as insignificant data. The firms in business activities which noted improved relationships were tractor/truck, aircraft and engines, while those firms who observed no change were predominantely in the electronic, defence, miscellaneous and instruments business activities. Table No: 7.18 shows the same data by employee size groups and more significantly it is noted that the employee size groups of larger firms from 2,000 employees upwards had observed improved relationships while the smaller firms at 100 to 999 employee size were observing no change.

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Table No: 7.17

RELATIONSHIP BETWEEN CMM OPERATOR AND USERS
USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY

Greatly Improved:	Improved:	No Change:	Deterioration:	Total:	%	Business Activity:
0	1	7	0	8	5.6	Defence
0	9	3	0	12	8.3	Aircraft
0	1	3	0	4	2.8	Tools
0	1	4	0	5	3.5	Machining
0	7	4	0	11	7.6	Engines
0	4	4	0	8	5.6	Pumps
2	13	4	0	19	13.2	Tractors
0	1	3	0	4	2.8	Food Proc.
1	1	2	0	4	2.8	Telecom.
0	5	10	1	16	11.1	Electron.
1	1	5	0	7	4.9	M/c Tools.
0	3	2	0	5	3.5	Controls.
0	1	3	0	4	2.8	Castings.
1	2	6	0	9	6.2	Motor.
0	3	7	0	10	6.9	Misc.
0	1	2	0	3	2.1	R & D.
0	1	2	0	3	2.1	Plastics
0	2	1	0	3	2.1	M & H
0	0	7	0	7	4.9	Instruments
0	0	2	0	2	1.4	Domestic Prod.
5	57	81	1	144		Total
3.5	39.6	56.2	0.7		100%	Percentage.

Table No:7.18

RELATIONSHIP BETWEEN CMM OPERATORS AND USERS
USERS OF ADVANCED MEASURING TECHNOLOGY BY EMPLOYEE SIZE

Relationship	Employee Size 10-49	50-99	100-499	500-999	1000-1999	2000-4999	5000-80000	Total	%
G. I. *	0	1	0	0	1	2	1	5	3.8
I.	0	1	9	6	8	17	13	54	40.6
N. C.	1	3	23	15	13	14	4	73	54.9
D.	0	0	0	1	0	0	0	1	0.8
Total:	1	5	32	22	22	33	18	133	
%.	0.8	3.8	24.1	16.5	16.5	24.8	13.5		100%

* Greatly Improved
Improved
No Change
Deteriorated.

In this instance it may be too unrealistic to expect no changes in relationship in the smaller firms mainly due to the probability of a more stable organisation structure, where the small number of employees makes for more frequent contact between individuals and therefore relationships, power and influence between people are more likely to be hardened into a pattern.

7.7 - DISSATISFACTION DUE TO DE-SKILLING.

Introduction.

The problems associated with de-skilling of blue collar employees due to the advance of new technology has already been discussed in this research, see chapter 4, page 202. This question concerning de-skilling was again raised in the field survey in order that further information be added to the research and thus derive greater understanding of some of the consequences of new measuring machine technology on the workforce. The firms using CMM equipment were asked if they thought the CMM equipment required less skill to operate and if so, would the inspector become dissatisfied with his work or not. Again 5 integrated variables were used namely,

- Strongly disagree that inspectors would become dissatisfied.
- Mildly disagree that inspectors would become dissatisfied.
- Neither agree nor disagree that inspectors would become dissatisfied.
- Mild agreement that inspectors would become dissatisfied.
- Strong agreement that inspectors would become dissatisfied.

Results of survey.

Table No: 7.19 shows that of 147 firms who responded to this question, 86 or 58.5 percent were strongly or mildly disagreeing with the notion that the inspector would become dissatisfied, while by contrast 33 firms or 22.4 percent had mild to strong agreement that he would become dissatisfied. Almost 20 percent or 28 firms could not agree or disagree with the proposal. The firms in business activities against this probability of dissatisfaction were electronics, tractor/trucks and miscellaneous. The firms in business activities who agreed with the notion of future dissatisfaction were aircraft and tractor/trucks although the firms in this grouping tended to be fairly small in numbers and spread evenly over most of the business activities. Table No:7.20 shows the same data by employee size and tends to indicate that firms in the larger size groups from 2,000 employees upwards to be against the notion and firms in the smaller size groups at 100 to 499 employees to be in agreement with the notion, that the inspector will become dissatisfied in the future due to de-skilling.

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Table No:7.19

DESKILLING WORK LEADS TO DISSATISFACTION
USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY

Business Activity:	Strongly Disagree:	Mildly Disagree:	Neither Agree nor Disagree:	Mild Agreement:	Strong Agreement:	Total:	%
Defence	3	1	2	1	1	8	5.4
Aircraft	4	4	1	2	2	13	8.8
Tools	1	0	2	1	1	5	3.4
Machining	1	1	1	2	0	5	3.4
Engines	3	3	2	1	2	11	7.5
Pumps	1	2	2	3	0	8	5.4
Tractor	7	5	3	1	3	19	12.9
Food Proc.	2	2	0	0	0	4	2.7
Telecom.	1	2	1	0	0	4	2.7
Electron.	8	4	4	1	0	17	11.6
M/c Tools	2	1	2	2	0	7	4.8
Controls	1	1	2	1	0	5	3.4
Castings	1	1	2	0	0	4	2.7
Motor	1	4	2	2	0	9	6.1
Misc.	5	3	0	2	0	10	6.8
R & D.	2	1	0	0	0	3	2.0
Plastics	1	0	0	2	0	3	2.0
M & H	0	2	0	1	0	3	2.0
Instruments	0	3	2	2	0	7	4.8
Domestic Prod.	2	0	0	0	0	2	1.4
Total:	46	40	28	24	9	147	
Percentage:	31.3	27.2	19.0	16.3	6.1		100%

Table No: 7.20

DESKILLING WORK LEADS TO DISSATISFACTION
USERS OF ADVANCED MEASURING TECHNOLOGY BY EMPLOYEE SIZE

Dissatisfaction	Employee Size 10-49	50-99	100-499	500-999	1000-1999	2000-4999	5000-80000	Total	%
Strong Disagreem't	1	2	6	12	5	11	4	41	30.4
Mild Disagreem't	0	0	9	4	6	12	7	38	28.1
Neither	0	0	6	4	8	6	3	27	20.0
Mild Agreem't	0	3	11	1	2	2	3	22	16.3
Strong Agreem't	0	0	0	1	2	2	2	7	5.2
Total	1	5	32	22	23	33	19	135	
%	0.7	3.7	23.7	16.3	17.0	24.4	14.1		100%

7.8 - THE EFFECT OF NEW TECHNOLOGY ON STATUS AND JOB INTEREST.

Introduction.

Prior research in the field of new numerical control machine tools has shown that operators exhibited an improvement in status and in job interest. This section of the research attempts to determine if such changes have been observed in both CMM operators and other inspectors not working on the new technology but associated with it through their day to day activities.

Firms using CMM equipment were asked if they thought their CMM operators and other inspectors had observed the following:-

- o Feeling of increased status.
- o Feeling of less status.
- o Greater interest in work.
- o Less interest in work.
- o No change.

Effects on status and job interest for the operator.

Table No: 7.21 shows that from the total of 143 firms who responded to this question, 33 firms or 23.8 percent noted no change while 74 firms of 51.7 percent observed increased status and 35 firms or 24.5 percent noted greater job interest. There were no reports of less status or less interest being noted in any firm. The firms in business activities where increased status was observed were pre-dominantely engines, tractor/trucks, aircraft and miscellaneous. The firms in business activities which showed greater interest were tractors, electronics and aircraft. The 2 most prominent business activities which reflected no change were with firms in electronics and machine tools business activities. Table No: 7.22 shows that with the same percentage analysis for each category of effect as that shown for business activities in Table No: 7.21, the firms in employee size groups from 100 employees upwards have a fairly even spread reporting observed changes in status. The employee size group of 2,000 to 4,999 has the highest value at 18 firms or 26 percent of the

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Table No: 7.21

EFFECT ON STATUS AFTER INTRODUCTION OF CMM USERS OF ADVANCED MEASURING TECHNOLOGY BY BUSINESS ACTIVITY

Business Activity:	Effect on CMM Operators: Incr. Status	Less Status	Greater Interest	Less Interest	No Change	Total	%	Effect on Other Inspectors: Incr. Status	Less Status	Greater Interest	Less Interest	No Change	Total	%
Defence	5	0	1	0	2	8	5.6	1	0	3	0	4	8	5.6
Aircraft	7	0	5	0	0	12	8.4	0	1	5	0	6	12	8.4
Tools	2	0	1	0	1	4	2.8	0	1	1	0	2	4	2.8
Machining	2	0	0	0	3	5	3.5	0	0	0	0	5	5	3.5
Engines	10	0	0	0	1	11	7.7	3	0	4	0	4	11	7.7
Pumps	3	0	2	0	2	7	4.9	0	0	2	0	5	7	4.9
Tractor	10	0	7	0	1	18	12.6	6	0	4	0	8	18	12.6
Food Proc.	2	0	0	0	2	4	2.8	1	0	1	0	2	4	2.8
Telecom.	3	0	0	0	1	4	2.8	1	0	1	0	2	4	2.8
Electron	5	0	6	0	6	17	11.9	2	0	2	0	13	17	11.9
M/c tools	2	0	1	0	4	7	4.9	0	2	0	0	5	7	4.9
Controls	3	0	0	0	2	5	3.5	0	0	1	0	4	5	3.5
Castings	3	0	0	0	1	4	2.8	1	0	0	0	3	4	2.8
Motor	3	0	3	0	3	9	6.3	0	1	4	0	4	9	6.3
Misc.	7	0	2	0	1	10	7.0	2	0	1	0	7	10	7.0
R & D.	2	0	1	0	0	3	2.1	0	0	0	0	3	3	2.1
Plastics	2	0	1	0	0	3	2.1	1	0	1	0	1	3	2.1
M & H.	1	0	1	0	1	3	2.1	0	0	0	1	2	3	2.1
Instru.	1	0	4	0	2	7	4.9	1	0	0	0	6	7	4.9
Dom. Prod.	1	0	0	0	1	2	1.4	0	0	0	0	2	2	1.4
Total:	74	0	35	0	33	143		19	5	30	1	88	143	
%	51.7	0	24.5	0	23.8		100%	13.3	3.5	21.0	0.7	61.5		100%

Table No: 7.22

EFFECT ON STATUS AFTER INTRODUCTION OF CMM
USERS OF ADVANCED MEASURING TECHNOLOGY BY EMPLOYEE SIZE

Employee Size.	Effect on CMM Operators							Effect on Other Inspectors						
	Incr. Status	Less Status	Greater Interest	Less Interest	No Change	Total	%	Incr. Status	Less Status	Greater Interest	Less Interest	No Change	Total	%
10-49	1	0	0	0	0	1	0.8	0	0	0	0	1	1	0.8
50-99	2	0	2	0	1	5	3.8	0	1	1	0	3	5	3.8
100-499	10	0	9	0	12	31	23.5	2	1	8	0	20	31	23.5
500-999	12	0	3	0	7	22	16.7	4	0	4	0	14	22	16.7
1000-1999	13	0	2	0	8	23	17.5	2	1	4	1	15	23	17.4
2000-4999	18	0	10	0	4	32	24.2	6	0	9	0	17	32	24.2
5000-80000	12	0	6	0	0	18	13.6	2	2	3	0	11	18	13.6
Total	68	0	32	0	31	132		16	5	29	1	80	132	
%	51.5	0.0	24.2	0	23.5		100%	12.1	3.8	22.0	0.8	60.6		100%

total of all firms in this category. Greater job interest for firms in employee size groups are shown at 100 to 499 and 2, 000 to 4, 999 employee size predominantely. The largest employee size group showing no change is at 100 to 499 employees and this is approximately 39 percent of all the firms reporting no change.

Effects on status and job interest for the other inspectors.

Table No: 7. 21 shows that 88 firms or 61. 5 percent of the total observed no change in the other inspectors in their assignments within the firms. Increased status was observed by 19 firms or 13. 3 percent and 30 firms or 21 percent observed greater job interest. It is interesting to note that 5 firms or 3. 5 percent noted less status amongst their other inspectors and one firm reported less interest. The firms in business activities who were most prominent in noting increased status were tractor/trucks and engines, while those firms who noted greater interest were in business activities such as aircraft, engines, tractor/trucks and motor. With respect to no change, the firms were found to be in electronics, tractor/truck and miscellaneous. Of interest the firms reporting less status were in business activities, aircraft, tools, machine tools and motor. Only one firm reported less interest and this was in the business activity of medium to heavy engineering. Table No: 7. 22 again exhibits approximately the same overall percentage results but does so by employee size groups. The 16 firms reporting increased status among their other operators are evenly spread from 100 employee size groups upwards, 6 firms are noted at the 2, 000 to 4, 999 employee size. With the 29 firms reporting greater interest, 2 employee size groups namely 100 to 1, 999 and 2, 000 to 4, 999, had the most numerous firms at 8 and 9 in each category. Of the 80 firms who noted no change, there was again a rough average of 16 firms per employee size grouping from 100 employees upwards. There was nothing significant about the firms who reported less status as they were shown in smaller and larger size groups. Again the one firm who reported less interest was in the 1, 000 to 1, 999 employee size group and does not signify any particular trend.

7.9 - OBSERVED EFFECTS OF NEW TECHNOLOGY ON A LARGE NUMBER OF FIRMS USING NEW MEASURING MACHINE TECHNOLOGY IN BRITAIN AND AMERICA.

The objective of chapter 7 was to analyse the findings from the large field survey of firms who were using new measuring machine technology. To achieve this, a large field survey was made of manufacturing firms located in both Britain and America. This survey which consisted of a written questionnaire had been designed to serve a dual purpose. The questionnaire had 2 sections; the first section applied to all firms whether they had new measuring machine technology or not, and the second section covered exclusively firms who had new measuring machine equipment. Chapter 6 discussed the analysis of the introductory or general section of the questionnaire as responded to by 287 firms, while this chapter 7 examines exclusively the 150 firms in the survey who actually used new measuring machines in their plants. The evidence from both chapters 6 and 7 has to be reviewed together in order to measure the extent of impact or effect on all 6 factors of the enterprise, as identified in the responses presented by 287 firms.

However, as chapter 6 has already described some of the findings from the field survey, this chapter will complete the observations in the same manner. Chapter 8 will summarise not only the conclusions from these 2 aforementioned chapters, but also the findings from all other chapters in this research project. In the meantime, the observed effects of new technology for chapter 7 on the 6 key factors of the enterprise namely, organisation structure, management, strategies, machine shop environment, control systems and people, the highlights are discussed as follows:-

<u>Organisation structure/management/strategies/control systems.</u>
There was no significant evidence derived from this section of effects of new technology on the organisation structure, management, strategies and control systems factors of the enterprise.

Machine Shop Environment.

There has been substantial growth of the measuring machine technology since the middle of the 1960s. 4 major suppliers tend to dominate the market but new suppliers are entering this currently expanding market and therefore technology may move too fast for some to retain their position in the market league. Certain types of business activities are more inclined to use measuring machine technology than others. The common feature with these business activities is the nature of their product which tends to be large, such as aircraft, tractors and engines. Evidence from the survey suggests that measuring machine technology is most popular with firms employing between 2,000 and 5,000 employees.

Accuracy was given as the most common reason for choice of a particular type of measuring machine. However cost combined with accuracy also rated highly as major reasons for acquisition of this technology. It was observed that British firms placed cost as their first criterion for a decision on which machine to purchase, while American based firms tended to be more concerned with accuracy.

The most common source of knowledge about the new measuring machine technology came from the technical press although American firms claimed that their major source of knowledge was the actual suppliers of the technology. It was noted that the least effective source was the headquarters of each firm where the locations were in different geographic bases.

Prior research in the literature would suggest that one method for new technology getting into firms could be through the migrating effect of short term managerial appointments and the carrying of new technological data from one appointment to another. To test this theory part of the question concerning who was most favourable in the firm towards acquiring new measuring machine technology, was to establish the service years of that individual in the firm. It was

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shown that the average years of service for this person was 16 years thus weakening the theory that new technology is passed on to firms by individuals. It was noted that the highest percentage of managers in favour of the measuring technology had a quality control discipline which is not too unexpected. On the question of time lag to get the new technology into the firm from the point of first knowledge, it was shown to be two and a half years approximately. It was observed that over 20 percent of the users of the measuring machine technology had not been involved in any visits to other users of measuring machines prior to making a decision to invest.

People.

The question concerning the problem of integration of tasks for craft inspectors with production machine operators resulted in an inconclusive response from the 150 user firms, as 50 percent were against the proposal and 35 percent for the proposal.

The question of increased influence gained by the craft inspector with the benefits of the new measuring machines showed that less than half of the 150 firms responding reported a no change effect on the inspection influence, but the balance of the firms did observe a change in influence due directly to the new technology. The firms reporting significantly increased influence were found to be employing 2,000 or more people and were involved in the manufacture of engines, trucks and miscellaneous items. Approximately 23 percent of the firms in the survey reported an increase in power of authority as gained by the craft inspector over the production supervisor, but the balance of 77 percent reported a no change effect.

It was considered that the introduction of the measuring machine technology would result in a closer working relationship between the production line supervisor and the craft inspector. The responses made by the 150 user firms showed that 62 firms or approximately 44 percent considered that an improvement in relationship had

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developed, while the balance of 56 percent indicated a no change situation. The problem associated with de-skilling of the craft inspector due to the introduction of new technology, did not cause the inspector to become dissatisfied with his assignment according to the responses from 58 percent of the firms in the survey. However 20 percent of the firms were unsure of the effect and 22 percent considered the craft inspector had or would indeed become dissatisfied with his task.

Does new technology affect status and job interest in an individual within a manufacturing firm? Evidently from the responses gained from the field survey, status does increase along with job interest as 52 percent of the firms observed this effect on their craft inspectors (25 percent of the firms reported an increase in job interest). There were no reports of a reduction of status or job interest by any of the 150 firms surveyed. A *Hawthorn-type effect was noted with other craft inspectors who remained on conventional measuring systems, as 13 percent of the firms observed increased status with these inspectors and 21 percent of the firms noted increased job interest. It was also observed that almost 4 percent of the firms who noted a feeling of less status and one firm reported less job interest since the introduction of new measuring machine technology to the firm.

*Hawthorn: From the studies of Elton Mayo at the Hawthorn Works of General Electric, Chicago, U.S.A. (60)

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Table No: 7.23

OBSERVED EFFECTS OF NEW TECHNOLOGY

MULTIPLEX MANUFACTURING PLANTS - USERS OF CO-ORDINATE MEASURING MACHINES.

Factor	Element	Change Type:	Effect
Organisation Structure	Horizontal Pressures) Vertical Pressures) Direct Authority Lines) Functional -do-) Information flow lines) Work flow disciplines) Informal - Formal)	D	Not Observed
Management	Support-Top Manager) Support-Middle Manager) Involvement) Acceptance-Responsibilities) Innovators.)	D	Not Observed
Strategies	Objectives) Long Term Plans) Education-Training) Teams-Teamwork)	D	Not Observed
Machine Shop Environment	Growth	A	Large firms faster
	Selection	A	Cost & accuracy
	Location	D	Not Observed
	Maintenance	D	Not Observed
Control Systems	R.O.I. Contribution) Utilisation) Efficiency)	D	Not Observed
People	Employment Shifts	D	Not Observed
	Skills	C	Moderate deskilling
	Resistance	A	No Resistance
	Integration	B	Resisting integration
	Satisfaction	C	Moderate to no effect
	Manning	D	Not Observed
	Status	C	Increasing
	Influence	C	Large firms more

Change Type - A-One step Change, B-Cumulative Change. C-Continuous Change, D-Nil or Not Observed.

CONNECTING SUMMARY

- Chapter 7 investigated the environment or the technology used by 150 firms within 20 different manufacturing industries. The findings showed that certain types of business activities had a greater propensity to use measuring machines than others, these activities tended to be more associated with large products produced in a small batch type of production system. In addition, it was shown that firms of a specific employee size range had more measuring machines in use than others.

- Observations on reason for choice of particular technology and the manner by which it was obtained by the firm, were shown to have common bases from one firm to another.

- Other findings on how this technology affected people provided evidence on changing relationships, concern for de-skilling, changes in status and job interest among other behavioural effects on people.

- Chapter 8 is the concluding chapter of this research project and it attempts to draw together the findings from the overall work. Similar to the introductory chapter, this final chapter details the findings by relating them to each of the 6 factors of the enterprise namely, organisation structure, management, strategies, machine shop environment, control systems and people. The objectives of this thesis are reiterated, the approach used for the investigation, conclusions for manufacturing industry and finally, general recommendations.

Chapter 8 - Discussions and Conclusions.

8.1 - THE OBJECTIVE OF THIS CHAPTER.

The objective of chapter 8 is to summarise the discussions and conclusions of this research thesis. The original objectives of this work were as follows:-

1. To investigate the problems associated with the introduction of specific new technology into manufacturing industry.
2. To derive and evaluate constructive conclusions from this investigation which would be of a sound contribution to manufacturing industry.

The motivation for this research was in the belief that new technology introduced to manufacturing industry was having an impact and effect on 6 major factors of the enterprise and that limited prior research on this subject revealed a need for such research work at this time.

Recent reports from the media and from some limited prior research suggest that serious problems are beginning to emerge in industry due to the introduction of new technologies. Most of these concerns relate to employment of people either in terms of unemployment created by redundancy or massive shifts in employment due to changes in skill and knowledge requirements. Other concerns relate to a need for British industry to remain competitive with other manufacturing countries by continuous investment in these new technologies and the achievement of optimum levels of productivity through the effective utilisation of such new technologies within manufacturing industry.

Most of the reports and the assumptions on the consequences of new technologies in manufacturing and other industries have been made on a national scale or macro-economic basis. Evidently for any changes to be made at national level, there have to be the same or similar changes made and observed at the micro-economic or plant level of the enterprise.

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It is to this latter assumption that this thesis has addressed itself by researching the problems associated with new technology as it is introduced and utilised by firms in various types of manufacturing activities. Having gained further knowledge and understanding of the consequences of new technologies at the enterprise or plant level through the results of this research, it is therefore assumed that these consequences will equally apply at national levels.

Two specific new technologies were selected as a vehicle to test the validity of the above assumptions. These technologies were in the main used by manufacturing industry although other authorities such as government, research and development and technological institutions also made limited use of this equipment. The first of these new technologies to be investigated was the numerical controlled (N. C.) machine tool, which although having been a feature of some modern machine shops since the late 1950s, its impact is only now being felt in industry. The reason for this relatively slow development has been in the main two-fold. Firstly, the early unreliability of the electronic control equipment which made manufacturing management apprehensive about investment and secondly, the evolutionary nature of the introduction of N. C., machine tools resulted in a merging effect with conventional machine tools and systems, thus minimising any major effect or impact on any particular factor of the enterprise.

The second new technology investigated in this thesis is that of the co-ordinate measuring machine or CMM. Similar to the numerical controlled machine tool, this new technology is used primarily by manufacturing industry but unlike the N. C., machine tool, it is not central to the manufacturing or metalcutting activities of the firm. It is in fact on the fringe of the machine shop performing a measurement task on the performance of these central metalcutting machine tools. The research into the effects of this CMM technology therefore have to apply to specific elements within the enterprise

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such as the organisation of quality control and inspection. The aforementioned N. C., technology being of a larger frame of reference has had effects on the whole enterprise and this was researched from this aspect.

To meet the requirements of the first objective of this research thesis, a model of the enterprise was devised to show the causal linking relationship between the new technologies and 6 key factors of the firm or enterprise. This thesis argued that the introduction of these new technologies would have an effect on these factors which would result in a degree of change within the elements of these factors.

8.2 - THE INVESTIGATION OF THE PROBLEMS.

The investigation process which was used in this research thesis to determine the problems associated with the introduction of new technologies into manufacturing industry had the following 5 steps:-

- Investigation of the single manufacturing plant on the impact and effects of numerical controlled machine tools.
- Investigation of a single manufacturing plant on the impact and effects of co-ordinate measuring machine technology.
- Investigation of a multinational organisation of 23 manufacturing plants on the impact and effect of co-ordinate measuring machine technology.
- Investigation of 287 manufacturing firms using and not using co-ordinate measuring machines to ascertain differences in the 6 factors of the enterprise for these firms.
- Investigation of 150 manufacturing firms on the impact and effect of co-ordinate measuring machine technology.

The problems identified by these investigations are summarised under each of the headings of the 6 factors identified with the enterprise in this research thesis.

Organisation Structure.

- Existing organisation structures cannot support new technologies effectively without some form of restructuring.
- Informal lines of communication and authority will emerge as an expression to meet the growing needs of new technology unless some planned mechanisms are introduced to formalise the system.
- Hierarchical levels will increase thus creating taller pyramids. New technologies were found to foster multiple levels rather than reduce them numerically.
- Existing work flow disciplines will have to be changed to accommodate new technologies; this in turn will lead to further changes in plant level systems.

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Management.

- Division of labour through changes in position titles will result in fewer higher level administration tasks and fewer staff appointments.

- First line supervision is being reduced to duties of man management.

- Senior management tend to resist new technology through a fear of not obtaining a return on investment.

- Middle management tend to resist new technology due to lack of acceptance of responsibilities, claims of unreliability with electronics, fear of disputes with trade unions on manning of machines and a reluctance to stop using familiar systems.

Strategies.

- Objectives such as product standardisation conflicts with the need for new technology.

- Low volume output of high value components coupled with relatively low labour costs constrains the need for new technology.

- Training of in-house maintenance and resulting wage claims for higher skills appear to be haphazardly organised.

- New technologies are creating needs for new skills and knowledge which appears to be getting scarcer.

- Firms in certain types of business activities have been shown to be less effective with new technology than other business activities.

- A large number of firms have no prepared plans for people displacement due to the effects of new technologies.

Machine Shop Environment.

- Firms which followed a policy of wide selection of different new technologies rather than standardising their processes created problems with maintenance and replacement parts.

- Early models of numerical controlled machine tools had unreliable electronic controls; this in conjunction with poor back-up service from suppliers of the new technology, resulted in very low efficiencies.

- A faster rate of growth of new technology in a firm appears to have greater impact and effect on all of the factors of the enterprise to the degree that disruptive effects may outweigh the advantages gained at least in the short term.

- Inadequate pre-planning, pre-investigation and identification of real needs leading to under-utilisation of new equipment appeared to be common to many firms.

Control Systems.

- Poor return on investments for new technologies was observed due to no adequate teamwork, poor training of both operators and planners, no communication between component designer and N. C., planner, poor tooling and maintenance, and other related factors.

People.

- Inter-union conflicts arise due to shifts in knowledge requirements from factory blue collar to office white collar.

- Conflicts are observed between the desires of the national trade union policies on new technology and the plant level trade union aspirations for their members.

- Mistiming of communication of new technology to trade unions leads to disruption in the enterprise.

- Wage differentiation and changes in manning due to new technology skill and knowledge requirements creates disharmony and dissatisfaction among craft employees at plant levels.

- Trade union officials at plant level are misled by sales literature of new technology which infers labour reduction and fewer problems for management.

- Craftsmen's major fear of new technology is related to loss of intrinsic job satisfaction and job status; this could slow down the introduction of other new technologies.

- Employees not assigned to new technologies are concerned about job security.

- Shifts in influence and power due to the skill and knowledge requirement of new technology are forcing changes in interpersonal and inter-group relationships.

- Craftsmen have only initial fear of new technology and this is normally related to the technicalities of the new systems, but further de-skilling and reduction in required knowledge could also constrain the advance of new technologies.

- Tasks integrated by new technology could lead to alienation between the craftsmen from different crafts directly affected by the integration.

- Although there was little evidence of resistance to new technologies in any of the research findings, it was shown that craftsmen would resist changes for the following major reasons:- protection of skills and knowledge, general fear of change, protection of status and the avoidance of having to change other systems.

The investigation of the problems associated with the introduction of the two specified new technologies into manufacturing industry were shown to reveal parallel findings in all of the five steps. In the single manufacturing plant pilot study, it was shown that organisational structural problems existed in both the senior levels with the N. C., technology and in the lower level structure of the inspection function for the measuring machine technology. The main difference in the problem lay in the magnitude of the pressures exerted by the new technologies.

In a similar way it was shown that the craftsmen in the study of the multinational plants exhibited the same type of concern for the consequences of new measuring machine technology in terms of loss of intrinsic job satisfaction and job status, as did the craftsmen in the major field study of 150 firms using new measuring machines.

On the basis of these results obtained from the 5 steps of this research thesis, it is considered that the problems associated with the introduction of specific new technology into manufacturing industry have been clearly identified in this project.

8.3 - THE CONTRIBUTION OF THIS RESEARCH AND THE IMPLICATIONS TO MANUFACTURING INDUSTRY.

The second major objective of this thesis was as follows:-

> To derive and evaluate constructive conclusions from this investigation which would be of sound contribution to manufacturing industry.

The problems previously discussed in this chapter, associated with new technology as it is introduced into manufacturing industry, are only now beginning to have serious impact and effect on the firms at plant level. Up until the last five years, technology as defined in this thesis and in terms of the manufacturing machine shop, has been changing at slow enough a pace for users to adapt, accept and absorb, without major catastrophes hurting the enterprise. Indeed the conflicts, if any, which have arisen, were concerned with grading of skill, wage claims for physical hand skills and unhealthy or dangerous work. Today and without doubt in the near future, industry in general and the machine shop in particular, are now facing a much accelerated rate of technological change.

The dilemma facing business leaders will on the one hand be the task of continually maintaining successful enterprises by maximising the return on assets and remaining profitable, while on the other, seeking to minimise the consequences of introducing new technologies into their plants. The consequences of the new technologies have already been discussed, therefore it is intended in this final section, to discuss the most constructive contributions which can be drawn from this research project.

The six factors of the enterprise as presented in the model given in Figure No: 1.1, and defined in the introductory chapter 1, were as follows:- organisation structure, management, strategies, machine shop environment, control systems and people. These factors are now discussed in terms of the contribution and the argument of this thesis.

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Organisation Structure.

Organisation structures have to take cognisance of the new technologies by establishing (1) a complete new structural framework, (2) changing the technology itself to adapt it to the existing structure, (3) creating a modular structure system which is flexible enough to accommodate itself into the overall structure without affecting any of the other established systems, and (4) setting up a mechanism within the established structure which will meet the complete requirements of the new technologies. The work of Chapple and Sayles (28) is important to this end proposing that the organisation should be constructed from the bottom upwards, basing the organisation on the actual flow and superimposing the structure on a known technology.

Much of the evidence to support the above argument comes from the observed changes in lines of authority both direct and functional which has been accompanied by a shift in the decision-making process at the operational level of the plant. Authority and responsibility are moving away from first line management towards the lower status office staff functions because the knowledge of the technology is in this area. Indeed the blue collar operator of the new technology be it numerical control (N. C.,) machine tools or co-ordinate measuring machine, is clearly more dependent upon the weekly planner and vice-versa than each of them are on their respective line superiors. The critical objective is one of effectiveness and as Bhattacharyya (22) has shown, very few British users of N. C., equipment are even getting 60 percent utilisation for a number of reasons but among them is poor organisation structure. Burns and Stalker's (17) well-renowned work on organic and mechanistic organisation structures tends to be somewhat dated as regards the needs of new technologies. The concept of the organic model with no clearly defined hierarcy and continual redefinition of roles and hence a lack of formal job title maybe suitable for research institutions but certainly not for a manufacturing plant. This research argues that formality must be given to informal organisation and that information lines laterally must be strengthened

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and not left loose even to the extent of introducing further new technologies such as visual display terminals. This is not to suggest a freezing of authority or decision-making by formalisation but more so a greater emphasis and support at the point where the most expert knowledge and skill is required to increase utilisation of the technology.

Enterprises with multi-plant and/or multinational plant locations have to consider the important problems of duplicated organisation structures and services. Establishment of central services or exchange of information necessitates the creation of strengthened functional line of authority and information flow lines for effective communication, all superimposed on the existing direct lines of authority and line management structure within the plant.

On the question of pyramid shapes for organisation structures, it is implied from the findings of this research that new technologies appear to foster multiple levels of hierarchy. It was clear from the evidence of the study of 50 organisation structures that the span of control for the most senior level of administration tended to be smaller for firms with new measuring machines compared to those firms without. Therefore by consequence the firms with new technology tend to have taller and narrower pyramids, although it was also found that firms with new technology had more sections at the lowest levels of the structure. The overall implications of this are that firms who invest in new technology minimise the disadvantages of communications common with tall pyramids, due to the increased efficiencies realised with the new technology within the structure. The ideal structure for a quality control organisation within an enterprise for manufacturing would appear to have a span of control of 4 and a 3 level hierarchy.

The major argument from this research on organisation related to new technologies is that open or organic systems in terms of Burns

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and Stalker are not sufficient if optimum effectiveness is to be derived from the investment. Structures have to be task orientated, that is to say, formal lines of authority have to be established as near to the new technology as possible and where the highest expertise of skill and knowledge of the new technology are contained.

Management.

Two observations are made in the first instance with respect to management and new technologies. Senior managers are rapidly becoming divorced from the complexities of the changing methods of advanced technology. The former concept of the chief executive "walking the shop" and being conversant with all the systems which existed when he was at a lower level of management no longer applies, mainly due to the accelerated pace of new technologies such as computer controlled machine tools, measuring machines and other electronic and micro-electronic developments. The second observation is that the first line supervisor is also becoming divorced from the new technologies mainly due to lack of training and to some degree due to a lack of need for the supervisor to be involved. Indeed as machine shops become more and more equipped with computer controlled machine tools, the role of the supervisor will disappear or change to one of pure man management.

These two observations have the following implications for manufacturing management. Senior management have to have no direct involvement in the daily operation of the new technologies, their role has to be concerned with policy and the assurance through the line organisation that maximum return on investment is being gained from the technology. The first line supervisor presents a more difficult problem but one which is inescapable, his role has to be phased out along with conventional machine shop technology. This research argues that there is a diminishing need for the first line supervisor as he exists today in the machine shop of manufacturing industry.

The next group of managers to be affected by new technology is the middle management strata. The findings from this research indicate that this group will be the least affected by new technology in manufacturing. However the most vital requirement for the middle manager is not to be necessarily conversant with the intricacies of how the new technologies operate, but more so to what applications these technologies can best be utilised. This requirement will necessitate continuous training and education on the particular possibilities of the new technology and a willingness on the part of the manager to accept some responsibility for seeking further innovations with the new processes.

The degree of management support for new technology appears to be directly related to the level of management. The most senior management give priority to return on investment, while middle management support or give passive consent to new technology depending how the technology affects them in the performance of their given task. Production line managers appear to seek conditions of minimum change as change tends to threaten established order, familiar systems and working relationships with people. Middle management on service activities, that is non production, such as inspection, maintenance, toolmaking and others, generally were found to support new technology. This attitude was considered to be developed from the basic nature of their task in continually seeking methods of improving their service without adding cost to the overall enterprise. This attitude was reflected in the middle management support for the co-ordinate measuring machine investment as discussed in chapter 4. This new technology seemed to be an investment which would not necessarily add value to the product yet without the investment, lower efficiences would result from other previous investments on equipment such as N. C., machine tools. In the study of the multinational organisation, it showed that where functional lines of authority exist between very senior administrators and middle management at individual plants in the enterprise then greater leverage was available to encourage the acquisition of these new

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technologies. It was also observed that interplant competition between managers tended to generate more demand for such technologies, this activity could have both advantages and disadvantages to the enterprise.

Major differences observed between firms using and firms not using co-ordinate measuring machine technologies indicated that management of the user firms had greater awareness of the potential efficiencies and benefits of new technologies as these user firms had greater activity with major technical changes on a wide variety of new technologies. As previously shown under organisation structure, the user firm senior management appeared to have less need for a wide span of control despite a taller pyramid structure. This indicates that the new technologies reduced the disadvantages of communication through a deep and complex hierarchy of levels. On the question of acceptance of responsibilities for the new technologies, it was evident that this was closely related to the reliability of the technology in terms of uptime, performance and general usefulness. It was noted for example, that in the case of the numerical controlled machine tools in chapter 3, the line managers encouraged the parallel use of conventional equipment and on the measuring machines discussed in chapter 4, that the inspection manager reverted back to first principle system of measurement when the new measuring machine failed to operate. The findings from this research show that the champions for innovation are found at middle management level, are employees with long company service and in most instances, are concerned with service activities rather than direct line production management. It was also observed in this connection that new technologies tend to foster more new technologies, that is to say, other applications are found which were previously not considered until the new technology was introduced.

Strategies.

It is apparent from this research that many manufacturing firms invest in new technology without having developed any detailed

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objectives or long term plans directly associated with that technology. This lack of planning maybe due to the unknown overall potential of the new technology as it would relate to each individual plant or firm or conversely those firms who tend not to be the front runners with innovations, may have set objectives and long term plans which result in constraining the new technology's introduction. The reasons given for the investment in new technology varied from firm to firm, but common points relate to cost reduction, increased productivity and in the specific case of the measuring machine, to obtain improved customer acceptance of products. It was observed in the multinational organisation and in other organisations with more than one plant, that strategies had been developed to avoid duplication of expensive equipment by the exchange of information and other services interplant. It was also noted that firms using new measuring machine technology had budgeted more finance to support the inspection service than firms without this technology, the implication from this would suggest that these user firms seek to maximise on their investment.

Very few firms appear to have formal education and training schemes related to new technology. Evidence from the research shows that most firms are dependent upon external support and either remain in this posture or develop haphazard training schemes to meet immediate needs. Training of course can be expensive but the consequences of incompetent employees on costly capital equipment can be of much greater expense. This research would indicate that training for new technologies is a necessary prerequisite for all firms in advance of using the new technology. Formation of special teams, especially for planning activities, appeared to be of an evolutionary rather than a developed strategy. It was noted that firms do not on average make dramatic changes to the systems of production or other related services, but tend to merge new systems with existing proven systems. This approach calls for a division of responsibilities of various employees and results in certain individuals spending a fraction of their working time on the new technology. As these technologies

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increase or the utilisation improves, then the time element increases and informal lines of authority and information become established. The findings of this research would imply that teams and team leaders created to control and maximise the utilisation of new technology are important to the overall success of these technologies and the timing for the formalisation of such teams is critical to the enterprise.

Machine Shop Environment.

In this research, environment is concerned with the physical nature of the new technology. The growth of numerical controlled (N.C.,) machine tools since the early 1960s has resulted in a reduction of conventional type machine tools and a reduction of blue collar employees. Economies have been apparent with energy in terms of horsepower for a given increase in productivity. The growth of co-ordinate measuring machines in manufacturing and other industries has developed since the mid 1960s with an acceleration of sales in the early to mid 1970s. The impact on the environment of the machine shop brought about by the co-ordinate measuring machine (CMM) has not been so apparent as that of the N.C., machine tool in terms of overall effect, but the CMM has had impact within its own sphere of activity, that is the quality control or inspection function. The importance of the CMM introduction to the environment of the typical manufacturing machine shop is that this equipment is entirely foreign to anything previously seen in the machine shop and in the viewpoint of this research, this is the beginning of a major environmental change which will directly affect manufacturing industry.

The early selection of N.C., machine tools in the firm studied in this research was shown to be haphazard with no particular long term plans. Equally the selection of CMM equipment was largely conditioned by availability of product and generally controlled by very few suppliers within the given market place. The haphazard selection of N.C., gave way to more specific selection systems due to problem of unreliability with the early models. Similarly the selection of CMM opened to a wider market of suppliers and improved systems of

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micro-electronics and the emphasis changed from availability to accuracy and cost as the major criteria for selection of systems. It was observed in the multinational organisation that while selection of CMM equipment was generally left to individual plants, the standardisation of software was important for the interchange of data and systems between plants. This concept was also apparent with N. C., technology where several plants were involved, in that the generation of master control tapes in one location eliminated the need for duplication of effort and costs at other locations. This control and centralisation of software, it would seem, will have very major consequences to subsidiary facilities of multinational and multiplant organisations in the future, as not only will the environment of the machine shop be standardised with a reduction of blue collar manpower, but also the need for any growth in planning support will be very doubtful.

Location of N. C., equipment was shown to be by trial and error in the early stages within the single manufacturing plant studied. Latterly this developed to a merging of N. C., technology with conventional technology in the machine shop. Currently this research shows that firms are creating N. C., sections within group technology systems of production working in controlled cells for the complete production of individual components. This concept is largely dependent upon the production system and product manufactured in each firm. For example, very high volume manufacture in a mass production system would arrange for identical N. C., machine tools with standardised tooling, while small to large batch production systems, which appear to be the most common systems in British industry, would seek group technology methods. The method of location of CMM inspection equipment varied from firm to firm, some attempted to integrate with high output N. C., equipment to minimise movement of components, while other firms chose to locate the CMM at a final check-out area, in an attempt to screen the quality of components. It was observed that firms with a propensity to make major technical changes were conscious of the resultant effect on plant layout within the firm.

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This research would argue that success or failure of new technology within the machine shop, is largely conditioned by degree of attention given by planning management to the location of this new technology within the machine shop environment. Maintenance systems on new technology as stated previously, were found to be dependent upon initial suppliers of the equipment and their ability to service and repair in accordance with the needs of the user firms. Many firms reported a dissatisfaction with the supplier service and opted for in-house maintenance of the new technology. The ever-increasing machine tool hour rate of cost makes for maximisation of machine tool uptime or any other critical equipment, the policy of pre-planned maintenance or preventive maintenance becomes an urgent criterion for new technology.

Control systems.

Return on investment has been discussed at length in this research both as a management decision factor and as a means of control to determine the degree of success related to the effectiveness in terms of financial return generated by the new technology. It was shown that many firms used the technique of return on investment analysis purely as a means of justifying a decision to purchase the new technology, as after installation, there appeared to be little attempt to measure the real return on investment. The study of the single manufacturing plant showed that the success of the return on investment for the N. C., machine tool was largely governed by the effectiveness of the operator of the equipment and the efficiency of support services such as tooling, maintenance and software programmes. The ROI for the co-ordinate measuring machine was less easy to measure compared to the N. C., machine tool, but basically the reduction of waiting time for a measurement critical to the continuous operation of the aforementioned N. C., equipment, appeared to be the best measure of effectiveness of the CMM equipment and therefore the best system of control. Specific exercises were carried out to test the actual savings in time when using new CMM technology over conventional measuring systems, these exercises showed conclusively that

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the new technology had decided time saving advantages.

Effective utilisation of the CMM equipment was shown to be inconclusive in this research. Craft inspectors desirous of maintaining hand skills and the knowledge of basic principles of measurement, tended to revert to these systems if the new technology of the CMM was down for maintenance or other reasons. This approach did not appear to have serious effects on the operation of the machine shop, at least in the short term, but the utilisation and ultimately the efficiency of the inspection equipment suffered and subsequently additional man hours became necessary. Utilisation has become a matter of top priority for the multinational organisation studied in this research. It is considered that low utilisation will only foster the proliferation of more new CMM technology, much of which would not be necessary had the original investment been fully burdened and controlled.

People.

From the findings of this research project, it seems that inevitably people at all levels within the enterprise will be affected by the impact of new technology. The detailed analysis of the single manufacturing plant showed employment shifts and displacement of blue collar employees almost surreptitiously with the steady growth of N. C., equipment, the consequence of the new N. C., technology did not result in any growth of white collar employees. The effect of CMM technology was less obvious with respect to the displacement of the craft inspector, although it was shown in the single manufacturing plant and in the multinational studies, that craft inspectors had been displaced and white collar planners added to support the new technology. The conclusion reached from this research is that employment shifts will increase in manufacturing industry with the introduction of new technologies. These shifts will consist of a reduction of blue collar employees and certain staff or white collar employees. The latter group of white collar employees will not increase as has been previously suggested in the literature, but a re-classification of job content

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will result in the dropping of obsolete systems for the adoption of new systems to support new technologies. The policy for dealing with employees displaced by automation used by a large number of firms in the survey, showed that re-training for other skills and the reduction of labour by normal attrition to be the most acceptable. Although no firms claimed the need to make people redundant due to the introduction of new technology, it appears that some firms admitted to having no redundancy pledges agreed with their plant level trade unions, in order that the path would be clear for the introduction of new technology, which would effectively displace people from a specific task. It would seem difficult for manufacturing firms to continue to honour no redundancy pledges or indeed to make them in the first place, with the ever-increasing pace of new labour saving technology, competition both within and without Britain, and indeed, the very survival of the firm in relationship to cost effectiveness and profit generation.

The impact of new technology such as N.C., and CMMs appear to enhance skills or create new demands for skills which had not been previously required. The finding in this research tends to contradict some prior research and the general impressions made by the media, with respect to automation and other forms of advanced technology, related to the manufacturing industry. Much is dependent upon the nature of the skill under discussion but in this research it was noted that craft machinist and craft inspectors tended to develop new skills and knowledge, related to the new technology, which had the causal effect of forging them into a new team relationship with the planning group and developed new roles for them in the planning of how specific tasks might be performed. The attitude survey shown in chapter 4 suggested that the craft inspectors were very concerned about the de-skilling effect of new technology but were less concerned about the possible reduction of their numbers. This concern for de-skilling was not reflected in a lowering of job satisfaction and it would imply that the newness of the technology was such that the inspectors were still on the up-slope of a learning curve, and until such times as this levelled, then the symptoms of dissatisfaction would not surface.

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Practically no resistance to new technology was observed in all of the research findings, except as previously discussed, among the middle management strata. Certain reactions by various groups in the firm may have implied a degree of resistance but this was interpreted as being concerned with gaining benefits or other advantages from the consequences of the new technologies, rather than an outright resistance to the change itself. As Woodward observed "you cannot escape re-opening the bargaining situation when you introduce any kind of technological change" (26). In the research of the multinational organisation, it was shown that craft inspectors would resist change if it were to affect specific conditions such as status, or cause alteration to other systems in harmony with inspection. It was also suggested that resistance would arise due to a basic fear of change. As stated earlier, there was no evidence of resistance in the multinational plants nor in any other firm. It has been suggested that the concept of the automated factory will have forerunner developments such as the merging of specific technologies. The merging of these technologies will force the integration of job responsibilities due to obsolescence of replaced systems and the emergence of new systems. The proposal to merge craft inspection with craft machinist or production was rejected totally as being unacceptable to the inspectors in particular, as it was claimed these specific roles are not compatible. This attitude to further advance certain technology may to some degree result in a constraint to these technologies.

It was evident in the study of the single manufacturing plant in chapter 3 that problems associated with manning of equipment will continue to cause disagreement between management and trade unions at plant level. Each group will have a specific point of view and compromising arrangements will probably be the outcome, with each group giving some ground such as a reduced ROI on one hand, to this displacement of some union members on the other. Evidence from this research project would support an argument that craftsmen had in fact gained in job status directly due to the introduction of the new technologies. This was evident with the N. C., machine tools researched in chapter

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3 and also in the attitude survey conducted in chapter 4 with respect to the co-ordinate measuring machines. The one group of people who appear to lose with the advance of new technology studied in this research are the first line supervisors. Indeed the influence or power of persuasion seem to increase for the blue collar craftsman over that of the supervisor. The supervisor unable to keep up with changing technology, appears to be having his role reduced to one of man management, leaving the new technology to be controlled by the white collar planner and the blue collar craft operator or inspector on the shop floor.

Most prior research on the concept of communicating new technology plans to employees advocate advanced communications as a prerequisite for successful introduction of the technology. The findings from this research takes an entirely different posture and would conclude that firms should plan their communication strategy to the same degree as they planned the investment of the new technology. Communications have to be given in accordance with the position of the employee within the enterprice. Blue collar workers and plant level trade union officials should be given least information up to the point of installation, at which point they ought to be accorded information by their immediate supervisor only if the new technology is to affect that employee in his current activity. White collar employees have to be involved at varying times, dependent upon their contribution to the acquisition of the technology, in terms of technical knowledge.

SUMMARY OF MAJOR IMPLICATIONS FROM THIS RESEARCH THESIS.

Each chapter of this project with the exception of chapters 1 and 2 concluded with a brief discussion on the observed effects of new technology, as it applied to the findings identified in that chapter. From the evidence given in these observations and in the investigation as a whole, it is concluded that not only was this research project worthwhile in terms of its contribution to knowledge of management, particularly manufacturing management, but in addition, it fulfils the basic argument of the hypothesis that new technology has had some impact and effect on the enterprise. The summarised major implications of this impact and effect on the model of the enterprise as illustrated in Figure No: 1.1, page 11, are given as follows:-

Organisation Structure:

Structures have to be re-considered in the light of new technologies if maximum advantages are to be gained. These considerations must include workflow disciplines, lines of authority and information. Size in terms of employees as postulated by Woodward et al, must not be assumed to be the sole determinant of structure as related to technology, (other measures of size are important namely, numbers of machine tools, area in surface square footage, power consumption and others).

Evidence from this research shows both horizontal and vertical pressures being subjected to the structure thus forcing management to react by widening spans of control and building deeper layers of hierarchical levels. This approach is not acceptable, as new technologies have to be integrated not simply added on to structures. The so called informal organisation systems, developed out of a need created by new technologies, have to be recognised and formalised to increase the effectiveness of the structure.

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Management:

All levels of management must be seen to give support to the new technologies and accept responsibilities for the success and failure of these technologies in the early stages of the commission. First line supervision has a reducing importance with the advance of technology, thus improvement in techniques of man management should be encouraged. Innovation and entrepreneurial activities are not the prerogative of the sole owner or the design engineer working in isolation, these activities must be an on-going responsibility for all levels of management in both service and production line management tasks.

Strategies:

Management by objectives should become a standard system of management as related to new technology. Long and short term planning is a prerequisite for the continuous success of the new technologies. Systems of education and training have to embrace all employees concerned with the technology, the timing of this training must be a feature of a carefully planned programme of communications. Teams appointed to develop and control the new technology should be encouraged to operate through all levels of the structure without constraints of authority.

Machine Shop Environment:

The growth of new technologies must be controlled to avoid technological leapfrogging as one new technology fosters the creation or apparent need for another. Selection of new technology should be controlled to the degree that product specification, productivity, cost and delivery are among the major criteria. Location of new technology in the existing machine shop must be given extremely careful planning to avoid problems both technical and human. Maintenance programmes have to be implemented either in association with a supplier or in-house or a combination of both.

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Control Systems:

Return on investment analysis has to be a continuous auditing function long after the new technology is in use and not purely as a means of justifying the initial acquisition. Systems of measuring utilisation and efficiency have to be applied rigorously.

People:

Communication with blue collar employees on pending new technology must be minimised and delayed until the point of introduction of the new technology. At this point only those blue collar employees directly associated need to be involved in the communication. Shifts in employment will be inevitable and people have to be given clear instructions on what these shifts will mean to them in terms of wage, conditions and other factors. Redundancy must be a last resort for management because it is costly in terms of finance and human skills. Increased output, new products and the creation of new and larger markets are the best alternatives.

The skills and knowledge of specific employees will increase particularly craftsmen and white collar staff planners. The development of teams, as previously stated, is vital to the success of the new technology especially as related to the above levels of employee. Some resistance will be encountered when craftsmen's tasks have to be integrated due to the merging of technologies. This resistance can be minimised if consideration is given to job security, status and the intergroup relationships between crafts.

The influence and power of authority as related to decisions directly associated with the technical nature of the task, will move away from the line supervisor towards the craftsmen and aforementioned white collar planner.

8.4 - GENERAL RECOMMENDATIONS.

Manufacturing industry all over the world is under increasing economic, social and political pressures to produce higher volume production at lower unit cost and with reduced human effort. Indeed, it has been forecast that turnover in production engineering by the year 2000 AD., will show a ninefold increase compared with that of 1960 (42). At the same time, it should be noted that a comparatively small increase in population has been predicted for the industrial nations. All round the world standards of living are going up and working hours are decreasing. The required productivity per worker must therefore increase enormously. Over the next 25 to 30 years, the "second industrial revolution" will continue to accelerate. Producttion and manufacturing methods and techniques will have to change and improve at an ever-increasing rate. The manufacturing machine shops of today will gradually be replaced by complete manufacturing systems, which will operate under the control of large computer systems.

This research has been concerned with the next stage of technological development before the abovementioned larger control systems become a reality and the effect and impact of new technology on the enterprise as it is known today. The introduction to the thesis expressed the need and importance of this research project identifying various authorities who have shown concern for the impact and effect of new technologies. The thesis will now terminate with some general recommendations drawn from the overall width of the research and directed at these aforementioned authorities as follows:-

- <u>Government.</u>

  The statements given below are concerned with policies which are recommended to be adopted by government to assist in the furtherance of new technologies in manufacturing industry.

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1. Regional and national manpower policies are required to deal with the changes in industrial and skill patterns brought about by new technological change.

2. Provision of government procurement to upgrade the technical level of industry and to couple new technology more effectively to collective social needs.

3. Encouragement of greater mobility of scientists and engineers engaged in laboratory work, such as the National Engineering Laboratory at East Kilbride, to move freely into public and private industry on short term contracts.

4. Increase the incentives such as tax and other rewards to manufacturing industry to ensure continued technological innovation.

- <u>Trade Unions.</u>

The statements below are directed at both national and plant level trade union officials -

1. Trade unions in general have to follow the example of the Association of Professional, Executive, Clerical and Computer Staffs (APEX) and set up working parties to study the impact of new technology on their own members in all sections of industry.

2. New technology investment has to be more clearly encouraged by both national and plant level trade union officials. No discussion implies resistance and tends to constrain employers and others in their deliberations on the decision to invest in new technologies.

3. Trade unions have to educate their plant level officials on how best to develop strategies to negotiate with employers on the introduction of new technologies. These strategies should include the encouragement of new technology in exchange for alterations to working hours and flexibility on the movement of members displaced by the new technologies.

- <u>Universities.</u>

The following statements are directed at universities and institutions of advanced technology and suggest action as follows:-

1. Create an awareness and a capacity for assimilation of new technologies made and used elsewhere in the world.

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2. Transmit knowledge related to new technologies to industry through the teaching process.

3. Provide skills and resources for the performance of applied research and technological developments.

4. Adopt new strategies such as those recommended in the Finniston Report which will give the engineering profession a much higher status and stronger emphasis in Britain, thus stimulating the importance of new technology to the increase of wealth of Britain.

5. Encourage more applied research on the real consequences of new technologies towards the minimising of social and economic problems.

o <u>Manufacturing Industry.</u>

These statements are in addition to those detailed in section No: 8.3 of this chapter and cover more general action required by industry as related to new technologies.

1. Maximum use has to be made of employers' associations for the interchange of information related to new technologies. Currently the work of these associations seems to be highly geared to resolving industrial relations' disputes which to some observers is a somewhat negative role.

2. The degree of risk associated with new technology has to be shared not only within private industry but to external authorities such as government agencies. However the benefits of knowledge related to the new technology have also got to be diffused without necessarily endangering competitive advantages.

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3. The abovementioned diffusion of information on new technologies is intimately bound up with, and complementary to, investment, education and management. If it is a radical new technology, it may require changes in production methods, company organisation and the skill requirements of management and the work force, as has been shown in this research thesis.

REFERENCES

REFERENCES

1. National Economic Development Council, Report on The Social and Employment Implications of Microelectronics by the Central Policy Review Staff. NEDC(78) 76.

2. Hickson D.J. et al "Operations Technology and Organisation Structure". Administrative Science Quarterly 14 (1969) pp 378-397.

3. Town H.C. and Moore H. Inspection Machines, Measuring Systems and Instruments. p.10. B.T. Batsford Ltd. London 1978.

4. Martin P. Metrology. Paper describing the history of Societe Genevoise De Instruments De Physique published in Geneva in 1967.

5. Moore, W.R. Foundations of Mechanical Accuracy, p.162. Published by The Moore Special Tool Company, Bridgeport, Connecticut, USA. 1970.

6. Farago, Francis T. PhD. Handbook of Dimensional Measurement, p.301. Industrial Press Inc. New York. 1968.

7. Clark Wm. Ferranti Ltd. Three Dimensional Measurements by Co-ordinate Measuring Machines. Paper No. 15. Nelex 74 Metrology Conference 15-18th October, 1974. N.E.L. Appendix A. p.21.

8. Black S. Co-ordinate Measuring Machines: A Worldwide Review of Manufacturers and their Systems, Metrology and Inspection. November 1977. p.25.

9. Althin, Torsten K.W. C.E. Johansson, 1864-1943. The Master of Measurement, Stockholm, Sweden, 1948.

10. Treywin, E.T. L.K. Tools Co. Ltd. Computer Controlled Co-ordinate Measuring Machines at an Economic Cost. Paper No: 6 Nelex 76: Metrology Conference 1976.

11. Black S. Co-ordinate Measuring Machines: How to overcome problems in use and get an effective return on investment. Paper for 3rd International Conference on Automated Inspection and Product Control. University of Nottingham. April 11-14th, 1978.

12. Measurement: Quick vs. Close: American Machinist - July 1967.

13. N. Swords Isherwood and P. Senker: Social Implications of Automated Small Batch Production, Technical Study on behalf of the Department of Industry, 1978.

14. Abbot L.F. Technological Development in Industry, A Survey of Social Aspects, Industrial Systems Research, 1978.

/....

15. Langrish J. and others. Wealth from Knowledge. Macmillan, London. 1972.

16. Myers S. and Marquis D.G. Successful Industrial Innovations: A Study of Factors Underlying Innovation in Selected Firms. National Science Foundation. May 1969.

17. Burns T. and Stalker G.M. The Management of Innovation. Tavistock, London 1962.

18. Jasinski F.J. Adapting Organisation to New Technology. Harvard Business Review. November-December 1969. p.79.

19. Woodward J. Management and Technology. HMSO London 1958 and Industrial Organisation: Theory and Practice, Oxford University Press, London 1965.

20. Anderman S.D. (trans. and ed.) Trade Unions and Technological Change. Allen & Unwin, London 1967.

21. Lundgren, E.F. Effects on N.C. on Organisational Structure. U.S. Automation. January 1969. p.44.

22. Bhattacharyya S.K. Penetration and Utilisation on N.C./C.N.C. Machine Tools in British Industry, a paper for the Manufacturing Systems Unit - Department of Engineering Production. University of Birmingham. November 1976.

23. Ettlie, J. Technology Transfer - From Innovators to Users. Industrial Engineer - June 1973. pp.16-23.

24. Perline M.M. and Tull K.I. Automation: Its Impact on Organised Labor, U.S. Personnel Journal. May 1969.

25. Office Technology. The Trade Union Response, Association of Professional, Executive, Clerical and Computer Staffs. March 1979.

26. Woodward, J. Resistance to Change. Management International Review, 1968. p.137.

27. Sayles L.R. Behaviour of Industrial Work Groups. New York. Wiley 1958.

28. Chapple E.D. and Sayles L. The Measure of Management. The MacMillan Co., New York. 1961.

29. Williams L.K. and Williams B.C. The Impact of Numerically Controlled Equipment on Factory Organisation. California Management Review. Winter 1964. pp25-34.

30. Schon D.A. Champions for Radical New Inventions: Harvard Business Review, March-April 1963.

31. Huggins E. How to Fail with Automation. Management Today December 1978. p. 93.

32. Times Newspaper The. Report on Dispute. Financial Times - June 11th, 1979.

33. Walker C. J. and Guest R. H. The Man on the Assembly Line. Cambridge, Mass. Harvard 1952.

34. Chinoy E. Automobile Workers and the American Dream. Doubleday. New York 1955.

35. Emery F. E. and Thorsrud E. Form and Content in Industrial Democracy. Tavistock - London 1969.

36. Trist E. L. et al. Organisational Choice. Tavistock - London 1963.

37. Blauner R. Alienation and Freedom. Chicago University Press. Chicago 1964.

38. Bright J. Research, Development and Technological Innovation. Homewood, Illinois. Irwin Inc. 1964.

39. Scott, W. H. et al. Technical Change and Industrial Relations. Liverpool University Press 1956.

40. Mumford E. Job Satisfaction. Longman - London 1972.

41. Hall K. and Miller I. Industrial Attitudes to Skills Dilution. British Journal of Industrial Relations 9/1. March 1971.

42. Merchant, M. E. Delphi-Type Forecast of the Future of Production Engineering. CIRP Annals. Vol. 20. No: 3. pp 213-225. 1971.

43. Shepard J. M. Automation and Alienation. The MIT Press. Cambridge, Mass. 1971.

44. Schumpeter, J. A. The Theory of Economic Development. Harvard University Press. Cambridge, Mass. 1949.

45. Jenkins C. and Sherman B. The Collapse of Work. Eyre Methuen Ltd. London. 1979. p. 130.

46. The Impact of Multinational Corporations on Development and on International Relations - Report by U. N. Department of Economic and Social Affairs in 1974.

/....

47. Bass B.M. and Barrett G.V. Man Work and Organisations. Allyn and Bacon Inc. Boston 1972. p.546.

48. Servan-Schreiber. The American Challenge. New York. Athenaeum. 1969.

49. Boner, J.R. Trouble Abroad: U.S. Companies find that foreign ventures don't always succeed. Wall Street Journal. 1968. 48 (216) 1.

50. Perlmutter, H.V. The Tortuous Evolution of the Multinational Corporation. Columbia Journal of World Business. 1969. 4, 9-18.

51. Weber, M. The Theory of Social and Economic Organisations. New York. Free Press 1964.

52. Fayol, H. General and Industrial Administration, Pitman. London. 1949.

53. Juran, J .M. Quality Control Handbook. McGraw Hill Inc. Section 7. 1974.

54. Starbuck, W.H. Organisational Growth and Development. Rand McNally and Company, Skokie, Illinois. 1965.

55. Business Ratio Report on Machine Tool Manufacturers. An Industry Sector Analysis published by ICC Business Ratios 1978.

56. Methodology for Unmanned Metalworking. Paper by T. Sata of Department of Precision Machinery Engineering, Faculty of Engineering, The University of Tokyo. 1977.

57. Automated Small Batch Production, a Technical Study By The National Engineering Laboratory on behalf of the Department of Industry. 1978.

58. 12th American Machinist Inventory of Metalworking Equipment 1976/78. Published by American Machinist. January 1979.

59. Fourth Survey of Machine Tools and Production Equipment in Britain. Published in Metalworking Production. 1977.

60. Mayo, E. The Social Problems of an Industrial Civilisation. Boston Harvard. 1945.

61. Dickson, J. Worker Participation Research Project - Industrial structure and context. University of Glasgow. 1977.

62. Oppenhein, A.N. Questionnaire Design and Attitude Measurement, Heinemann, London. 1966.

APPENDICES

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APPENDIX A

CONCERN FOR NEW TECHNOLOGIES BY VARIOUS AUTHORITIES

APPENDIX A

Recent commentary by the undernoted authorities indicates the increasing concern and attention being devoted to the effects of new technology in industry. A fuller description on the attitudes of each of the under-mentioned authorities is given in this appendix under the heading of:-

- o Government
- o Trade Union
- o Universities and Institutions of Higher Technology.
- o Management Consultants to Industry and Government.
- o Employers.
- o Professional Institutions.

Government

"New technology should not lead to the massive levels of unemployment predicted by some forecasters, Micro-electronics offered a better prospect for the industrial and economic future of the country and hence employment, than probably any other advances since the industrial revolution." Lord Gowrie, Employment Minister. October 1978.

"The Government's activities in the field of micro-electronics cover -

- encouraging the development of the semi-conductor industry.
- promoting the application of micro-electronics.
- an examination of the employment and social consequences.

Micro-electronics is only one factor in technological change. Many of the studies which have claimed to show the effects of micro-electronics have in fact dealt with technological advance in a much wider sense. We have concentrated as far as possible on those areas where the impact of micro-processors is large in relation to other social and technological developments and which can be identified as of sufficient importance to be worthy of study in their own right." Central Policy Review Staff, National Economic Development Council, November 1970.

"A modern industrial nation must live by technical advance in manufacturing - not only the radical or discontinuous innovation which may

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produce rockets, X-ray scanners or float glass but the less dramatic continuous, variety which takes place every day. A string of studies on technical advance - often calling it "technical change" to avoid any implications of moral judgments - have established that it is far less affected by laboratory discoveries than many people think: that, although science is important in manufacturing technical change is not usually caused by the new use of scientific knowledge. Change should instead be related directly to technical and commercial skills." Michael Fores, Government Economic Service, Department of Industry. November 1977.

Trade Union.

"British Trade Unions were advised recently to launch their own research into the impact of new technology on working life and not to learn about it through manuals written by computer engineers or employers." Professor Kristen Nygaafd, Norwegian Trade Unionist and Computer Specialist. December 1978.

"New technology was eating away at the human content of the workplace to such an extent that people would soon be faced with nothing short of the collapse of work. Economic forecasts in the U.K., and West Germany indicated that on present policies there could be 5 million unemployed in each country by the late 1980s." Clive Jenkins, General Secretary of the Association of Scientific Technical and Managerial Staffs. September 1978.

"The urgent need for Government action to avoid a further massive rise in unemployment from the advance of new technology was made a front-line issue in a major debate on employment problems on the opening day of the T.U.C. Conference." T.U.C. Conference 1979.

"The emphasis of discussions to end the six-week blackout in independent television has changed markedly from the beginning of the dispute. Then it was a straightforward pay issue - now the key issue to both sides is new technology." Financial Times, September 1979.

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The advance of micro-electronics has already led to job losses in key industries and services in Western Europe, and the process will accelerate in the 1980s unless governments mend their economic ways. This is the conclusion of a major new study on The impact of micro-electronics on employment in Western Europe in the 1980s, published this week by the Brussels-based European Trade Union Institute.

The institute, which is the research arm of the European Trade Union Confederation, charts the impact of the introduction of chip technology in the last few years and makes the following conclusions.

- The worst job losses have been felt first by industries in whose products electro-mechanical parts have been replaced by micro-electronics. Increases in the output of these goods have not fully compensated job losses resulting from the dramatic decrease in components which go into the final assembly. In one electronic telex, for example, a single microprocessor takes the place of 936 mechanical parts, and the new machine takes just 17.7 manhours to put together, compared with 75.3 hours needed for the old one. Industries affected include watches, cash registers, office and telecommunications equipment.

- The use of micro-electronics in products has also affected the location of manufacturing. There is a tendency, says the report, for components to account for a bigger proportion of both the value and the employment content of the final product. This works in favour of the dominant Japanese and U.S., semiconductor manufacturers, and against employment in Europe.

- Jobs have also been lost in the application of chips to industrial processes. Printing is one example; assembly over a wide range of industries, including cars, is another.

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o Services, which have expanded consistently in Europe over the past decade, are also beginning to feel the pinch. Banking, in particular, has ceased its heady growth of the early 1970s and in a number of countries expansion has come to an end.

Policies. The overall employment effects of the new technology in the 1980s, concludes the report, will depend on governments' economic policies. The main concern at the moment is that "the application of technology is being advocated by national governments and employers, not in terms of the potential demand that can be realised......... but as a way of maintaining or increasing the competitiveness of national economies and so gain larger shares of stagnant world trade. From an international or even from a Western European perspective, such an approach is self-defeating."

The institute also adds that, to harness the new technology for the general good, the trade unions will need to be involved.

The Union of Shop Distributive and Allied Workers (USDAW) the largest shopworkers' union with 469,000 members offered talks to plan the introduction of laser-scanning electronic checkouts. The chairman of the Employers' Association stated that "laser scanning and article numbering was the most dynamic development in U.K., retaining since the introduction of self-service." London Conference - Article Number Association. November 1979.

Universities.
The Department of Human Sciences and Advanced Technology (HUSAT) research group at Loughborough University of Technology has set up a research programme to be concerned with human factor problems, particularly in methods of applying advanced technologies, ranging over many problems from the effects of computerisation and automation to the evaluation of particular examples of complex machinery. June 1979.

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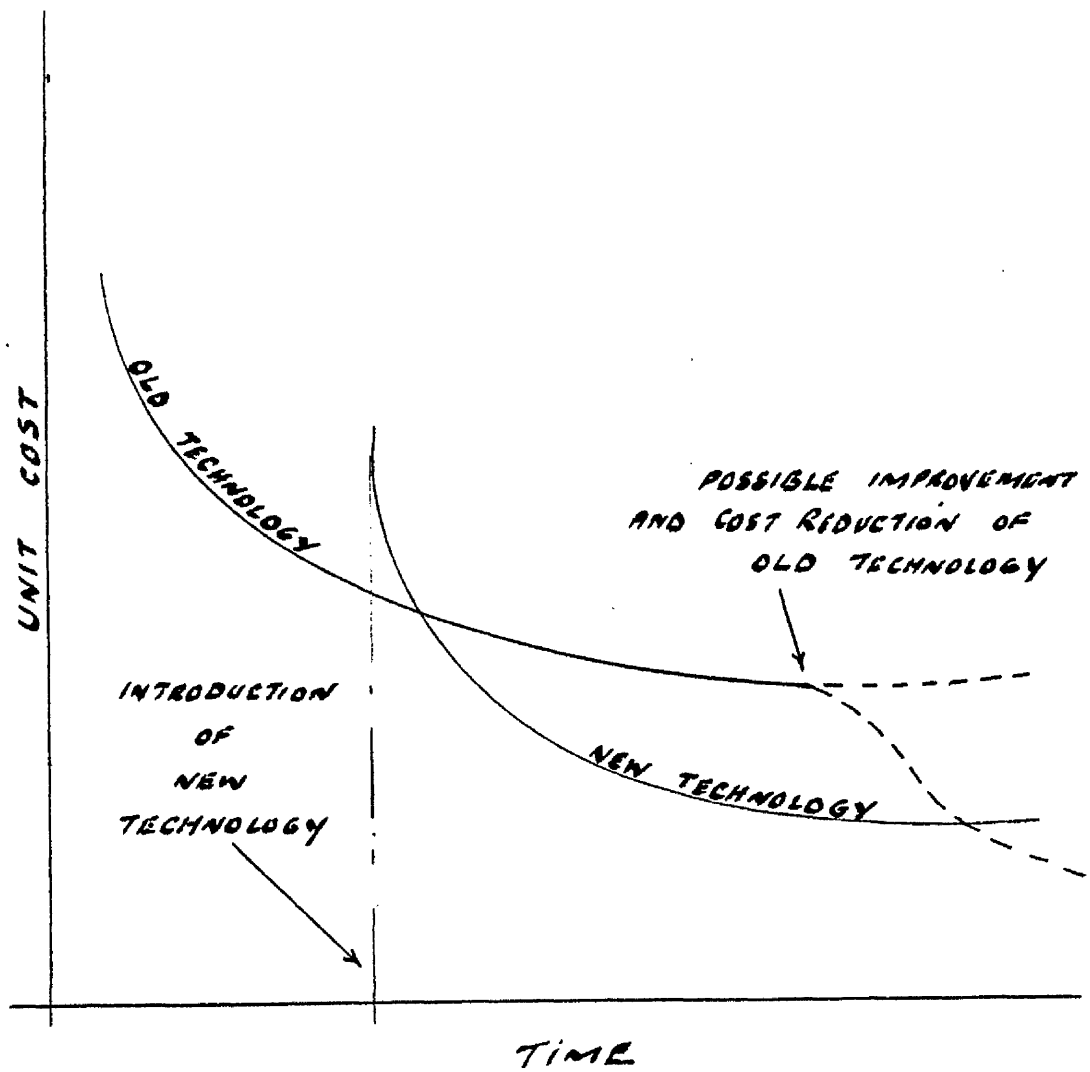
Dr. James Utterback of MIT sees the dilemma for companies in established technology: to begin with, the new technology has a high unit cost, and may not seem a threat. But, as production volumes and competition increase, it quickly progresses down a learning curve and becomes much cheaper. By then, it may be too late for the established company to move into the new technology. Equally it may be too late for it to improve and cost reduce, the old technology to make it competitive again (the lower of the two dotted lines - Unit Costs = How New Technology Can Oust the Old - or Vice Versa).



"The importance of the micro-processor revolution is still completely underestimated in Britain both in terms of its employment consequences and of its overall economic consequences. This is partly because the "automation scare" of the 1950s did not materialise or materialised rather slowly and in a much less dramatic way than had been predicted by some of the early prophets of computerisation. New technologies such as micro-processors are extremely small, extremely reliable and extraordinarily cheap. Moreover they are coming in at a time when there now exists a fairly large pool of skilled people (although not large enough) already familiar with electronic computer technology and systems analysis. The scale of applications in the UK has so far been too small to have perceptible effects on the aggregate employment trend. The impact will come in the 1980s and 1990s and it will take a new cycle of investment in manufacturing and the services before the full consequences are felt." Professor Christopher Freeman, Professor of Science Policy at the Science Policy Research Unit, University of Sussex.

"More automation and greater use of robots in manufacturing industry - up to a level common among Britain's industrial rivals - was called for in a report prepared by the Government's Advisory Council on Applied Research and Development (ACARD). Countries - such as Japan, America and West Germany, which were making the greatest use of the new manufacturing technologies - found that an increased demand for skilled people more than offset the initial unemployment. There would be a need for a major shift in industrial resources to the new technology.

Report's principal recommendations are that:

- o The role of introduction of automated manufacturing techniques into UK industry must be accelerated.
- o National centers for demonstrating the new technologies must be established.
- o Government and industry should work out the best way of establishing a British robotics industry.
- o Facilities to promote the use of the more capital-intensive new welding techniques are needed.

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- o Adhesive bonding should be used more widely by industry.
- o Education programmes must reflect the most advanced ideas in joining and assembly operations.
- o Universities and polytechnics should have more specific roles in introducing the new technologies like those used in West Germany."

Sir Henry Chilver, Cranfield Institute of Technology.

Employers.

"If British industry is to succeed, it must succeed in developing and applying new technology as well as or better than its competitors. There is a skill shortage and that could grow as more new technology becomes available demanding more skills." Sir Alistair Pilkington for C.B.I.

Institutions.

"Technological and Scientific exploration - in the broadest sense - creates the potential for invention and for change. When implemented commercially, major technological change will often have consequences on the nature of work; on jobs, and possibly on the environment. Such consequences can be socially desirable or not." The Production Engineer. 1976.

"Aspects of industrial policy in which a consensus approach is required include support for exports, research into new technologies and methods of improving productivity." British Institute of Management. 1978.

"The Institution of Production Engineers in the UK and the American Institute of Industrial Engineers have co-sponsored a US and European Conference group to discuss new manufacturing technology and how it should be managed." November 1979.

Consultants.

"British Companies maybe slow to adopt micro-electronics. They may be several years behind competing nations in the application of electronics. But, there is no doubt that British managers are very, very aware

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of their potential impact. If there is one area which is going to be affected most, it is mechanical engineering. On the one hand it is hard to see a bolt hole for the unskilled and semi-skilled once the new technologies have made in-roads upon mechanical and general engineering, upon traditional areas of manufacture and indeed on the largest areas of service employment.

If awareness levels in the UK maybe rising fast, this probably owes much to those trade unions which have expressed alarm at both the possible effects on employment and at management's unpreparedness."
P.A. Management Consultants for the Department of Industry.

"Most successful companies in Britain have been found to have -

- o A clearly defined hierarchy of management built to constrain and discipline its workforce to produce standard responses to standard circumstances.
- o Financial procedures designed to control, and by that eliminate the growth of peripheral risky expenditure on projects that are not central to the company's purpose.
- o Accountant led management, oriented to short term goals.
- o Product plans built round marketing and selling power, price and PR rather than new and therefore risky technology.
- o Relative ignorance of Japan and Taiwan."

P.A. Consultants, November 1979.

APPENDIX B

DATES OF PARTICULAR SIGNIFICANCE IN THE HISTORY OF DEVELOPMENT OF MEASURING INSTRUMENTS AND MACHINES

APPENDIX B

SIGNIFICANT DATES IN THE HISTORY OF DEVELOPMENT OF MEASURING MACHINES

1855	Joseph Whitworth exhibits his measuring machine which was a linear type of machine based on end measurement.
1862	Foundation of Societe Genevoise d'Instruments de Physique (S.I.P.) as a corporation in Geneva for the manufacture of physical instruments.
1863	Professor Marc Thury builds the first Linear Dividing Machine with means to correct the errors of the lead screw and a temperature compensator.
1875	Signing of the "International Meter Convention" in Paris.
1909	Construction of the first industrial measuring machine with optical reading on a Standard Scale, measuring length of 40 in. (1 metre).
1921	S.I.P. manufacture the MP-4 the first industrial jig borer.
1924	Founding of the Moore Special Tool Company in Bridgeport Connecticut in 1924, specialising in highly accurate gauges and dies.
1930	S.I.P. Manufacture and market the first three co-ordinate measuring machine called the MU-214B with a range of 6" x 16" x 4" for the Z, X and Y axis respectively.

1932	Moore designs and manufacturers his first jig borer.
1934	S.I.P. develop a jig borer with optical settings called the Hydroptic.
1940	Moore invents the jig grinder.
1950	Moore converts a jig borer to perform as a universal measuring machine.
1950	S.I.P. develop the world's first longitudinal dividing machine and longitudinal comparator controlled by means of photo-electric microscopes.
1959	Ferranti Ltd., Scotland, manufacture and market the first cantilever co-ordinate measuring machine for industrial use called the F1-22.
1960	S.I.P. have sold 900 of their original three co-ordinate measuring machine first marketed in 1930.
1961	S.I.P. manufacture and market the Trioptic measuring machine.
1962	Diginal Electronic Automation (D.E.A.) Turin, Italy are founded with support from Fiat, to produce three co-ordinate measuring machines.
1963	Leitz-Strasmann of West Germany introduce their universal measuring machine. D.E.A. market the first bridge type co-ordinate measuring machine.
1965	Several well known gauge manufacturers begin to market three co-ordinate measuring machines namely: C.E. Johanson, Brown and Sharpe, Carl Zeiss etc.
1965 to Date	Twenty-four firms manufacturing three-co-ordinate measuring machines in nine different countries throughout the world (6).

APPENDIX C

THE MOIRE FRINGE SYSTEM OF GRATING

APPENDIX C

Moire Fringe Principle

When measurement is required of relative movement between two parts, this can be obtained using Moire Fringes. An optical scale is fixed to one part and a smaller scale within a reading head is fixed to the other moving part.

The optical scale consists of equally spaced lines places at intervals and transferred in multiples such that the average line placement is extremely linear. Moire Fringes are formed when two such grating scales are crossed. These fringes are formed at right angles to the equally spaced lines of the scales. Direction information is also obtained because the fringes move in opposite directions for positive and negative movement of the parts.

In the transmission case using two glass gratings, a lamp/lens arrangement provides a collimated beam for illumination, and four photocells pick up the fringes to provide two electrical phases in quadrature, e. g. sine and cosine wave forms. Electronic operations are then performed on the wave forms depending on the requirement of the application (e. g. digital read-out).

A varient on the technique utilises stainless steel reflecting scales which provide fringes and subsequent electrical outputs in an identical manner as described above.

APPENDIX D

A WORLDWIDE REVIEW OF MANUFACTURERS AND THEIR SYSTEMS OF CO-ORDINATE MEASURING MACHINES.

metrology and inspection

CO-ORDINATE MEASURING MACHINES

a world-wide review of manufacturers and their systems

by Sam Black
MBA CEng MIProdE
FIQA AMBIM

This Review is published by the journal *Metrology and Inspection* and additional copies, price £8·50 (post paid) can be obtained from the publishers: IPC Business Press Ltd, (Sales and Distribution), 40 Bowling Green Lane, London EC1R ONE.

Co-ordinate measuring machines
A world-wide review of manufacturers and their systems

Sam Black
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FIQA AMBIM

IN February and April 1974, *Metrology and Inspection* published two articles entitled *Co-ordinate Measuring Machines – a Review*. These articles concentrated mainly on the UK market including both manufacturers in the UK and agents for manufacturers from other countries. Since that time there has been considerable development in this field of metrology.

Sam Black, Quality Control Manager at Caterpillar Tractor Co Ltd, Glasgow, Scotland has been carrying out applied research towards the preparation of a dissertation for a Ph.D Degree within the Department of Management Studies at the University of Glasgow. The major theme of his research has been concerned with the co-ordinate measuring machine user and the organisational problems, training, improved production systems etc. In the course of his research for user problems he gathered extensive information on the overall width of the current market, touching base with manufacturers in Japan, USA and Europe. His findings make it possible not only to publish an update on the 1974 Review but also to look much wider and see what the world offers.

The world of three-axes co-ordinate measuring machines is dominated by twenty-three major companies manufacturing in nine different countries (Table 1) stretching from organisations such as Ferranti Ltd here in the UK, to manufacturers like Makino and Tokyo-Seimitsu in Japan. From a point of view of types of design each manufacturer offers most of the known varieties namely, Bridge, Portal, Cantilever, Universal or Bench† and capacities for standard machines vary from anything as small as 125mm axis movement to a maximum of almost 10 000mm on the x axis: the most popular size falls between the 500 and 1000mm range. The quite recent development of horizontal spindle machines equipped with rotary tables to provide a fourth axis represents a new departure which opens up the possibility of rotating quite large workpieces on a machine whose measuring strokes are nominally of only limited capacity.

Many companies have franchise arrangements between one country and another, thus extending their individual markets while guarding their basic patents and licence. This kind of arrangement tends to standardise design somewhat, although the concept of the co-ordination of three-axes over a basic surface plate tends in itself to limit the extent of difference in design. One aspect which appears to be limited only by imagination is the software and peripheral equipment surrounding the basic machine and this seems to be the significant difference between those organisations who have been longest in the CMM business and the newer groups. Indeed since the last review of CMM made in *Metrology and Inspection* in February/March 1974, this advance in peripheral equipment has been quite dramatic and some aspects of this will be discussed in detail later.

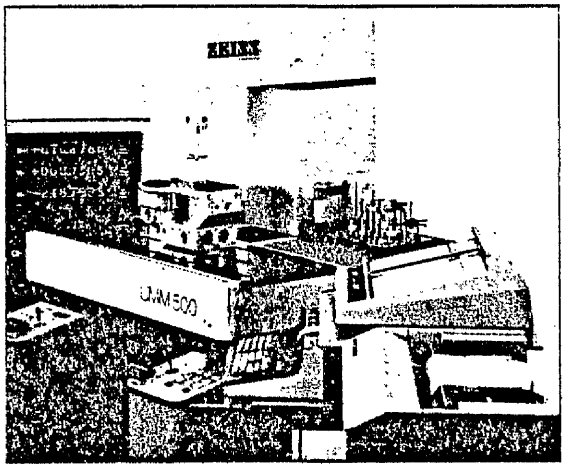
Referring again to the 1974 Review, while several companies mentioned have grown, advanced and even diversified in the last three years, some have pulled out of the business altogether either as an agent or manufacturer. During the research for this article the author found thirty-nine companies in the USA all in the business of measuring machine manufacture; however after deeper investigation there are only five major companies actually in the business, although there are several special purpose manufacturers which we shall also describe later. Table 2 lists the main machines available today and their chief characteristics.

†For the purpose of this article and because of the complexity of current types, a bench machine describes one which has a pillar behind the worktable on which an arm of adjustable height is carried. Z axis movement then derives from a vertical spindle at its outer end. To distinguish cantilever from the more recent horizontal spindle machines, the latter are those which have a pillar-type construction which is either fixed or moving to give x axis motion but through which a horizontal spindle passes to provide a y axis, the spindle moving up or down within the column for z axis motion. Similarly, portal machines are defined as having a fixed bridge structure under which the table passes, bridge-type machines have a travelling bridge structure, while gantry machines have fixed columns and a travelling gantry. It must be noted in many instances that no clear-cut distinctions are possible as many machines incorporate one or more features from other types.

Sam Black is the Quality Control Manager of the Caterpillar Tractor Co Ltd facility 10 miles east of Glasgow. Last year he enrolled as a part time student at Glasgow University via the Scottish Business School to do applied research for a PhD Doctorate within the Department of Management Studies.

Part of Black's work is concerned with researching the changing technology within the machine shop and the effect this is having on the users and organisation structures of the enterprise. He has chosen Co-ordinate Measuring Machines as an example for this change and is interested in any work being done on this subject with respect to use, manufacture or further development of the concept.

In the course of his research he has studied CMM manufacture from many companies and countries as far off as Japan and in this respect is currently developing an international review on this subject.



The Zeiss UMM 500 is a highly developed computer controlled measuring machine.

East Germany

Prior to the Second World War, there was only one Carl Zeiss organisation. Today there are two separate companies named Carl Zeiss – one in East Germany and one in West Germany. The Carl Zeiss organisation in East Germany is commonly called Carl Zeiss Jena and this helps to identify it from that of Carl Zeiss which operates out of Oberkochen, West Germany. Both organisations naturally continue to make similar products including coordinate measuring machines. The East German Carl Zeiss Jena Company offer two basic systems. The first is a large rugged gantry type machine with four pillars supporting a mobile gantry and carrying a five probe measuring head. It has a capacity of 750 × 750 × 400mm and has peripheral back-up equipment such as minicomputer and teleprinters.

The second system the DKM02–300 actually offers two models. The second model is named the DKM1–300D. These machines are of the cantilever design and claim greater accuracy than the larger system. The capacity is 320 × 220 × 150mm. The major difference between the two smaller models is that the DKM02–300 is offered with an optical read-out while the DKM1–300D has a digital display.

Among the tools available with these machines are special attachments for both vertical and horizontal scanning of the work piece. Peripheral equipment such as high speed printers, punch tape and mini computer are available as part of a modular arrangement.

West Germany

Carl Zeiss of West Germany offer two basic CMM systems namely the UMM 500 and UMM 800. The UMM 500 is without doubt a highly comprehensive system of coordinate measuring. It is in terms of design and application a CMM of tomorrow, although we have it today. It therefore makes it difficult to justify in a few words of description. The basic structure is of the cantilever design with the x axis movement coming from the surface table and the y and z movements from the cantilever head. It has a capacity of 500 × 200 × 300mm. All axes are motorized, measuring accuracy per co-ordinate is given as $\pm$ (0·8 + 250 μL) mm. The machine is equipped for automatic probing, has a star probe, 3d zero point and online desk calculator. Two very neat control panels are situated on the right and left knee of the base support. They carry two joysticks for stage travel and the probing in all co-ordinates, the left-hand keyboard is used for preselection of the operating mode of the 3d probe head, the right hand keyboard calls up the required measuring routines. Data processing is performed with HP9810A desk calculator with alphanumeric printer and an integral control panel with exchangeable designation masks makes the computer part of the measuring procedure. Plotters, typewriters, tape readers and magnetic tape cassettes can be connected as peripherals.

The UMM 800 is of entirely different design to the 500 as it is a rugged bridge system with the whole structure moving along a high sided base plate structure. The measuring probe head is carried on the bridge and has similar control panels with joysticks on the right hand knee of the side support. The capacity is 800 × 800 × 300mm making it suitable for fairly large components and special ancillary equipment. The 800 is equipped with the same peripheral gear as the 500.

The recent introduction of two further bridge type machines aimed at workshop use, the WMM 550 and WMM 850, extends the Carl Zeiss range. Evolved from the UMM series, these machines use granite for the table and beams, incorporate the spatial probing facility and joystick control of the UMM machines and cover measuring capacities of 550 × 500 × 450mm and 850 × 700 × 600mm respectively. A CNC option is available, making the machines into a fully automatic measuring centre.

The Mauser Company offer two models within the Komeg system, the KM-Z has a capacity of 2000 × 1200 × 1000mm and is of a bridge design. The bridge has a double pillar support on one side and a single moving pillar on the other. This design permits better access for loading work pieces but still provides a very robust machine. The position of the drive and measuring systems is selected to provide optimum guiding and high measuring accuracy (Abbe principle). A Zeiss 3-axis measuring head is incorporated in this machine, Zeiss software is used for the computer which is completely integrated with the machine function and the worktable is motorised for easy movement of the component to the probe on the z axis. The KM1000-Z has a capacity of 1000 × 800 × 600mm and is of exactly the same design and concept as the larger model.

F. A. G. Kugel Fischer manufacture four models ranging from capacities of 400 × 400 × 400mm up to 3000 × 1800 × 1000mm in the largest model. The design of these machines is of the cantilever type with good ergonomic location of controls.

Ernst Leitz offer two cantilever designed models not unlike the F. A. G. model, except for the special control console which is located at the knee position on the front of the machine. The two models are the Leitz-Strasmann which has a capacity of 1000 × 300 × 200mm and the UPM-3D which is an automatic machine with a capacity of 200 × 100 × 200mm. More recently Leitz have introduced a portal bridge machine based on granite elements, the PMM 864, giving a capacity of 800 × 600 × 400mm. This is a CNC machine with a built-in rotary table and facility for profile scanning. Full data processing and visual display facilities are offered with it.

France

Renault Machine Tools manufacture the MMT 1300 coordinate measuring machine which has a capacity of 1300 × 800 × 500mm and a claimed resolution of 0.002mm. The machine construction is of the bridge type design, the base being a solid granite tee-slotted worktable supporting a travelling bridge structure running on special air bearings along each side of the worktable making it easy for rapid manual movement. The measuring head runs across the y axis supported on the bridge gantry again on air bearings. There are fine micrometer adjustments on all axes and a hand pendant control is available for easy programming by the operator.

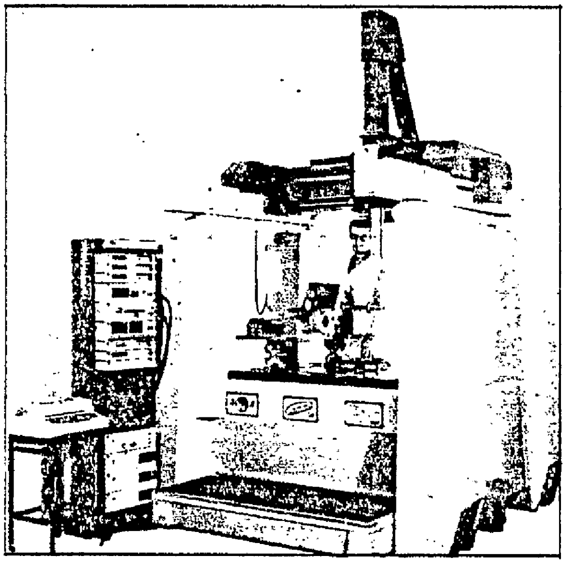
The MMT 1300 has a complete set of probe accessories including a multi-directional electronic probe, a rotary table and a peripheral back-up of digital readout, calculator, printer and plotter. A further option is the availability of a longer base table extending the x axis from the standard 1300mm up to 6000mm; the axes can be motorised if required.

Italy

There are two prominent manufacturers of CMM in Italy; they are Digital Electronic Automation (D.E.A.) and Olivetti. The former is indeed the giant in the CMM business in terms of the measuring range and capacities offered in their six major systems as well as the standard models which we will describe shortly. D.E.A. cover many special purpose applications especially related to large components such as aircraft frames and motor car production. The D.E.A. range starts with the Iota models used principally for solving high precision measuring problems on parts of small and medium size, the standard model has a 760 × 500 × 400mm capacity, while a newly developed version has a greater capacity 1320 × 500 × 400mm and is capable of accommodating long and narrow piece parts. The table is mounted on a three-point base and the bridge structure carrying the head moves on air bearings at either side of the granite table. Measurement is by direct reading optical scales and resolution at the read-out is 0.002mm with a seven-digit display plus direction. The Iota models, in keeping with other D.E.A. machines, have live electronic probes as a feature of the probe range allowing measurements to be taken 'on the fly' together with indexable five position tool holders. The second of the D.E.A. range of six basic systems is the Gamma which is

Table 1. Summary of the world's co-ordinate measuring machine producers.

Country	No. of companies	No. of models or systems	Maximum capacity range (mm)	Types
East Germany	1	2	x – 750 y – 750 z – 400	Gantry Cantilever
France	1	1	x – 1300 y – 800 z – 500	Bridge
West Germany	4	12	x – 3000 y – 1800 z – 1000	Universal Bridge Cantilever
Italy	2	9	x – 9970 y – 1600 z – 1000	Bridge Cantilever Gantry Horizontal spindle
Japan	3	10	x – 1200 y – 1000 z – 350	Bridge Portal Gantry Cantilever
Sweden	1	4	x – 750 y – 450 z – 300	Cantilever Bench
Switzerland	3	5	x – 700 y – 500 z – 300	Bridge Gantry Portal Cantilever Universal Bench
UK	4	14	x – 2950 y – 1130 z – 1168	Bridge Cantilever Portal Gantry Bench Horizontal spindle
USA	5	26	x – 1830 y – 760 z – 915	Bench Bridge Portal Cantilever Universal
9 Countries	24	83	Largest (Italy) x – 9970 y – 1600 z – 1000	7 types



The peripheral equipment which can be added to this Gamma machine puts D.E.A. into the semi-automatic market.

a four pillar gantry-type CMM with a capacity of 1000 × 800 × 500mm. This machine with additional peripheral equipment begins to put D.E.A. into the semi-automatic market capable of displaying and recording master dimension values, pre-set tolerances, block identification numbers and deviations between the theoretical and actually measured values.

The remaining D.E.A. systems, namely the Sigma, Beta, Delta and Alpha, are the larger capacity group and offer various advantages to the user. The Sigma differs somewhat from the other models having a three point suspension system, three columns and springs supporting the moving members. With its claimed accuracy of ±0.01mm per metre and a measuring envelope of 1800 × 1000 × 1000mm, it is designed principally to overcome the problem of making precision measurements on large parts without concern for vibrations or workpiece weight.

The Beta family, with eleven models ranging from 800mm to 9970mm on the long measuring axis, is designed basically for the workshop environment. These machines are of the four pillar type and come in two versions – standard and super – the difference being in accuracy and resolution. The Beta L line has been expanded and comes in models with 4, 6 or 8 supporting columns which stand on reinforced concrete foundations, lending itself readily to applications such as aerospace and off-the-road vehicle industries.

Despite the size of these machines, read-out resolution is claimed at 0.01mm and even finer with additional mini-computer systems. The Delta model is again a four pillar structure with the measuring head mounted on a gantry traversing between the top beams, this time with a long z axis stroke starting at 2050mm. Components such as large fabrications are easily measured. The capacity of the machine ranges upwards from 5000 × 2400 × 2050mm and all axes are motorised. In the most sophisticated version, the Delta is supplied with DEAC 1001, one of the most advanced integrated circuit stored programme computers now in existence; besides performing normal inspection and three dimensional measuring and layout operations, it can also execute continuous surface scanning with in-line data processing both for inspection checks and preparations of tapes for NC milling.

The Alpha CMM is the largest inspection and measuring system in the world and can be built to handle almost any dimension, although the effective working volume can reach 7000 × 2500 on the horizontal plane with 2000mm in the vertical plane. The structure of this giant is similar to the Delta range, with large supporting columns carrying a moving inspection head on a bridge system. Like its smaller brother, this machine has all the facilities for producing punched tape. An added feature, available due to its extra heavy construction, is continuous path milling operations on wood, plastics or light metal models through the use of an automatic indexing milling head.

In addition to the large range of CMM models, D.E.A. also offer a wide range of touch finger probes, mechanical tooling and modular electronics with computer integration.

The other major Italian company in the CMM business is of course Olivetti, a company with a very wide diversification of interest yet meeting a ready market with its special range of co-ordinate measuring machines named Inspector. These machines come in three basic systems known as the Mini, Midi and Maxi within which there are several models offered. The Inspector Mini is a very compact cantilever design with a capacity of 170 × 170 × 170mm stretching to 420 × 320 × 170mm for the three models within this system; it boasts an accuracy of ±2·5μm on average for each axis and each axis has a motor driven micrometer adjustment. The middle range system, Inspector Midi, is again the vertically presented cantilever design with capacities from 800 × 400 × 255mm up to 1150 × 400 × 405mm within the three models offered. It has several interesting features such as an angular orientation device, ±30 degrees in the x, y axis to facilitate component alignment, and a special rotary table.

The largest Olivetti Inspector systems come in two distinct designs. The first is of the horizontal type with all movements, whether x, y or z, being obtained by moving the horizontally mounted probe – a fourth axis is possible when the rotary table, which is standard, is incorporated. There are four models in this system, two Midi and two Maxi, with a maximum range of 900 × 1400 × 600mm and a claimed accuracy of ±8μm. The second design is the vertical bridge type Inspector Maxi, coming in two models 900 × 1140 × 405mm and 900 × 1640 × 405mm respectively. Again the accuracy for the x, y and z axes is ±8μm.

The interesting feature with all the Olivetti Inspector systems is their robust solid looking appearance. All of the models are backed up with Olivetti electronic and calculating systems offering such things as central memory extensions, integrated alpha numeric printers and asynchronous line control unit for time-sharing applications and for connection to compatible peripheral units.

Japan

There are two major manufacturers of co-ordinate measuring machines in Japan – Tokyo Seimitsu Co and Mitutoyo Manufacturing Co – and three companies involved in importing CMM – Tokyo Seimitsu Co, importing Ferranti equipment, Tokyo Boeki Co, importing Bendix machines from the USA and Kokusai Koki Company bringing in D.E.A. machines from Italy. Makino milling machine whose main business is machine tool manufacture, especially numerical control, manufacture one model of CMM.

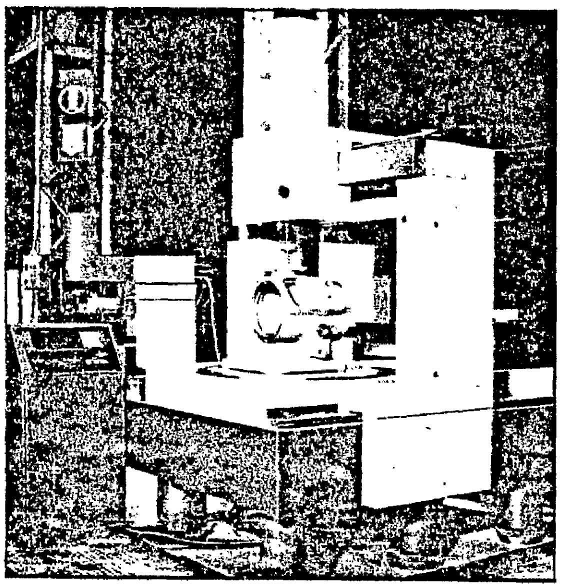
Tokyo Seimitsu Co, a large inspection equipment manufacturer, offer eight models of CMM mainly designed around the Ferranti and Bendix style of equipment. Three of the models offered are in fact Ferranti

Mercury, Conquest and Cordax, the other models are all cantilever designs ranging from the 700-3B to the M1000-3B, the two exceptions are portal bridge and the neat 300-3B with mobile table and the robust A1000C which is a smaller version of the Ferranti Saturn. The Japanese equipment makes maximum use of peripheral equipment such as printers and plotters.

Mitutoyo Manufacturing Co, founded as a gauge maker away back in 1934, now offer six models of CMM all of which are of bridge and gantry design supported by almost oriental styled side walls. The smallest models, which are bench type, the A11 and A12 Microcord, have capacities of 300 × 300 × 200mm and 500 × 400 × 200mm for x, y and z axes respectively. Uniquely they offer both a standard and economy class in these ranges, the main difference being resolution of 0.005mm in the economy class and 0.001mm in the standard model. In addition, the indicating accuracy and repeatability are much finer with the standard model. The larger models are the A21 and A22 Microcord and they have capacities of 700 × 500 × 250mm, the A22 being a slightly larger machine with an added feature of a motor driven granite elevating table. Both machines are floor mounted. All models are operated manually and come with a standard package of fixed probes; a 3D electronic touch probe is offered as an optional extra.

Apart from the two companies previously mentioned who import CMM into Japan, the only other large 3-axes CMM is manufactured by Makino Milling Machine Company of Tokyo. Their machine is the recently developed TM-1210 and has obviously been developed from an NC machining centre originally used for light milling and point to point drilling on a mobile base table. Its principal use is with complex curved surfaces and profiles of a 3-dimensional nature; it has a large volumetric work area of 1200 × 1000 × 350mm for x, y and z respectively with automatic feed in all directions and a rapid traverse of 2400mm/min.

One interesting feature of this machine is its use for NC tape preparation. The model on the table is continuously traced by the tracing operation, the movements of the machine at that time are detected independently for the x,

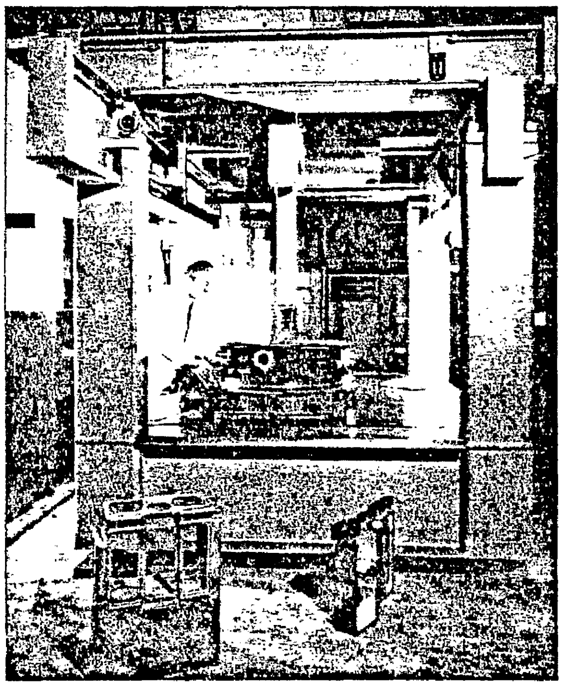


This Olivetti Inspector Maxi machine, like all models in the range, is backed up with electronic and calculating systems.

y and z axes and these values are directly output in NC tape as the machine automatic tracing part programme by means of a high-speed tape punch. The TM-1210 body is controlled and driven by the Fanuc 330 control unit based on control commands from the mini-computer. In the case of 3-dimension co-ordinate measurement, the 2-axes other than the approach axis are positioned, the measurement point of the work on the table is then approached, the amount of displacement x, y, z or the feeler is detected by the Accuratrace 6 tracer head and approach is stopped at the point at which the composite displacement coincides with the set value. The amount of mechanical movement at this time is detected by the positive detector and the data are printed out by a typewriter when basic co-ordinate measurement is performed by point measurement and the co-ordinate values of the measured points are clarified by means of drawings etc. Automatic measurement is possible by inputting the expected value in the form of a measurement programme and the expected values and their difference are typed out.

Sweden

C. E. Johansson, the world-renowned maker of gauges, entered the inspection machine business about five years ago with the Cordimet 350 which has a measuring capacity of 350 × 250 × 200mm and a fixed column carrying the measuring head which moves only the z-axis, the table providing x and y movements. Since that time they have offered the Cordimin, which is in essence a combination of a miniature co-ordinate measuring machine and a toolmaker's microscope, with a 125 × 100mm x and y range and a facility for digital indication of z co-ordinate value as an optional accessory. It has a measuring accuracy of ±0.005mm true position in x-y plane for any z value, within ±3 sigma.



The worktable on the Ferranti Saturn 2000S is separate from the main frame to avoid distortion due to heavy components.

More recently Johansson have introduced the Cordimet 700 which is in effect an enlarged version of the original Cordimet. The measuring range has been extended somewhat to 700 × 450 × 300mm for the x, y and z axes respectively. The 700 is virtually a cantilever machine and has been made robust enough to accept heavier components and the diabase for both the y and x axes have equally been extended to accommodate the increased range, thus the measuring head is no longer stationary as in the former model but moves about the worktable which has a facility for swivel and levelling; the measuring accuracy of ±0·01mm and repeatability of ±0·005mm are the same as the original model. The Cordimet 700 now takes C. E. Johansson into the medium size market of CMM equipment. Similar in construction to the Cordimet 700 is a recent introduction – the 1200.

Switzerland

Switzerland may lay claim to being the country where the first co-ordinate measuring machine was evolved, the honour falling to Societe Genevoise – no doubt in one of their highly efficient gauge laboratories. However, there are three major companies involved in the manufacture of CMM in Switzerland today.

Henri Hauser Ltd offer the 5M-DR co-ordinate measuring machine among their wide range of other equipment such as jig borers, jig grinders, profile projectors etc; indeed their CMM is of a similar design to the jig borer concept with a fixed portal type structure carrying a probe measuring head over a mobile table for the long x axis. It has a capacity of 700 × 500 × 300mm for the x, y and z axes and a directional digital readout display with 6 metric digits. The accuracy claimed is 0.003mm.

Tesa S.A. manufacture the Validator 10, which is a single column cantilever design made principally as an economic cost saving device for easy adaptability in most workshop environments. This machine with a capacity of 300 × 300 × 125mm is mounted on a basic bench type structure and would be operated on at a sitting position. It comes equipped either as standard or as optional with a full range of gadgets such as a tool trolley, digital printer, table calculator etc.

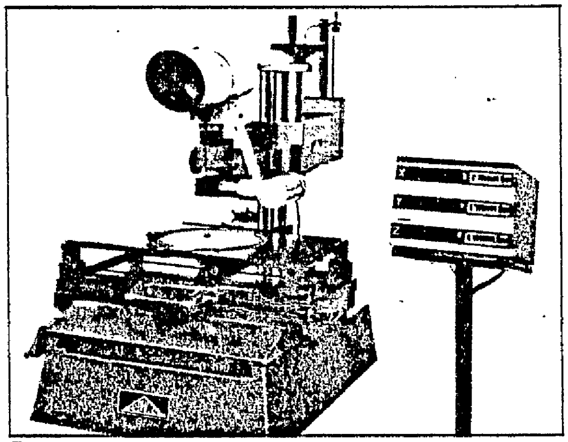
Societe Genevoise D'Instruments De Physique was probably the first company to produce a true three co-ordinate measuring machine in the shape of the Trioptic universal measuring machine, first marketed in the early 1960's and closely followed by models from Moore in the USA and Ferranti in Scotland. Today Societe Genevoise offer three models. The Mu-314 is a bench type universal three axes measuring machine with a capacity of 400 × 100 × 145mm and its principal purpose is the checking of gauges, tools, jigs, reference masters and the general inspection of precision work pieces produced in small quantities. The original Trioptic is still offered and, while the capacity is the same as the original version at 400 × 200 × 200mm and although the basic design is identical, the latest model has the benefit of electronically amplified multidirectional probes with analogue reading for horizontal and vertical measurement.

The latest product from the Societe Genevoise group is the SIP 422m, again based on the same design as the Trioptic but backed by all the latest peripheral equipment such as multidirectional probe, control by on-line desktop calculators, data processing and printers. The measuring range is 400 × 200 × 200mm, it can support a maximum work load of 150 kg and it has an average accuracy for all axes of 0·8μm. With its wide variety of optional back-up equipment the SIP 422m becomes an extremely versatile co-ordinate measuring machine. Automatic positioning data can be set on digital switches to allow true positions to be reached by the moving members and any discrepancy read off the digital display.

United Kingdom

There are several agents for the sale of CMM in the UK, but there are only three major UK manufacturers. Ferranti is the oldest as far as three-axes machines are concerned and today they offer a range of eight standard models obviously meeting a wide variety of applications. The flagship of the range would be the Cordax series which comes in three sizes. The Cordax 3000 has a capacity of 760 × 508 × 660mm while the Cordax 7000 has a capacity of 1830 × 760 × 915mm for the x, y and z axes respectively. Each model is of the cantilever design constructed on a base frame which is an all welded steel fabrication providing support for both work table and the x axis beam. Another special feature of the Cordax range is the provision in the x and y axes of fine positioning control which permit continuous adjustment over the full length of axis travel. The 3000 and 5000 are fitted with elevating tables, but all models utilise the well-proven Ferranti Moiré fringe measuring system providing instantaneous digital readout. The measuring accuracy claimed is ±0.0075, ±0.0125 and ±0.0025mm for the 3000, 5000 and 7000 respectively. All the models are supported with a wide range of accessories such as probes, microscopes, computers and printers.

The Ferranti Saturn is a CMM with a difference in that it departs from the now familiar Ferranti cantilever design and moves to a gantry type design which has four pillars supporting a mobile bridge carrying the measuring head and probe. It has a large capacity at 2000 × 1250 × 1000mm for the x, y and z axes respectively, note



The Windley Crown illustrated is complete with optical projector and glass rotary table.

especially the long z travel; there is motor drive on all axes and the worktable is separate from the main frame such that heavy components do not distort the frame; accuracy of ±0.05mm per axis is claimed. The Saturn is backed by the computer-aided inspection system comprising a Digital Equipment Corporation PDP-8 computer, with associated software, a purpose built Ferranti interface unit and a Data Dynamics 33ASR teleprinter. This system combined with electronic probes makes the Saturn an extremely versatile machine. The operator can measure an output data from the component by means of simple keyboard characters, calculations such as off-set correction, deviation, out-of-tolerance, time position and many others.

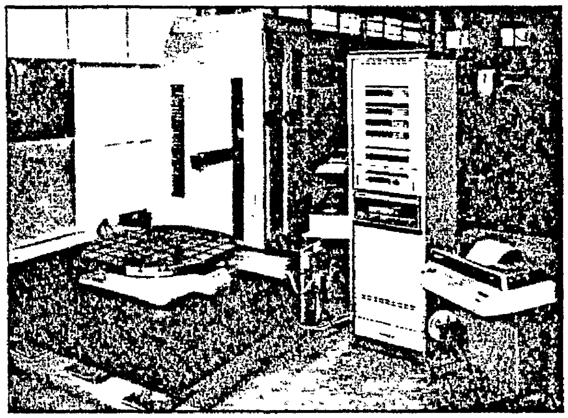
Ferranti offer the Cordax 1000 which is a $2\frac{1}{2}$-axes model, that is a 3-axes measurement capability with 2-axes counter. This machine with its capacity of 610 × 450 × 203mm is suitable for bench mounting and it includes a built in swivel table. The Mercury is a low cost modular concept machine with a capacity of 508 × 406 × 203mm with a ±0.025mm accuracy. Again it can be used on a basic surface table. The Conquest is in the medium range and has a capacity of 610 × 380 × 200mm. It has a motorised elevating rable, an accuracy of ±0.010mm and is backed by a wide range of Ferranti accessories including a printout unit and a computer.

The Cordax DCC (Direct Computer Control) measuring machines are the latest development from the Ferranti stable and are designed to automatically measure the dimensional co-ordinates of a wide variety of workpieces such as cams, gearboxes, video picture tubes and so on. The integral digital computer performs the tasks of probe positioning, data acquisition, processing and display, machine control including nominal position calculating ability, fault sensing and other significant functions. The Cordax DCC is available on the Cordax 3000, 5000 and 7000 machines.

Windley Bros Ltd produce two models of CMM, the Crown and the New Crown 3D. The Crown, first introduced in 1973, is a highly compact bench type machine with a capacity of 350 × 300 × 200mm and has a projector measuring system available as an option, the additional projector arm complete with focus slide is mounted to the back of the usual horizontal arm, and by withdrawing and re-engaging a reference key, the whole arm assembly can be indexed 180 degrees to bring the projector arm over the working area. There are two models offered at this size: one is fitted with coarse and micro-feed controls on all three axes giving read-out accuracy of 0.002mm, while the second model is primarily designed for taper probes and has a read-out accuracy of 0.010mm.

The New Crown 3D is of a bridge design carrying the probe head and moving along a high density black granite table on frictionless air bearings. The 750 × 700 × 500mm capacity provides a wide range of capability for component measurement and marking out methods. Again the two models are available with 0.002mm and 0.010mm accuracy of read-out respectively. Both taper probes and electronic probes can be utilised on the Crown models.

L K Tool Co Ltd offer a range of three major systems covering the bridge, cantilever and bench designs. The Maxi-Check Dimension Four represents the largest standard model produced although L K Tool Co Ltd appear to have the capability and pioneering inclination to make co-ordinate measuring machines to suit almost any customer need. The Maxi-Check Super may be an example of this; however the Maxi-Check has five models within its system ranging from 560 × 1156 × 533mm to 2950 × 1130 × 1168mm. It claims an overall accuracy on the x axis of ±0.010mm up to ±0.038mm for the range of five models. The Dimension Four System is of the bridge design carrying the measuring head along with an integrated digital readout on both metric or Imperial. This machine offers, as standard, plug in options for teletype printer unit, mini computer, power control to give rapid movement of fine adjustment and inching modes or, alternatively, to take a choice of NC or CNC modules, a wide variety of probes are available including a three axes electronic probe. The peripheral equipment available for the Maxi-Check can include a very useful Hewlett Packard 2644 Visual Display Unit with cartridges. This unit coupled with a high speed printer can just about meet all the information needs a customer would desire at this time.



The Metre Four is the latest machine in the range offered by L. K. Tool Co Ltd.

The Maxi-Check Super has a capacity of 9000 × 3000 × 1800mm with a construction similar to the other Maxi-Check models only with a much larger working surface. It is intended for NC operations linked to a computer and plotter and has a claimed accuracy of ±0.025mm.

The Micro Four (now evolved as the Metre Four) is a CMM designed for high precision measurements of four axes because of the rotary table facility and provides for inspection of all angular faces and holes on rectilinear components etc. The range of capacity is 600 × 280 × 450mm with a claimed accuracy of 0.004mm. Again this model has the ultra sensitive 3-axis switch, this is used in conjunction with the teletype unit of the L K Micro-Four for the automatic recording of data on each axis. The horizontal spindle design makes for easy operation and has extremely wide versatility when linked with the previously described peripheral equipment.

The Micrometer is a small bench type CMM with a capacity of 40 × 20 × 40mm, manually operated using taper probes for fast checking of small components on the standard rotary table.

United States of America

Of the thirty-nine companies listed in the US publication *Quality 1975* as being manufacturers or suppliers of measuring machines, only five are actually involved in manufacturing three co-ordinate measuring machines in the USA, the others are suppliers of non-USA manufacturers' products, manufacturers of components for CMM, such as granite surface tables, and manufacturers who have withdrawn from the CMM business since July 1975. The remaining major US manufacturers are the Bendix Corporation, Boice Division of Mechanical Technology Incorporated, Brown and Sharpe Manufacturing Company, Moore Special Tool Co Incorporated and Hansford Manufacturing Corporation.

The Bendix Corporation Automation and Measurement Division manufacture the Sheffield Product Line which is in fact the Cordax system previously described under the Ferranti group for UK manufacturers. Bendix and Ferranti have a licensing agreement between their products. The Cordax line will not be described again, except to mention that Sheffield offer a whole range of non-standard special purpose CMM generally developed from one of the basic Cordax systems. Some examples of tolerance, time position and many others.

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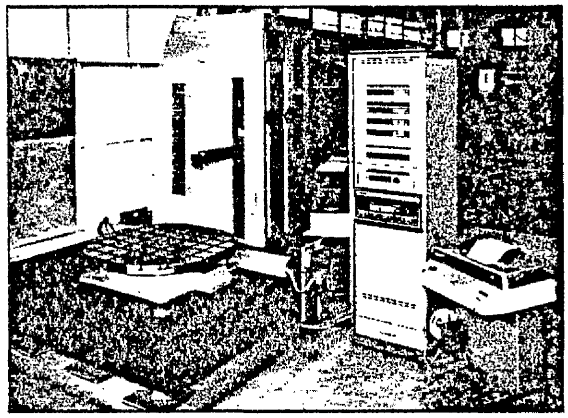

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The Acrocord is the trade name given to the CMM products manufactured by the Boice Corporation. There are six models within the range stretching in capacity from 740 × 450 × 325mm up to 1800 × 900 × 750mm with a measuring accuracy ranging from ±0.0125mm to ±0.015mm depending upon the model selected. All of the models are of the cantilever design and use granite worktables as surface plates, power elevation is available on the three larger models only and all axes have air bearings for smooth linear motion with minimum need for maintenance due to the absence of wear.

The Boice equipment use the Linear Inductosyn Scale developed by Farrand Controls Inc. This system minimises the possibility of errors created by dust, chips, smoke, oil or fumes. It utilises the inductive coupling between conductors separated by a small air space. It is claimed that angular accuracy of the Inductosyn Scale of better than one second of arc and linear accuracy of better than 50 microinches is achievable. All six models are interfaced with peripheral equipment such as computers, printers, plotters etc, according to the needs of the customer.

Brown and Sharpe offer four models of their Validator system ranging from capacities of 685 × 1200 × 915mm to 1200 × 1800 × 915mm for the x, y and z axes respectively. The basic design is of the bridge formation – the measuring probe head being carried on the bridge superstructure and sitting on a surface table. The interesting aspect of the Validator system is the ready availability of a library of thirty-four standard measuring programmes which will obviously minimise set-up and measuring time, these can be computer assisted or totally computer controlled, therefore the system has peripheral equipment available such as computers, printers and tape readers together with a wide range of probes.

Moore Special Tool Company manufacture four systems of CMM among their extensive range of measuring equipment and machine tools. Moore was one of the early pioneers of three-axes co-ordinate measuring machines somewhat like Societe Genevoise in Switzerland. The M-32Z is a universal measuring machine with a portal bridge design. It has a capacity of 800 × 450mm for the x and y axes and a 250mm vertical travel for the z axis. It has high accuracy at 0.6μm for any 30mm of movement. The machine can be equipped with pre-select positioning and readout systems. The M-48Z has the same portal design as the M-32Z but it moves into a larger capacity range with 1200 × 600 × 250mm for the x, y and z axes respectively. This model can be equipped with remote operation controls, is adaptable to laser interferometers and retrofit provisions for input and output interface to computer control.

The two smaller models in the Moore range are the M-18Z and M-14Z. These are in effect of the jig borer design and are adapted from the two axes models to permit a third vertical z axis movement. The capacity of the M-14Z is 230 × 360 × 360mm and the M-18Z is 280 × 450 × 400mm for the x, y and z axes respectively, again in keeping with the larger models previously described. These machines are of very high accuracy claimed at 0·4μm maximum error for any 30mm of travel. Peripheral equipment such as microscopes with close-circuit television monitoring is available as an optional extra.

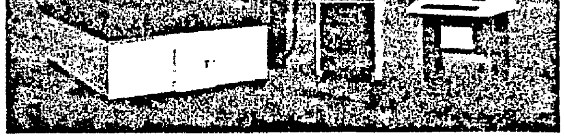
The Hansford Manufacturing Company produce seven models of the Rapid-Check system, these machines are of a fairly simple bridge type design and come in capacities stretching from 700 × 700 × 250mm to 1600 × 1000 × 250mm. The base of the machine is a granite surface plate supporting a lightweight bridge structure running on self-aligning ball bearings. The bridge structure can be offered separately to fit to an existing surface plate. The machine comes equipped with a digital read-out display console and a set of conical probes. A computer and printer are available as options but the real purpose of this machine is rapid manual checks of large sheet metal components for which it seems an ideal design.

Summary

Since the publication of the first review there are several companies which no longer manufacture nor act as agents for co-ordinate measuring machines. The following have now come out of the business: P.M.C. Industries and Lucas Machine Division of Ohio, USA, C. E. J. Cage Co of Michigan USA, Fine Limit Group Sales Ltd of the UK, Coventry Gauge Ltd of UK, and Farrand Control of New York, USA.

It should also be noted that current arrangements for the manufacture, design and marketing of Maxi-Check machines are undergoing change and may result in both L. K. Tool Co Ltd and Notsa Engineering Co Ltd producing independently.

Many other companies offer very special purpose or customer design three-axes co-ordinate measuring machines. Some of these have already been mentioned in the standard type range and will not be covered again. The remaining specialists are: Johann Fischer of Aschaffenburg, West Germany, Cranfield Unit for Precision Engineering of Bedford, UK, Fellow Corporation of Vermont, USA (specialist in gear measurement), Eaton-Leonard of California, USA (vector/tube measurement), Gaertner Scientific of Chicago, USA for microscopic 3-axes measurement, Jones and Lamson of Vermont, USA with the metric eye, Penumo Precision Inc of New Hampshire, USA, Stiefelmayer of West Germany, Portage, Double Quick Inc, Ohio, USA, Pratt and Whitney Machine Tool Division, Connecticut, USA, Opto Mechanisms Inc of New York, USA, and Potter Instrument Co Inc, New York, USA.



The Validator 300, one of four computer controlled models from Brown & Sharpe.

TABLE 2. CHARACTERISTICS OF THREE-AXIS CO-ORDINATE MEASURING MACHINES AVAILABLE WORLD-WIDE

Manufacturer (UK Agent)	*Model/Name*	*Capacity*	*Type*	*Construction*	*Control*	*Probe*	*Display readout*	*Special features*
East Germany								
Carl Zeiss Jena (C.Z. Scientific Instruments Ltd)	DKM1–750 DA	x – 750 y – 750 z – 400	Gantry	Welded steel and cast surface plate	Motorized	Electronic	Digital Printer Tape	
	DKM02–300	x – 320 y – 220 z – 150	Cantilever	Cast with precision guideways	Manual	Electronic	Digital Optical Printer Tape Punch	
France								
Renault (Rank Taylor Hobson)	MMT 1300	x – 1300 y – 800 z – 500	Bridge	Granite base welded steel gantry.	Manual	Electronic	Digital Printer Plotter	
West Germany								
FAG Kugel Fischer	PL 100	x – 1000 y – 1000 z – 1000	Cantilever	NA	NA	NA	NA	
	MGM 546	x – 500 y – 400 z – 600	Cantilever	NA	NA	NA	NA	
	MGM 400	x – 400 y – 400 z – 400	Cantilever	NA	NA	NA	NA	
	MGC 3000	x – 3000 y – 1800 z – 1000	Cantilever	NA	NA	NA	NA	
Ernst Leitz	Leitz-3D	x – 1000 y – 300 z – 200	Cantilever	Cast base centre lathe concept.	Motorised	Electronic	Digital Printer	Wang-2200 desk calculator with visual display
	UPM–3D (Automatic)	x – 200 y – 100 z – 200	Cantilever	Table type model on stand	Motorised automatic	Electronic	Digital Thermo-printer Typewriter Plotter	Wang-2200 desk calculator with visual display
	PMM 864	x – 800 y – 600 z – 400	Portal Bridge	Granite base and guideways	Motorised	Automatic	Digital Printer Plotter	Wang-2200 desk calculator with
Mauser Komeg (Hahn & Kolb Co Ltd)	KM–Z	x – 2000 y – 1200 z – 1000	Bridge	Machine bed and fixed gantry	Automatic	Electronic	Digital Printer Plotter	Zeiss 3-axes measuring head
	KM1000–Z	x – 1000 y – 800 z – 600	Bridge	Machine bed and fixed gantry	Automatic	Electronic	Digital Printer Plotter	

Table 2. *(cont.)*

Manufacturer (UK Agent)	*Model/Name*	*Capacity*	*Type*	*Construction*	*Control*	*Probe*	*Display readout*	*Special features*
Mitutoyo (B Draper Co Ltd)	Microcord A10	x – 300 y – 300 z – 200	Gantry	Welded steel supports on cast surface plate	Manual	Conical and electronic	Digital	Economy models available
	Microcord A12	x – 500 y – 400 z – 200	Gantry	Welded steel supports on cast surface plate	Manual	Conical and electronic	Digital	
	Microcord A21	x – 700 y – 500 z – 250	Gantry	Welded steel supports on cast surface plate	Manual	Conical and electronic	Digital	Remote control hand calculator of data
	Microcord A22	x – 700 y – 550 z – 250	Gantry	Welded steel supports on cast surface plate	Manual	Conical and electronic	Digital	
Tokyo Seimitsu	M7003B	x – 700 y – 550 z – 250	Cantilever	Welded steel precision bearings	Manual	Conical	Digital	Licence with Bendix and Ferranti
	M1000A–3B	x – 1000 y – 550 z – 250	Cantilever	Welded steel precision bearings	Manual	Conical	Digital	
	700–3B	x – 700 y – 450 z – 250	Cantilever	Welded steel precision bearings	Manual	Conical	Digital	
	300–3B	x – 700 y – 300 z – 200	Portal bridge	Welded steel	Manual	Conical	Digital	
	A1000C	x – 1000 y – 800 z – 600	Gantry	Welded steel	Automatic	Electronic	Digital	
Sweden								
C. E. Johannson	Cordimet 700	x – 700 y – 450 z – 300	Cantilever	Diabase worktable on cast iron stand	Manual	Conical electronic	Digital	Calculator and software options
	Cordimet 350	x – 350 y – 250 z – 200	Cantilever	Diabase worktable on cast iron stand	Manual	Conical electronic	Digital	Turret head
	Cordimet 1200	x – 1200 y – 800 z – 550	Bridge	Granite	Manual	Various including electronic	Digital	Computer and calculator facility, range of programmes print-out etc.
	Cordimin	x – 125 y – 100 z – 75	Bench	Diabase worktable on cast iron stand	Manual	Conical electronic	Digital and optical	
Switzerland								
H. Hauser (Societe Genevoise Ltd)	5M–DR	x – 700 y – 500 z – 300	Portal	Cast base welded steel gantry	Motorised	Conical various	Digital	

Table 2. *(contd.)*

Manufacturer (UK Agent)	*Model/Name*	*Capacity*	*Type*	*Construction*	*Control*	*Probe*	*Display readout*	*Special features*
Carl Zeiss (Hahn & Kolb Co Ltd)	UMM 500	x – 500 y – 200 z – 300	Universal Cantilever	Precision machine guideways	Automatic	Electronic	Digital Printer Plotter	Operator cockpit concept
	UMM 800	x – 800 y – 800 z – 300	Bridge	Granite surface plate	Automatic	Electronic	Digital Printer Plotter	
	WMM 550	x – 550 y – 500 z – 450	Bridge	Granite table and guideways	Automatic	Electronic	Digital Printer Plotter	CC on rotary axis (optional)
	WMM 850	x – 850 y – 700 z – 600	Bridge	Granite table	Automatic	Electronic	Digital Printer Plotter	CC on rotary axis (optional)
Italy								
D.E.A. (Societe Genevoise Ltd)	Iota	x – 1320 y – 500 z – 400	Bridge	Granite base fabricated bridge	Motorised fine adjustment	Electronic	Digital Printer	Touch finger probe
	Gamma	x – 1000 y – 800 z – 500	Gantry	Granite base fabricated columns	Manual	Electronic	Digital Printer	
	Beta	x – 9970 y – 1600 z – 1000	Gantry	Integral granite surface plate	Manual	Electronic	Digital Printer	Various sizes of capacity
	Sigma	x – 1800 y – 1000 z – 1000	Gantry	Three fabricated columns support suspended vibration free table.	Motorised	Electronic	Digital Printer	
	Delta	x – 5000 y – 2400 z – 2050	Gantry	Four independent columns surface plate independent.	Motorised	Electronic	Digital Printer	Two sizes
	Alpha	x – 7000 y – 2500 z – 2000	Gantry	Six or more columns surface plate independent	Motorised pendant	Electronic	Digital Printer	World's largest CMM (6 sizes)
Olivetti (Olivetti Ltd)	Inspector Mini	x – 420 y – 320 z – 170	Cantilever	Stabilised aluminium diabase table	Motorised	Electronic	Digital	
	Inspector Midi (Vertical)	x – 1150 y – 400 z – 405		Welded and normalised steel. diabase guideways	Motorised	Electronic	Digital	
	Inspector Midi (Horizontal)	x – 400 y – 650 z – 400	Horizontal spindle		Motorised	Electronic	Digital	
	Inspector Maxi	x – 900 y – 1640 z – 405	Bridge	Fine grain granite	Motorised	Electronic	Digital	
Japan								
Makino Milling Machine Co (Numerical M/ch Tool Co Ltd)	TM–1210	x – 1200 y – 1000 z – 350	Portal bridge	Welded steel gantry – machined guideways.	Automatic	Accura-trace	Tape reader	NC tape preparation

Table 2. *(contd.)*

Manufacturer (UK Agent)	*Model/Name*	*Capacity*	*Type*	*Construction*	*Control*	*Probe*	*Display readout*	*Special features*
Societe Genevoise (Societe Genevoise Ltd)	SIP 422M	x – 400 y – 200 z – 200	Universal jig borer	Cast iron machineways rack and pinion.	Automatic	Electronic	Digital	Multi-directional probe
	Trioptic	x – 400 y – 200 z – 200	Universal jig borer	Cast iron machineways rack and pinion.	Manual		Micro-meter dials	Earliest CMM CMM produced in world
	MU–314	x – 400 y – 100 z – 145	Bench	Cast iron machineways rack and pinion.	Manual		Optical.	
Tesa (Matchless Machine Tool Co Ltd)	Validator 10	x – 300 y – 300 z – 125	Cantilever	Diabase surface plate cylindrical vertical column	Manual	Various electronic	Digital Printer	

United Kingdom

Ferranti Ltd	Cordax 1000	x – 610 y – 455 z – 203	Cantilever	Welded Steel	Manual	Conical	Digital	Licence with Bendix
	Cordax 3000	x – 760 y – 508 z – 660	Cantilever	Precision bearings	Manual	Conical	Digital	
	Cordax 5000	x – 1220 y – 610 z – 915	Cantilever	Precision bearings	Manual	Conical	Digital	
	Cordax 7000	x – 1830 y – 760 z – 915	Cantilever	Precision bearings.	Manual	Conical	Digital	
	Saturn 2000	x – 2000 y – 1250 z – 1000	Gantry	Precision bearings	Motorised pendant	Electronic	Digital	5-way probe
	Conquest	x – 610 y – 380 z – 203	Cantilever	Precision bearings	Manual	Conical	Digital	
	Mercury	x – 505 y – 405 z – 203	Cantilever	Precision bearings	Manual	Conical	Digital	
	Cordax DCC	for 3000 to 7000 models	Cantilever	Precision bearings	Automatic	Electronic	Digital	Point-to-point operation
L K Tool Co Ltd* Notsa Engineering Co Ltd	Maxi-check	x – 2950 y – 1130 z – 1168	Bridge	Granite table air bearings	Automatic pendant	Electronic	Digital VDU Printer	Plug-in options
	Maxi-check Super	x – 9000 y – 3000 z – 1600	Bridge	Granite table air bearings	Motorised pendant	Various	Digital VDU Printer	

*It should be noted that this was written before the manufacturing and marketing arrangements between L K Tool Co Ltd and Notsa Engineering Co Ltd came to an end. Notsa are also now marketing Maxi-Check machines and L K Tool Co Ltd have added the Metre Four to their range.

Table 2. *(cont.)*

Manufacturer (UK Agent)	*Model/Name*	*Capacity*	*Type*	*Construction*	*Control*	*Probe*	*Display readout*	*Special features*
L K Tool Co Ltd	Metre Four	x – 2000 y – 500 z – 1000	Horizontal spindle	Granite table cast iron rear column	Automatic	Various	Digital Printer	CNC on rotary axis
	Micro Four	x – 600 y – 280 z – 450	Horizontal spindle	Granite table on cast base	Manual	Various	Digital	
Windley Bros Ltd	Crown	x – 350 y – 300 z – 200	Bench	Cast iron table-heavy steel vertical tube	Manual	Conical	Digital	
	New Crown 3D	x – 750 y – 700 z – 500	Bridge	Granite table air bearings	Manual	Conical	Digital	

United States of America

Manufacturer (UK Agent)	*Model/Name*	*Capacity*	*Type*	*Construction*	*Control*	*Probe*	*Display readout*	*Special features*
Bendix Corporation (Ferranti Ltd)	Cordax 1000	x – 610 y – 455 z – 203	Cantilever	Welded steel	Manual	Conical	Digital	Licence with Ferranti
	Cordax 3000	x – 760 y – 508 z – 660	Cantilever	Precision bearings	Manual	Conical	Digital	
	Cordax 5000	x – 1220 y – 610 z – 915	Cantilever	Precision bearings	Manual	Conical	Digital	
	Cordax 7000	x – 1830 y – 760 z – 915	Cantilever	Precision bearings	Manual	Conical	Digital	
	Cordax DCC	to suit 3000/ 7000	Cantilever	Precision bearings	Automatic	Electronic	Digital	Point-to-point operation
Brown & Sharpe	Validator 300	x – 1200 y – 1800 z – 915	Bridge	Granite surface plate	Manual	Electronic	Digital Printer	Ready to use standard programs
	Validator 200	x – 900 y – 1800 z – 915	Bridge	Granite surface plate	Manual	Electronic	Digital and Printer	
	Validator 50	x – 685 y – 1200 z – 915	Bridge	Granite surface plate	Manual	Electronic	Digital and Printer	
	Validator 100	x – 900 y – 600 z – 450	Bridge	Granite surface plate	Manual	Electronic	Digital and Printer	
Moore Special Tool Co (Catmur Machine Tool Co Ltd)	M–32Z	x – 800 y – 450 z – 250	Portal	Cast iron components precision lead screws and machineways	Manual	Electronic	Micrometer dials and digital	TV microscope optional extra
	M–48Z	x – 1200 y – 600 z – 250	Portal	Cast iron components precision lead screws and machineways	Manual	Electronic	Micrometer dials and digital	
	M–18Z	x – 280 y – 450 z – 400	Jig borer Universal	Cast iron components precision lead screws and machineways	Manual	Electronic	Micrometer dials and digital	Very high precision

Table 2. *(cont.)*

Manufacturer (UK Agent)	*Model/Name*	*Capacity*	*Type*	*Construction*	*Control*	*Probe*	*Display readout*	*Special features*
	M–14Z	x – 230 y – 360 z – 360	Jig borer Universal	Cast iron components precision lead screws and machineways	Manual	Electronic	Micrometer dials & digital	
Boice Corporation	Acrocord C301	x – 710 y – 450 z – 325	Cantilever	Cast iron air bearings	Manual	Conical	Digital	Air lubricated hydrostatic bearing systems
	Acrocord CL–301	x – 1000 y – 500 z – 325	Cantilever	Cast iron air bearings	Manual	Conical	Digital	
	Acrocord C–201	x – 800 y – 750 z – 450	Cantilever	Cast iron air bearings	Manual	Conical	Digital	
	Acrocord CL–201	x – 1200 y – 750 z – 650	Cantilever	Cast iron air bearings	Manual	Conical	Digital	
	Acrocord CLL–201	x – 1800 y – 900 z – 750	Cantilever	Cast iron air bearings	Manual	Conical	Digital	
	Acrocord B–401–3620	x – 750 y – 900 z – 500	Cantilever	Cast iron air bearings	Manual	Conical	Digital	
Hansford Manufacturing Corporation (Hahn & Kolb Ltd)	Rapid Check 2828	x – 700 y – 700 z – 250	Bridge	Granite surface plate	Manual	Conical	Digital	Suitable for large sheet metal components
	Rapid Check 4028	x – 1000 y – 700 z – 250	Bridge	Granite surface plate	Manual	Conical	Digital	
	Rapid Check 5228	x – 1300 y – 700 z – 250	Bridge	Granite surface plate	Manual	Conical	Digital	
	Rapid Check 6428	x – 1600 y – 700 z – 250	Bridge	Granite surface plate	Manual	Conical	Digital	
	Rapid Check 4040	x – 1000 y – 1000 z – 250	Bridge	Granite surface plate	Manual	Conical	Digital	
	Rapid Check 5240	x – 1300 y – 1000 z – 250	Bridge	Granite surface plate	Manual	Conical	Digital	
	Rapid Check 6440	x – 1600 y – 1000 z – 250	Bridge	Granite surface plate	Manual	Conical	Digital	

Although every effort was made to ensure that the information contained in this table and the accompanying article was correct at the time of going to press, the publishers cannot accept responsibility for errors and omissions or for any changes introduced after publication.

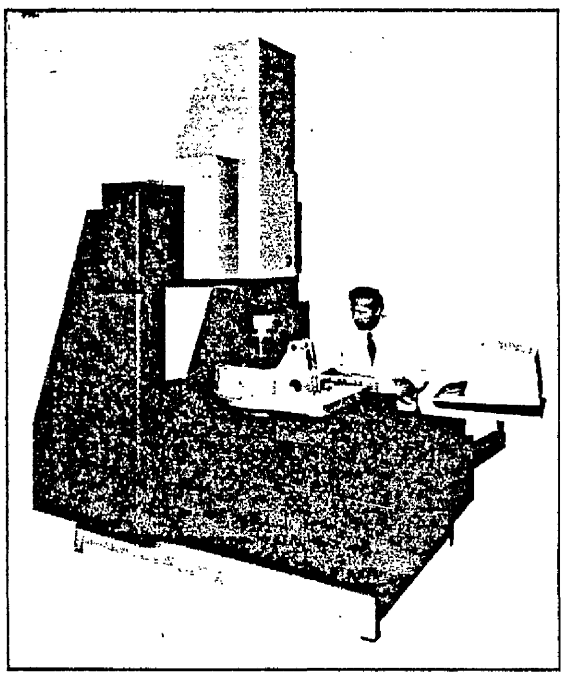
And still they come . . .

CO-ORDINATE MEASURING MACHINES of the kind loosely referred to as inspection machines or inspection centres have been with us for a little over ten years. Computer assisted machines came a little later – but it is the computer as much as any other development which has made today's developments possible. Unless we are mistaken it is the computer programme technology that will transform their use in the years to come.

In the meantime, and only a day or two before this issue with its World-wide Review of Co-ordinate Measuring Machines was going to press, details of two new machines from West Germany reached us. They are the Leitz PMM 864 and the Carl Zeiss WMM 550 and 850. That really makes three.

Without having seen the machines, which were at Microtecnic, it may be incautious to suggest that they share several features in common – and features which were first seen in the Zeiss UMM 500. They are quite different in construction though.

The Leitz PMM 864 is a portal bridge type machine, ie it has a fixed bridge at one end of its base, the table moves beneath this while two further axes are provided by (a) movement of the carriage along the bridge and (b) vertical movement of the measuring spindle in the carriage.



The Leitz PMM 864 co-ordinate measuring machine is of the portal bridge type with a capacity of 800 × 600 × 400mm. A rotary table is a feature of this machine.

Measuring capacity is 800 by 600 by 400mm and read-out resolution is 0.5 micron with a positioning accuracy to 0.5 microns. The accuracy of the machine is given as

$U_{95} = \pm (1.2 + \frac{L}{400})\,\mu m$ for each axis.

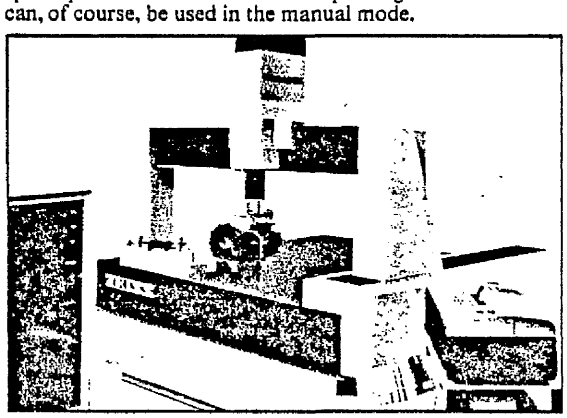
It has a table size of 1000 by 750mm and a rotary table is one of the features of the machine. A star-type probe is used and the contact pressure is between 0.1 and 0.4 N. Up to five alternative probes can be used. Each of the axes is motorised and joystick control from the control panel is provided for the axial movements. Full CNC facilities can also be used. The system uses a Wang 2200 PCS II-2 computer, VDU, plotter and peripheral equipment.

Although the Zeiss machine is of bridge construction, these two new models, the WMM 550 and WMM 850 retain many of the features of the UMM 800 which was first shown at Microtecnic in 1975. The spatial probe assembly, joystick control, very light contact pressure which permits the use of light probes, are among these features. The WMM series also has facilities for using a computer controlled rotary table and for computer control of the whole measuring cycle. It can thus be used as a full CNC measuring centre.

With the main elements, including the spindle made from granite, the machine offers a very rigid and sturdy structure – as might be expected of a machine designed for the workshop as well as the standards room. Positioning repeatability is claimed to be 0.5 microns and machine accuracy is given as

$U_{95} = (2.5 + \frac{L}{150})$ microns.

Traverse speeds from 1 micron/sec to 70mm/sec are provided. A HP 9810 calculator printer and a wide range of programmes enable virtually any measurements to be undertaken, including fourth axis computer control, high-speed print-out and four colour plotting. The machines can, of course, be used in the manual mode.



The latest additions to the range of CNC machines available from Carl Zeiss are the WMM 550 and the WMM 850 (illustrated). Both are of bridge construction.

APPENDIX E

TRADE UNION POLICY ON NEW TECHNOLOGY

APPENDIX E

The thinking and strategy demonstrated by the local shop stewards at Caterpillar, Glasgow plant in 1966, during the course of negotiations for the manning and involvement in advanced technology and automation is reflected in the statement shown below which was taken from the Financial Times dated Tuesday, 21st August, 1979.

TUC urges stewards to seek control over automation plans.

Shop stewards and union leaders are being urged by the TUC to strengthen their collective bargaining to give workers some control over company plans for automation.

The TUC yesterday published a list of demands that unions should consider when negotiating "new technology agreements", along with its final report to the annual Trades Union Congress next month on the employment consequences of the micro-electronic revolution.

Mr. Len Murray, TUC General Secretary, says in a foreward to the report that the question for the unions is not just whether to accept or fight new technology which he calls one of the greatest challenges facing society. The issue was how the benefits could be equitably shared and the costs minimised.

"We have to ensure that, unlike the first industrial revolution, this second revolution now upon us will not trample underfoot the welfare and interests of those directly affected in the process of change."

The TUC's checklist deals with union organisation, company information, output and manning objectives, re-training, shorter hours, distribution of the benefits, safeguards against "supervision by machine", health and safety and procedures for review.

/....

Its report dwells on the need for more, not less, government involvement in industrial planning and more growth in the economy to create consumer demand for the goods and services that machine productivity can yield. It says overall employment effects are difficult to measure, but says that women workers will be the prime casualities of electronic processes. Unions are encouraged to prompt firms into developing new products and pursuing new markets so that automation is accompanied by an increase, not a cut, in numbers employed.

The main principles recommended to negotiators are that change must be by agreement, and unions consulted before new equipment is even bought. Unions should make "more vigorous use" of status quo clauses in the short term to impress on employers the need for consultation. They should decide what they want - whether it is more jobs, or shorter hours, for instance - before it is too late to alter plans.

The TUC is concerned to stop union in-fighting as old demarcation lines are blurred by new processes.

It says a no-redundancy guarantee should be sought, and that even natural wastage should be treated warily since that "redistributes" unemployment to the first-time job seeker.

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APPENDIX F

RETURN ON INVESTMENT ANALYSIS FOR COMPUTER ASSISTED CO-ORDINATE MEASURING MACHINES.

APPENDIX F

G42-220

CATERPILLAR MACHINE INVESTMENT ANALYSIS

__________ FACILITY PROJECT NO. __________

I. INVESTMENT

1. INSTALLED COST OF PROPOSED MACHINE (SECTION V) . . . . . £ ______
2. DISPOSAL VALUE OF ASSETS TO BE RETIRED . . . . . £ ______
   M# ____ YR. PUR. ____ DISP. ____ M# ____ YR. PUR. ____ DISP. ____
   M# ____ YR. PUR. ____ DISP. ____ M# ____ YR. PUR. ____ DISP. ____
3. NET INVESTMENT: LINE 1 LESS 2 (PLUS £ ____ DOWNGRADE INVEST., IF ANY) £ ______
4. REWORK COST - PRESENT MACH. (IF CONSIDERED) . . . . . £ ______
5. NET ADDITIONAL INVESTMENT (LINE 3 LESS LINE 4) . . . . . £ ______

II. NEXT YEAR ADVANTAGE

	PRESENT MACHINE AS IS	PRESENT MACHINE REWORKED	PROPOSED MACHINE
6. LABOR (SECTION VI)	£	£	£
7. MANUFACTURING BURDEN (____% OF LINE 6)			
8. MACHINE REPAIR (SECTION VII)			
9. OTHER MANUFACTURING FACTORS (SECTION VIII)			
10. LOSS OF DISPOSAL VALUE BY ONE YEAR DELAY			
11. TOTAL COST BEFORE CAPTL. ALLOW. (LINES 6 THRU 10)	£	£	£
12. AFTER TAX EQUIVALENT: LINE 11 x (1 - TAX RATE)			
13. CAPITAL ALLOWANCE (SECTION V)			
14. TOTAL NEXT YEAR COST (LINE 12 PLUS LINE 13)	£	£	£
	(A)	(B)	(C)

15. FIRST YEAR SAVINGS FROM REWORK (14A LESS 14B) . . . . . £ ______
16. FIRST YEAR SAVINGS FROM PROPOSED MACHINE
    (14A LESS 14C + £ ____ DOWNGRADE SAVINGS, IF ANY) . . . . . £ ______

III. RETURN ON AVERAGE INVESTMENT

17. SAVINGS AS % OF REWORK COST [LINE 15 ÷ £ (LINE 4 x .5)] . . . . . ____%
18. SAVINGS AS % OF PROPOSED MACHINE COST [LINE 16 ÷ £ (LINE 3 x .5)] . . . . . ____%
19. ADD'L. SAVINGS AS % OF NET ADD'L. INVEST. [(LINE 16 LESS 15) ÷ £ (LINE 5 x .5)] . . ____%

IV. RECOMMENDED ACTION

SIGNED __________ PLANNING ANALYST ______ DATE

SIGNED __________ ACCOUNTING ______ DATE

V. CAPITAL ALLOWANCE - PROPOSED INVESTMENT(s)

INVESTMENT ADDITION	DESCRIPTION	A COST	B LIFE	C FACTOR	D (A x C) ALLOWANCE
CAPITAL		£			£
EXPENSE					
	TOTAL	£			£
REWORK PRES. EQUIP.					
CAPITAL		£			£
EXPENSE					
	TOTAL	£			£

VI. LABOR

			PRESENT MACHINE				PROPOSED MACHINE			
	PART NO.	REQ. PER MO. (NORMAL)	OPER. NO.	WORK ORDER PERF. HRS.	MONTHLY PERF. HRS.	SETUP HRS.	OPER. NO.	ESTMTD. PERF. HRS.	MONTHLY PERF. HRS.	SETUP HRS.
-	A	B	C	D	E (B x D)	F	G	H	I (B x H)	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13	SUB TOTAL									
14	OTHER PERF. HRS.									
15	PERF. HRS. TRANS. FROM OTHER MACHS.									
16	TOTAL MO. PERF. HRS. & TOTAL SETUP HRS. . . .									

INVESTMENT	MO. PERF. HRS.		MACH. EFF.				MO. SETUP HRS.	
AS IS		÷		% =		+		=
REWORKED		÷		% =		+		=
PROPOSED MACH.		÷		% =		+		=

INVESTMENT	TOTAL MO. HRS.		ANNUAL HRS.		LABOR RATE		LABOR COST
AS IS		x 11.6 =		x	£	=	£
REWORKED		x 11.6 =		x	£	=	£
PROPOSED MACH.		x 11.6 =		x	£	=	£

VII. MACHINE REPAIR

PRESENT MACHINE: MAT'L. £________ + LABOR £________ + BURDEN (____%) £________ = £________

(LAST 3 YEARS) ANNUAL AVERAGE £________

*REASON (IF ESTIMATE DIFFERS FROM ANNUAL AVERAGE):

VIII. OTHER MFG. FACTORS (PERISH. TOOLS, P.T. MAINT., SCRAP, REWORK, POWER, MATERIAL, DOWNTIME, OVERTIME, SUPPLIES, INVENTORY, SUB-CONTRACT, ETC.)

	PRESENT MACHINE		PROPOSED MACHINE
	AS IS	REWORKED	
	£	£	£
1.			
2.			
3.			
4.			
	£	£	£

APPENDIX G

SAVINGS ACHIEVED BY IMPROVING C. M. M. CAPACITY AT GLASGOW PLANT.

APPENDIX G.

SAVINGS ACHIEVED BY IMPROVING C.M.M. CAPACITY AT GLASGOW PLANT.

PRODUCTION MAN HOURS.

Misc. Large Parts Cyl. Block/Head etc.

Total Production Man Hours lost per day waiting set-up approval	=	22 hours
Total Annual Hours lost	=	5280 hours
Annual Savings achieved by commissioning Saturn C.M.M.	=	5280 x £1.26
	=	£6,653

Numerical Controlled - Hydraulic - Undercarriage and Misc. Small Parts Areas.

Total Production Man Hours lost per day waiting set-up approval	=	20 hours
Total Annual Hours lost	=	4,800 hours
Annual Savings achieved by commissioning Gamma C.M.M.	=	4,800 x £1.26
	=	£6,048

INSPECTION MAN HOURS.

Misc. Large Parts Cyl. Block/Head etc.

Total time spent by 3 Inspectors doing checks utilising present facility	=	5,400 annual hrs.
Total time spent by 3 Inspectors doing checks utilising proposed facility	=	3,348 annual hrs.
Savings achieved by commissioning Saturn C.M.M.	=	2,052 hrs x £1.26
	=	£2,585

APPENDIX G (CONTD.).

SAVINGS ACHIEVED BY IMPROVING C.M.M. CAPACITY AT GLASGOW PLANT.

Numerical Controlled - Hydraulic - Undercarriage and Misc. Small Parts Areas.

Total time spent by 3 Inspectors doing checks utilising present facility	=	5, 400 annual hrs
Total time spent by 3 Inspectors doing checks utilising proposed facility	=	3, 348 annual hrs
Savings achieved by commissioning Gamma C.M.M.	=	2, 052 hrs x £1. 26
	=	£2, 585.

SCRAP - FIELD & PLANT REWORK SAVINGS.

Numerical Controlled - Hydraulic - Undercarriage and Misc. Small Parts Areas.

2P4747 - Housing.

Total Number of parts scrapped annually due to positional errors (dowels to bores)	=	246 parts
Annual Scrap Cost	=	246 x £7. 3
	=	£1, 801

8S1039 - Housing.

Total Number of parts scrapped annually due to excessive T.I.R. between bores	=	384 parts
Annual Scrap Cost	=	384 x £3. 9
	=	£1, 499

7S7936 - End Collar.

Total number of parts scrapped annually due to positional errors in bolt holes	=	257 parts
Annual Scrap Cost	=	257 x £1. 9
	=	£487

APPENDIX G (CONTD.).

SAVINGS ACHIEVED BY IMPROVING C.M.M. CAPACITY AT GLASGOW PLANT.

5M4436 - End Collar.

Total number of parts scrapped annually due to positional errors in bolt holes	=	360 Parts
Annual Scrap Cost	=	360 x £.7
	=	£249

7S9181/2 - Track Link.

Total Number of parts scrapped annually due to bore pitch error	=	2,496 parts
Annual Scrap Cost	=	2,496 x £1.57
	=	£3,911

TOTAL ANNUAL SCRAP COST SAVINGS ACHIEVED BY COMMISSIONING GAMMA C.M.M.	=	£7,947

The above scrap costs were extracted from the Monthly I.B.M. Scrap Analysis Print Out Sheets.

APPENDIX G (CONTD.).

2P902 - Cyl. Block.

Total number of parts requiring to be reworked in Plant due to valve lifter c/bore face being off parallel to camshaft bore	=	30 Blocks
A further 30 blocks in the field required rework (information supplied by COSA Service Dept.)		
Overall number of blocks requiring to be reworked	=	60 Blocks
Estimated savings achieved by commissioning Saturn C.M.M.	=	£9,000

Final Drive Failures - 1P1897 - Gear and 9S9650 - Hub.

Total number of final drives requiring to be reworked due to reamed hole positional errors on 1P1897 Gear and 9S9650 Hub. (information supplied by COSA Service Dept.)	=	72 Final Drives
Estimated cost to rework final drives	=	£16,000

Due to the non-recurring nature of the above rework only the Cyl. Block rework cost has been included in the Machine Investment Analysis Sheet.

2P4747/5M598 Housings, 5M603 Cover, 6M2202 Bracket 5M6665/3S3020/3P3143 - Bevel Gear Case.

Total Hours per day to rework parts due to positional errors	=	5 hours
Total Annual Hours	=	1,200 hours
Annual Cost Savings achieved by commissioning Gamma C.M.M.	=	£1,512
OVERALL SAVINGS ACHIEVED BY COMMISSIONING SATURN C.M.M. (INCLUDING £2,000 SAVINGS ON INSPECTION CHECKING FIXTURES)	=	£20,238
OVERALL SAVINGS ACHIEVED BY COMMISSIONING GAMMA C.M.M. (INCLUDING £6,000 SAVINGS ON INSPECTION CHECKING FIXTURES)	=	£24,092
TOTAL OVERALL SAVINGS ACHIEVED BY COMMISSIONING TWO NEW CO-ORDINATE MEASURING MACHINES	=	£44,330

APPENDIX H

EVALUATION OF TIME-SAVING GAINED WITH COMPUTER ASSISTED CO-ORDINATE MEASURING MACHINES

APPENDIX H.

EVALUATION OF TIME SAVING GAINED WITH COMPUTER-ASSISTED MEASURING MACHINES.

To evaluate the time savings, parts were taken from the wide variety of piece parts produced in the machine shop. The parts chosen represented the best cross section of examples which would go across either the surface table or the CMMs. Each component was checked by an experienced inspector and in order to maintain good time comparisons the whole exercise was carried out by different inspectors.

The parts and operations checked were as follows: -

Timing Gear Housing - 2P1152 - at Op. 80. (Check position of bores and dowel holes).

Oil Pan - 4N8959 - at Op. 40. (Check hole pattern on flange face).

Flywheel housing - 6N6032 - at Op. 85. (Check position of counter-bore, dowel holes to starter bore and position of 0. 812 dia. holes).

Torque convertor housing - 3P5986 - at Op. 990* (check bores, dowel holes, drilled holes on flange and holes on opposite side).

Cylinder Head - 3H5980 - at Op. 70 (Check dowel holes to initial locations).

Gear Final Drive - 1P1897 - at Op. 105 (Check bolt holes). See Plate No.4. 6.

Accessory Drive Housing - 2P4747 - at Op. 40. (Check position of holes in flange and position of bearing bore).

Power take off housing - 5M598 - at Op. 20. (Check location of bores and dowel holes).

Power take off cover - 5M603 - at Op. 60. (Check location of holes and bores).

* Op. 990 is not a machining operation. It is a final inspection operation where all dimensions are checked for conformance to specification.

Master work order layouts are provided for each component and these gave details of the operations prior to the particular one checked, as stated above. Job method sheets are also included/-

/which give precise instruction to the operator on tooling, machining procedures, feeds and speeds and gauging to be used.
Each component was set up on the surface table first and the inspection operation carried out. The time to complete the check was recorded, the parts were then checked on a CMM, either the Cordax or Portage, depending on their size, and finally on a Gamma or Saturn, again depending on the overall size of the part.
On the following two pages are complete tables of the results and differences in time achieved using a CMM and a CCMM.

Example Calculation:

Oil Pan - 4N8959.

A. Surface plate time = 210 minutes
CMM time = 150 minutes

Improvement on surface plate = $\frac{210-150}{210} = \frac{60}{210} = 28.6\%$

B. CCMM time = 90 minutes

Improvement on surface plate = $\frac{210-90}{210} = \frac{120}{210} = 57\%$

C. CCMM Improvement on CMM = $\frac{150-90}{150} = \frac{60}{150} = 40\%$

/...

Part number and name: (check description).	Operation checked:	Surface Plate Time:	CMM Time:	Imp'nt on plate:	CCMM Time:	Imp'nt on plate:	CCMM Improvement on CMM
Timing gear housing - 2P1152. (check position of bores and dowel holes).	Op. 80 one setting	40 mins. one setting	40 mins.	0%	30 mins.	25.0%	25.0%
Oil Pan - 4N8959 (check hole pattern on flange face).	Op. 40 one setting	210 mins. one setting	150 mins.	28.6%	90 mins.	57.0%	40.0%
Flywheel housing - 6N6032 (check psn of counterbore, dowel holes to starter bore. Check position of (10) 0.812 dia. holes).	Op. 85 two settings	180 mins. two settings	105 mins.	41.5%	60 mins.	66.6%	43.0%
Torque Convertor Housing - 3P5986 (check bores, dowel holes, dowelled holes on flange and holes on opposite face).	Op. 990	425 mins.	210 mins.	50.5%	150 mins.	65.0%	28.5%
Cylinder Head - 8H5980. (check dowel holes to initial location).	Op. 70	60 mins.	40 mins.	33.3%	10 mins.	83.5%	75.0%

Part number and name: (check description).	Operation checked:	Surface Plate Time:	CMM Time:	Imp'nt on plate:	CCMM Time:	Imp'nt on plate:	CCMM Improvement on CMM
Gear final drive - 1P1897 (check bolt holes	Op. 105	420 mins. two settings.	N.A.	-	15 mins.	96.5%	-
Accessory drive housing - 2P4747 (check position of holes in flange and position of bearing bore).	Op. 40	60 mins. two settings	N.A.	-	15 mins.	75.0%	-
Power take off housing - 5M598 (check location of bores and dowel holes).	Op. 20	90 mins. two settings.	30 mins.	66.6%	30 mins.	60.6%	0%
Power take off cover - 5M603 (location of holes and bores).	Op. 60	150 mins.	30 mins.	80.0%	30 mins.	80.0%	0%

From the table the calculation of the overall average figure for savings in time for:-

A. The CMM in comparison to the surface plate.

B. The CCMM in comparison to the surface plate.

C. The CCMM in comparison to the CMM.

A. CMM in comparison to the surface plate:-

$$\% \text{ average time saving} = \frac{(\text{Total surface plate time - total CCMM time})}{\text{Total surface plate time}}$$

$$= \frac{1155-605}{1155} \times \frac{100}{1}$$

$$= 47.6\%$$

N.B. 1P1897 and 2P4747 were excluded from the above evaluation since manning on the CMMs was at a reduced level.

B. CCMM in comparison to the surface table:

$$\% \text{ average time saving} = \frac{(\text{Total surface plate time - total CCMM time})}{\text{Total surface plate time}}$$

$$= \frac{1635-430}{1635} \times \frac{100}{1}$$

$$= 73.7\%$$

/...

C. CCMM in comparison to CMM:

$$\% \text{ Average time saving} = \frac{(\text{Total CMM time - total CCMM time}}{\text{Total CMM time}}$$

$$= \frac{605-400}{605} \times \frac{100}{1}$$

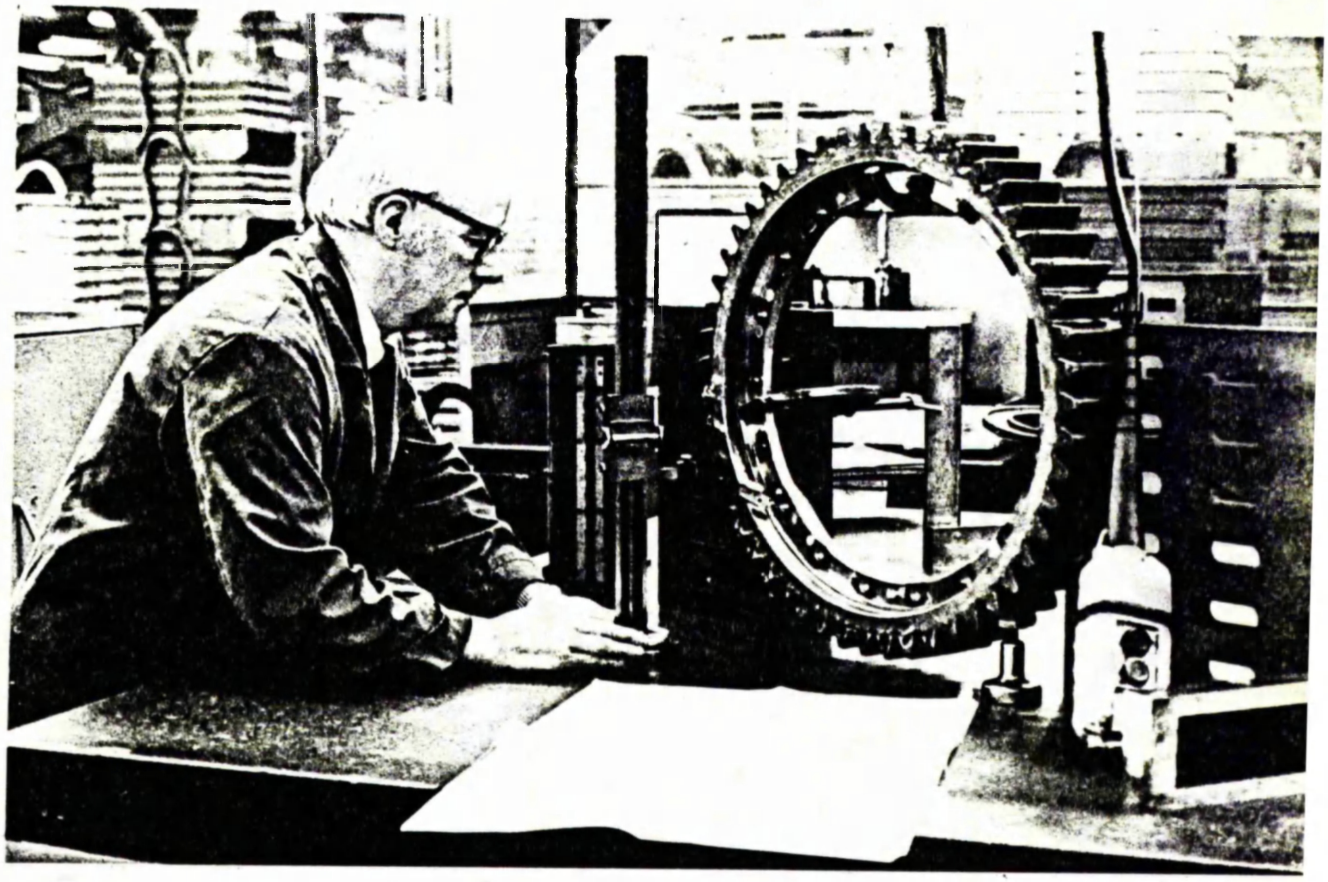
$$= 33.9\%$$

As seen above the CCMM gives a 73. 7% time saving. This means that inspection man hours involved in checking the parts checked were divided by a factor of

$$\frac{100}{100 - 73.7} = 3.8$$

e. g. a job taking 60 minutes on average would be reduced to 15. 78 minutes on average.

The Large Final Drive Bull Gear on a Standard Surface Table



APPENDIX I

IN-PLANT SURVEY ABOUT CO-ORDINATE MEASURING MACHINE OPERATORS

APPENDIX I

A. SAMPLE QUESTIONNAIRE - OPERATOR GROUP

IN-PLANT SURVEY ABOUT CO-ORDINATE MEASURING MACHINE OPERATORS.

Name: ____________ Section: ______ Shift: ______

(or answer as required).

1. How long have you been operating CMM? ____ years ____ mths.
2. What age are you? ____ years
3. How long have you been on inspection work? ____ years
4. What was your job immediately before this? ____________
5. What did you do five years ago? ____________
6. Was the move to operating the CMM a promotion? ___Yes ___ No
7. How do you feel about this job compared to your last Job?

	Much More	More	About Same	Less	Much Less
Self-status					
Self-assured					
Concerned re new fangled technology					
Influenced over machine operators					
Power with line supervisor					
Ease of operating					

8. What kind of reaction have you had from Production Supervisors and machine operators about the service the machine give?

	At Start	Currently
Surprised at the speed of measuring		
Distrust results and asked for plate check		
Prefers plate check		
Do not understand printout data		
No reaction		
Other		
Other		

9. What if anything makes you unhappy about operating this machine?

Too simple - no interesting calculations	
Like to double check against plate	
Do not like all the computer 'mumbo-jumbo'	
Other	
Other	

10. Do you do any other work in addition to operating CMM?

___ Yes ___ No

If yes, what? ____________________

11. Do you think your work relationships with line supervisors and machine operators has improved or not since moving to the CMM?

Relationships with:	Greatly Improved	Improved	No Change	Got Worse:
Line Supervisor				
Machine Operators				
Other Inspectors				

12. Does anyone else operate this CMM apart from you and other shifts?

___ Yes ___ No

If yes, state who ____________________

13. After you complete your check, who analyses the data printout results?

You only	
Inspection Supervisor	
Planner	
Line Supervisor	
Other	

14. Who trained you on the CMM? ____________________

Approximately how long did it take you to learn to do a complete check yourself?

_____ months.

15. What did you find most difficult about the learning process?

Operating controls	
Setting-up parts	
Programming the machine	
Understanding the results	
Other	
Other	

16. If you were not a CMM operator what other work would you prefer?

____

/...

17. Do you find it easy to pick up a half checked job from the previous shift?

Normally easy	
Prefer to start from scratch	
Need minor checking	

18. How do you rate the following factors with the CMM in terms of importance?

	Vital	Very	Important	Unim-portant	Not even consid'd
Faster Checking					
More Accuracy					
Better repeatability					
Less waiting for prod.m/cs					
Less hand calculations					
No awkward fixtures					
Easy to operate					

19. How much faster do you think on average it takes you to set-up a part on the CMM as compared to surface plate methods?

% Faster	10	20	30	40	50	60	70

20. As measuring machines become more and more accurate and results almost infallible, do you think the inspector should become part of the production team under a line supervisor?

Strongly Disagree	Mild Disagree	Neither Agree nor Disagree	Mild Agree	Strongly Agree

21. How much does it concern you that as machines, even measuring machines, become more and more automated, this could affect the following:

	Very Concerned	Concerned	Not worried one way or another	Encouraged by progress
Less skill to operate				
Less knowledge required				
Fewer operators				

22. Where do you think the CMM would best be located?

In special air controlled room	
Wall partition with no roof	
Wall partition with roof	
Open work shop	
Other	

23. What technical qualifications if any, do you have?

Time Served Apprenticeship	
City & Guild's Certificate	
National Certificate	
Degree	
No qualifications	
Other	

24. Do you hope to gain further promotion in the Company?

___ Yes ___ No

If yes, to what? ______________________________

APPENDIX J

IN-PLANT SURVEY ABOUT PEOPLE CLOSELY RELATED TO C. M. M. BUT NOT OPERATORS.

APPENDIX J

B - SAMPLE QUESTIONNAIRE - CONTROL GROUP

CONTROL GROUP

IN-PLANT SURVEY ABOUT PEOPLE CLOSELY RELATED TO CMM BUT NOT OPERATING.

(or answer as required)

Name: ______________ Section: ______ Shift: ____

Current Job: ______________________________

1. How long have you been doing this job? ________
2. What age are you? ________
3. If on inspection how long have you worked at this? ________
4. What type of inspection do you do? ________
5. Would you like to operate a CMM? ___ Yes ___ No

   Why? ______________________________

   ____

6. How do you think you would feel about the following if you operated a CMM?

	Much more	More	About Same	Less	Much Less
Self-Status					
Self-Assurance					
New fangled technology					
Influence over machine operators					
Power with line supervisor					
Satisfaction with work					

7. How do you think line supervisors and operators react to the service from CMM?

	At start of CMM	Currently
Surprised at the speed of measuring		
Distrust results and asked for plate check		
Prefers plate check		
Do not understand printout data		
No reaction		
Other		
Other		

/...

8. Can you think of any disadvantage about operating these machines?

____

____

9. Do you think you would have more or less influence with the production supervisor if you were a CMM operator than you have right now?

Much more	More	About Same	Less	Much Less

10. Do you think anyone should be allowed to use the CMM? ________

____

11. As measuring machines become more and more accurate and results almost infallible, do you think the inspector should become part of the production team under a line supervisor?

Strongly Disagree	Mildly Disagree	Neither Agree Nor Disagree	Mild Agree	Strong Agree

12. How much does it concern you that as machines, even measuring machines, become more and more automated, this could affect the following?

	Very concerned	concerned	Not concerned one way or other	Encouragec by Progress
Less skill to operate				
Less knowledge to operate				
Fewer operators				

13. Where in your opinion should a CMM be located?

In a special air controlled room	
Wall partition with roof	
Wall partition without roof	
Open workshop	
Other	

/....

14. What technical qualifications if any, do you have?

Time Served Apprenticeship	
City & Guild's Certificate	
National Certificate	
Degree	
No qualification	
Other	

15. Would you hope to gain further promotion in the Company.

___ Yes ___ No

If yes, to what? ____

APPENDIX K

HOW THE ATTITUDE SURVEY WAS CONDUCTED AT CATERPILLAR, GLASGOW

APPENDIX K

HOW THE ATTITUDE SURVEY WAS CONDUCTED AT CATERPILLAR, GLASGOW.

Two survey vehicles in terms of questionnaire were designed in February 1977. The design of the basic questionnaire was based on a system used by Enid Mumford of Manchester Business School in a study of computer personnel, which subsequently was published in her book on Job Satisfaction (40), also on a design format by Dr. John Dickson on a Worker Participation Research Project (61). The questionnaire design for attitude measurement was based on the A. N. Oppenheim system (62).

A test pilot questionnaire was conducted on several managers within the quality control organisation at Glasgow plant, and after modifications a second pilot was designed and given to a group of weekly planners within the quality assurance group. Primarily the planners were asked to study the questionnaire then complete it as best they could, secondly they were all interviewed individually on their own results in an attempt to develop deeper and more penetrating questions which would hopefully result in more complete and accurate answers. It was imperative for approval to be obtained for the survey from senior managers and in particular the trade union hierarchy which often look on questionnaire surveys with some degree of suspicion except when the survey is conducted by some external body and that the trade union get copies of the results as well as management. Fortunately at the time of this proposed study, the assistant convenor for all hourly blue collar shop stewards was in fact an inspector who had been an operator for a short period of one of the two computer assisted measuring machines. He therefore immediately understood the technology and not only gave his agreement to the survey but asked to be included as one of the test group. From this point it was a matter of talking with inspection supervisors in each area as previously described then to each line shop steward to ensure that they understood the objective and knew that their senior hierarchy had made agreement to the whole exercise. It was decided following the second pilot run with the weekly group that it maybe interesting to involve those inspectors who

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had not been operators of any type of measuring machines and to research how their expectations may have shaped had they been given the opportunity to operate the new technology. (This thought concerning an operator and non-operator group was later developed successfully in the major survey of 287 companies as will be described in a later chapter of this research).

Two questionnaires were finally designed in May 1977, these are shown in Appendices I and J. At the time of the survey there were a total of 48 employees who had operated some form of measuring machine at Glasgow plant (this included the 12 resident operators and the back-up inspectors who numbered 8 at that time leaving 28 former operators who now held different assignments at Glasgow plant). The non-operator group which was called the Control Group for this exercise numbered only 24, mainly due to the fact that only those close enough to the measuring machine equipment were chosen, as others, for example, in assembly would have been too far away from the equipment to make any accurate contribution to the survey. The Operator questionnaire had 24 questions while the Control Group questionnaire had 15 questions, 12 of the questions in each paper were common with slight changes in terminology in order that specific comparisons could be drawn between each group. The survey was launched in June 1977 by initially talking to the whole group of resident inspector operators together with their back-up inspectors. The purpose of the survey was explained in good detail and the manner in which the questions should be approached. Each of the operators then completed the questionnaires and were permitted to ask for clarification of any particular point. The completion of each paper was done individually and anonymously without signature and no cross discussion took place apart from the aforementioned clarification points. The balance of the former operator group was done somewhat painstakingly and certainly time-consumingly one by one with personal interview. When all the results had been obtained for the Operator Group, the second questionnaire was launched on the Control group, this was again done on both a group and individual basis depending upon the availability of

/.....

the employees concerned. The whole data collection exercise was completed by mid July 1977, obviously the advantages of being on site at Caterpillar during the whole exercise and not dependent upon any postal or other communication system, permitted a quick and almost a 100 percent response to this important section of the research.

The combined results of the data collection presented a maximum of 1512 points of response, multiplied in some instances where a multi variance response question was included. However it was not considered a large enough data bank to justify sorting through a computer programme and therefore all the data was manually sorted and analysed into specific groups of significance, as will be described in the next section under research findings.

APPENDIX L

RESULTS CHART SHOWING CATERPILLAR, GLASGOW IN RESPECT TO THE INTERNATIONAL STUDY OF 300 ORGANISATION IN THE UK., USA AND EUROPE

APPENDIX L.

RESULTS CHART SHOWING CATERPILLAR GLASGOW IN RESPECT TO THE INTERNATIONAL STUDY OF 300 QUALITY CONTROL ORGANISATION IN THE U.K., U.S.A., AND EUROPE.

INTRODUCTORY PART:

Question No:	Caterpillar Glasgow	Remarks
1	Caterpillar Tractor Co. Ltd.	
2	Glasgow, Scotland	
3	Earthmoving Equipment	3 models
4	Subsidiary to Caterpillar Tractor Co., Peoria, Illinois, U.S.A.	
5	Small Batches	100 to 500 parts per run.
6	Considerable major technical changes in preparation for new product line.	
7	Gradual change to production system towards more automation.	
8	A complete long term plan has been developed and will be updated annually on a 5-year basis.	
9	764 powered machine tools.	
10	24 N.C. machine tools	3% of all m/c tools.
11	423,000 sq.ft. of machine shop space	1.2m.sq.ft.total fty.
12	60 sq.ft. per machine tool.	m/c tools take 45840 sq.ft.balance is other equip.storage and passageways.
13	14,000 sq.ft. for Inspection	Approx 3% of total fty.
14	1,700,000 kwh per month of power consumption for machine shop.	
15	Plant Manager - Chief Executive	reports to V.P. Europe.
16	Current organisation chart attached	

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No:	Caterpillar Glasgow:	Remarks:
17	1958	First Manufacturing Plant for Caterpillar outside USA.
18	2338 employees all payrolls.	
19	1692 hourly paid employees.	72% of total employees.
	964 hourly direct production	41% of total employees 57% of hourly employees.
	100 hourly inspection	6% of hourly paid employees.
	26 weekly inspection	
	24 monthly inspection employees	All inspection employees represent 6% of total employees.
20	Shop floor inspection predominantly.	
21	Normal wastage and re-training to other skills.	
22	£1,200,000 annual budget for labour and material expense.	£8000 per inspection employee. £510 per employee in plant.
23	Resistance to Change 1. No to protect. status 2. Yes to existing ways of doing things. 3. Perhaps to protect handskills and knowledge. 4. Yes to protect job. 5. No to avoid scraping of assets. 6. Yes to avoid need to change systems. 7. Yes to general fear of change. 8. Yes to avoid conflict with organised groups. 9. Perhaps places Inspection in scientific role.	Depends much on who answers the question - paradoxically managers tend to resist change because of a basic fear of negative re-action by manual operators but generally the shop floor recognise the need for change and are ready to accept.
24	Yes - Long term plan developed for more automated CMM for Inspection. Yes - more automatic gauging integrated into machine tools.	

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PART 2 - CO-ORDINATED MEASURING MACHINES.

No:	Caterpillar Glasgow:	Remarks:
1		

Make:	Model	Reason:	Date:
Ferranti	Saturn 2000S	Cost	1975
Ferranti	Cordax 300	Avail.	1968
D. E. A.	Gamma	Accur.	1976
Portage	350	Size	1969

2	Conference - Exhibition in 1968.	
3	Yes, Quality Control Manager, 12 years.	
4	Approximately 2 years.	
5	Visited suppliers and users.	
	Tests show approx. 70% gain on each i. e. production and set-up.	Makers claim 90% but much depends upon geometry of components.
7	Stored for five years.	
8	Wall partition without roof but prefer air conditioned clean room.	Various schools of thought but cleanliness is essential and clean rooms a must in cast iron dust environment.
9	In one case best site in the other it was a compromise site.	
10	Yes.	
11	Yes. Mainly electronic on the DEA machine and some programming faults on the Ferranti.	Major objective was to get compatability with all software.
12	Contribution Factors. 1. Profit - some increase 2. Productivity - major increase 3. Cost Reduction - major increase 4. Speed of checks - major increase 5. Accuracy of checks - major incr. 6. Set-Up times reduction - major incr. 7. Repeatability of checks - some incr. 8. Reliability of checks - some increase. 9. Calculating errors - minor increase.	Major factor tends to be productivity but CMM has to be utilised fully to justify its existence.

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No:	Caterpillar Glasgow:	Remarks:
13	Decision Factors. 1. Faster - Vital 2. Accuracy - Very 3. Repeatability - Important 4. Labour Saving - Important 5. Less Production Downtime - Vital 6. Better Data - Vital 7. Reduced Inventories - Very 8. Cost Saving Gauges - Important 9. Keeping up to date - Important 10. East of operating - Not considered 11. No need for special fixturing - Important 12. Safer - Vital. 13. Quicker detection of machine tool variations - important.	
14	Yes	
15	Combination of service and self help.	
16	Scrap Cost - currently lower Rework - currently lower. Field complaints - currently lower.	Key outcome of any quality plan.
17	Combination of all factors.	
18	Basically a very good investment provided proper utilisation is made of the equipment. The market for CMM will grow over the next 20 years.	
19	No, probably most work has been absorbed.	This is the normal result technology does not replace people - it displaces them.
20	Yes, 3 extra planners were added to the section.	
21	Currently 6 full time operators mostly in the 40 to 44 year bracket with 12 to 15 years service.	
22	Average age of all other inspectors is 41.	Inspectors generally graduate from top machine operatives.
23	All CMM operators come from surface plate work.	

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No:	Caterpillar Glasgow:	Remarks:
24	Grades and wages remained the same.	Other advanced technology being installed in parallel
25	Both the Influence and Power of the operators have increased.	Computers carry a mystic about them.
26	Relationships have improved.	
27	Strongly disagree that integration will take place.	Inspection force will reduce.
28	Mildly disagree that the inspector will become dissatisfied with tomorrow's work.	Tomorrow's job will be preventive and analytical.
29	Both the CMM operator and the other inspectors experienced a feeling of increased self status.	
30	On average it takes 12 weeks to competently operate the CMM. This would include basic programme interpretation.	
31	At the beginning no involvement but laterly yes. Next time we invest we will include the operator in a visit to the supplier.	Important to get early acceptance on the shop floor from operator and manager.
32	Yes. Operators failed mainly due to lack of confidence in themselves - they normally returned to their previous assignment*	* This is a written and agreed procedure at Caterpillar.
33	No labour problems as yet.	

OVERALL RESPONSE TO QUESTIONNAIRES SHOWN IN APPENDIX I AND APPENDIX J.

	Result:	Some Conclusions:
1.	Mean value on operating experience was 2.2 yrs with maximum of 4 yrs.	Indicative of newness of technology and comparable with worldwide survey of manufacturers which revealed an 8 to 10 year commercial life. (Equipment order and delivery takes approx. 2 yrs - this shows the order of concern for continuous re-investment of new technology.
2.	Operatives of the new equipment averaged 36 years of age - the Control Group had approx. the same average while the average age of all inspection personnel was 41 years.	Tendency to stream younger men into the new technology - perhaps in the belief that it is harder to train "old dogs" new tricks.
3.	Total inspection experience including the new technology time was 8.16 years for the operatives and 6.5 years for the Control Group.	Although the operatives were found to be younger on average than the inspection group as a whole, their depth of experience in inspection work prior to going into the new technology was considerable.
4.	New technology operatives were 100% blue collar prior to moving to inspection. 58% were machine operatives, 16% bench fitting, the balance were from misc. blue collar jobs.	Company system in promotion from within thus tending to push people up through various grades of skill especially on machine tools. Inspection is highest labour grade and considered a 'good' job.
5.	5 years ago 30% of today's operatives were already in the inspection field - the balance were still in m/c operating tasks.	Confirms depth of skill and knowledge within Inspection field itself.
6.	The move to the new technology was a definite promotion for 92% of the operatives.	Confirms author's theory on the actual effect of "apparent" labour-saving new technology. People gain despite de-skilling. The status and financial attraction overcomes the fear of the new and unknown technology.

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Result:

7. 90% felt that their individual status had improved since moving to the new technology. 54% said much more and 37% more. 29% felt much more self assurance and 30% more while 31% said no change. There was an even distribution about the no change on the question of concern for the new technology, 25% more and 24% less. 45% felt they had more influence over the machine operator. 12% felt that they had much more power with the Production Supervisor.
   14% felt that the new technology was much more easy to operate - 29% said more but 28% said it was more difficult than their previous job.
   (The Control Group were almost 100% certain that they would derive greater satisfaction of job should they move to the new technology).

8. This question had a time frame from first to current reaction. Results showed that 37% of the Production Supervisors distrusted the new technology and asked for double checks by the plate method. Currently 70% do not understand the output.

9. Generally the operatives were happy with the new technology although 23% thought it 'too simple' and 27% did not like the computer at first. (The Control Group were concerned about finding problems which were previously acceptable and being deskilled by automation).

10. 70% of the group did other work mainly on standard surface plates in addition to their work on the new technology.

Some Conclusions:

(7) The greater the mystic of new technology then the greater it seems to surround the operative with importance and thus status. Equally confidence grows with successful operation of the "magic". Strangely not many would admit being over-awed by the technology even at the start (nobody wants to step down from a promotion). The m/c operatives began to feel that the inspection was actually trying to help him. Production Supervisors tend to respect computer print-outs as being authentic and all true. Physically the new technology is easier to handle however mentally it sets greater demands especially at the start of a learning curve. (Almost all would gain promotion).

(8) Prod. Supervisors will readily understand the basic plate check-they view the new technology with an element of distrust as they cannot see how it all happens. Consistent reliable results overcome this and leave only a question of education to solve the output problem.

(9) It would appear that initially anyway the operatives are happy with the new technology - job enrichment!
Both points are true to some degree.

(10) Certain work is in fact quicker on the basic plate than other methods-also the operatives obviously like to keep their hand in with the old methods.

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Result:	Some Conclusions:
11. Work Relationships with the Production Supervisor improved. 50% said greatly improved - 49% said improved. Relations with machine operators improved for 66% of the group while the balance felt no change.	New technology seeks improvement and guidance for the user. Both Prod. supervisors and m/c operators feel the inspector through this new machine is trying to find ways to pass the component not reject it.
12. 66% stated that other people used their new technology mainly white collar planners. (Control Group felt anyone should use it - like the office desk calculator).	New operatives tend to guard their tasks for personal security of job. Control Grp members have nothing to lose.
13. The operatives analysed their output 100% with 51% approximately being double checked by the Inspection supervisor.	The print out data has to be "translated" to the m/c tool controls for correction or adjustment if necessary to bring the component into line.
14. The mean point on the Learning Curve to Competent Operation of the new technology was 3.4 months. 50% of all operators were training and instructed by one man. 33% were trained by their predecessor on the machine.	Manufacturers of this new technology suggest that operators could be trained in as little as 4 hrs; this is evidently sales propaganda. Training tends to be conducted by few people when new technology is introduced for obvious reasons of limited knowledge.
15. 70% of the operative group thought that programming the machine was the most difficult part. A further group thought understanding the output and remembering the manual code routines.	Each new component presents a new geometry and therefore a new challenge to the operative as he seeks the optimum programme for speed and effectiveness.
16. If they were not on this new technology 25% of the group would have preferred white collar planning and 29% supervision. The balance had no preference.	The majority of this group seek further personal fulfilment and are on a promotion drive.
17. New technology often creates problems at hand over times if a job is only partly measured. 37% felt it was 'easy' to pick up the threads of a half complete task but 58% stated that they preferred to start from scratch.	Oviously if the component is fully programmed then it becomes a question of letting the m/c go thru its cycle to the end. If the measure is done manually then there is a good risk that specific checks will be omitted. The good inspector would not take that risk.

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Result:	Some Conclusions:
18. Operatives were asked to rate certain items as they thought of them in terms of importance. 70% thought faster checking was of vital importance. 25% thought faster checking was very important. 50% thought more accuracy of vital importance and 33% very important. 20% thought better repeatability of vital importance and 50% very important.	All of these factors are personal i. e. between man and machine and tend not to threaten the operator in any real terms.
12% thought less waiting for production machines to be very important. 37% saw this item as important but 45% though it unimportant.	This is one of the key ROI factors <u>but</u> it is not necessarily important to the operative.
54% thought that less hand calculations were important and 33% saw these as unimportant.	
33% thought that no awkward fixtures were important while 20% saw these as being unimportant. 25% saw the east of operation to be important; 37% thought it unimportant and 25% not even discussed.	The group who thought it unimportant we assume lean this way in comparison to some of the other factors but as for it and ease of operation one would assume that these would be seen as at least important in the eyes of the operative.
19. Each operative was asked to estimate how much faster it was to do a set up on the new technology. 37% thought it 60% faster and 25% stated 70% plus.	Manufacturers of this new technology suggest that it can be up to 90% faster. In separate tests carried out at Caterpillar on 10 components we averaged 68% faster.
20. Operatives were split on the question of merging the inspection role into the production team. 33% strongly disagree. 29% mild disagreement. 16% neither agree nor disagree. 20% mildly agree. (Control group were 80% against this proposal).	Probably a problem which will have to be faced in the future as the Inspection Technology and Production Technology merge into one - so must the manpower one might assume.

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Result:	Some Conclusions:
21. Contrary to the positive trend on the question 18 on factors of importance operatives are very much aware of the de-skilling tendency. 50% were very concerned about less skill. 33% were concerned and 12% not worried. 28% were very concerned about less knowledge. 50% were concerned and 25% not worried. 45% were very concerned about fewer operatives - 33% were not worried and 16% were encouraged by progress. (The Control Group were less concerned about less knowledge and less skill but 66% thought the question of fewer operatives to be a matter of great concern).	Key question on how easy or difficult the in-roads of new technology will be into industry. Trade Unions are suspicious of all de-skilling (except those unions whose members are not necessarily time-served). New technology tends to improve the lot of the individual operative but must inevitably reduce the overall number of people employed which again is contrary to trade unions' objectives.
22. 70% of the group thought the new technology should be housed in a special air conditioned room, 20% said the open workshop was better. (The Control Group tended to agree with the majority).	This response may be due to the concern for cleanliness and therefore accuracy <u>or</u> it maybe for status improvement.
23. Over 58% of the operatives were time-served and 60% held some form of technical qualification.	
24. 66% of the group thought they could get further promotion again mainly to supervision; 33% and planning 33%.	As all of this group were on the top hourly paid grade they could only move to a weekly or monthly paid assignment in a promotion or alternatively move sideways to another and different task.

APPENDIX M

THE RESEARCH DESIGN FOR THE MULTINATIONAL PLANTS

APPENDIX M.

The Research Design for the Multinational Plants.

Introduction:

A description of the worldwide organisation of Caterpillar Tractor Company is given in Appendix N tracing its early history through to the most recent developments of product, plant and process technology. Caterpillar's twenty-five manufacturing plants located in ten different countries throughout the world as shown in Table No:N1 has to yield, due to its sheer magnitude and committed objective of continuous growth, a very substantial amount of knowledge on the impact of new technologies in the manufacturing industry. It was therefore decided to include the Caterpillar multinational in the research project in order to further probe the argument that new technologies are making such an impact on manufacturing industries that it is having an effect on the production systems, organisation structures and people employed in these industries. Quite apart from the possible contribution that this section may have to managements of other multinational organisations in terms of the conclusions and recommendations which will be forthcoming in this section, the strategy used and the results obtained will be an important forerunner to a much wider research of many manufacturing industries in a later chapter.

The Concept of the Research Method.

The research vehicle to be used for the multinational study was in the main a written questionnaire designed to suit the Caterpillar system and type of organisation. In addition to the questionnaire, the research was further reinforced by personal visits to 10 Caterpillar plants, 6 in the U.S.A., and 4 in Europe - this allowed for face to face interviews and shopfloor observation of both the new technology hardware and the personnel using the equipment. Therefore much of the data presented in the returned questionnaire was embellished with information gained during these personal visits. In general the purpose was to seek the necessary information through 25 Quality Control Managers located in each of the

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worldwide plants, but as the data was highly detailed, many other employees from various disciplines in each plant would require to make some input in order that the questionnaires would be correctly completed. What type of information was requested and why? The basic objective remained the same in that the research was to attempt to isolate factors of new technology which could have an impact on manufacturing industry. It was therefore indispensable to not only probe the technology of measuring machines but also to investigate other relators such as machine tools, floor space and expense budgets. To accomplish this it became necessary that three questionnaires be designed, one to cover the central question of Co-ordinate Measuring machines, a second to review Plant and Machine Shop and finally a third to examine People and the Organisation of Quality Control. There were a total of 66 questions in the final design of the combined questionnaires with some specific questions carrying multivariant responses thus extending the research to a possible 258 bits of data.

Again as in the exercise conducted in the single manufacturing plant of Caterpillar at Glasgow as discussed in Chapter 4, a pilot study was conducted in the single plant at Glasgow in order that a test of viability and true measurement of the proposed questionnaire be obtained. This was achieved by splitting the combined questionnaire into its three component parts and asking the most qualified manager in each particular function to attempt questions and complete the answers, as best he could, note his time in completing the exercise and comment on any improvements which may change the design for the better. The Plant Engineering Manager was asked to complete the section on Plant and Machine Tools, a subject on which he was very knowledgeable, then four managers in the Quality Control Department were asked to complete the other two questionnaires making a total of eight returns, four on the People and Organisation of Quality Control and four on the Co-ordinate Measuring Machines. This first pilot run was conducted between October and November 1977 and resulted in several changes to the overall design of all three questionnaires, some questions were dropped out while others were added, again in an endeavour to obtain the best possible vehicle to

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get the required research data. The final questionnaire which was ultimately used in the multinational research is shown in Appendix K and it should be noted that the questionnaire had been purposely photo-reduced and reprinted on both sides of a quarto size sheet thus cutting the overall size by 75 percent and hopefully giving the respondent less work to do working through a thick questionnaire. All of the information collected in the survey of the multinational has not been discussed in the text of this Chapter.

The whole strategy behind the design of these questionnaires to the 25 manufacturing plants of the Caterpillar Tractor Company was indeed a stepping stone toward the wider exercise of researching a large number of manufacturing plants in a variety of different types of business activities. The 10 questions with a possible total data bank of 21 bits on the Plant and Machine Shop questionnaire were considered of prime importance in order that the following questions could be developed and answered:-

Five Key Elements of Enquiry on Plant and Machine Shop.

1. What is the size and nature of the existing technology related to machine tools and in particular numerical control machine tools?

2. When social scientists and other researchers discuss "size", they invariably use people as the common measurement factor but there are several other size parameters in industry. This research looks at floor space, machine tool size, kilowatt hour power consumption and size in accordance with finance that is, how large is the budget? These questions may provide more accurate details on why new technologies should differ in impact from one firm to another. Two firms with identical numbers of people may demonstrate different degrees of impact, the casual effect could be related to an inadequate financial budget or insufficient floor space devoted to the inspection or quality control function.

3. The question of impact or effect on production systems is included in the Plant and Machine Shop section of the questionnaire. Most production systems are controlled by the relationship of one machine tool to another, for example, rough mill, turn, drill, finish mill, grind, then final inspect could be a typical operational flow. However with the introduction of advanced measuring technologies does this sequence change?

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4. Long term forecasts suggest that all gauging of production components will be completed in or during the machining operation on the machine tool. Are firms already planning for this or will they continue after-the-fact measuring technologies for some time in the future?

5. The final question on the Plant and Machine Shop questionnaire was adapted from James R. Bright's list of 12 Reasons Why New Technology is Opposed. (45) These reasons have been reduced to 9 and translated to apply to an inspection workforce within the manufacturing industry.

Nine Key Elements of Enquiry on People and the Organisation of Quality Control.

The second section of the three part questionnaire was concerned with People and the Organisation of Quality Control. Both of these factors i. e. people and organisation feature prominently in the basic hypothesis of this research project as it is intended to ascertain if there is any causal link between the new technologies of measuring machines and changes brought about on the people or the organisation. This questionnaire has a total of 27 questions with a maximum possibility of 114 bits of data, but it seeks to establish the following principal factors:-

1. What is the current shape of the Quality Control Organisation structure and what new changes have been made, if any, to accommodate the new advanced measuring technologies? Again related to this is the question of size, how many people are in the plant and at what level of payroll? U. S. manufacturing firms consider manpower ratios as an important indicator of a healthy or unhealthy organisation, for example what is the ratio of direct "producing" employees to that of indirect "servicing" employees? This question is highly important as new machine tool technologies are tending to reduce the number of direct employees required for the same or greater output but what is happening to the aforementioned ratios if similar new technologies are not pushed into the indirect areas?

2. Does the age of a manufacturing plant have any influence on its ability to keep up to date with the latest "state-of-the-art" technologies? Do older plants have greater difficulties showing good return on investment on proposed new equipment when the existing equipment is adequate? This question will be developed in greater depth during the research of a large number of manufacturing firms.

3. Do the manufacturing plants note a movement of control from the shop-floor to the office function because of the new advanced technology? What is the labour turnover, age of operatives and previous experience of operators of new technologies?

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4. One of the major points of difference between trade unions and employers must be that of sharing the benefits of new technologies. If the time taken to perform a given task is halved and operators, although not made redundant, are moved to other available work, should the operator of the new equipment enjoy a higher rate of pay? It was shown that in the Caterpillar Glasgow plant's early experience with N. C. equipment that eventually the management had to create two new levels of pay structure before the trade unions would accept the new technologies (Chapter 3, Section 3. page). Many employers would claim that the benefits derived from the new technologies are shared by all employees in terms of the continuous operation of the plant as a viable proposition against competitive forces.

   Another related factor must be that of skill, if new advanced technologies tend to de-skill employees do employers re-write the job description to recognise fewer skill or knowledge requirements or are these aspects of job evaluation ignored to avoid possible disputes and ultimate disruption within the plant?

5. What added influence or power has the inspector gained through the new computer technology at his elbow? How has this affected if at all his relationship with his peers such as other inspectors and machinists, then his superiors such as production supervisors? What has been the production supervisor's reaction to the new service? Has the new technology had any effect on the inspector's status?

6. Technology is advancing so rapidly that while it was comforting at one time to consider that the new changes would not come to affect people in their own work lifespan, this is no longer the case. Changes which were noted in terms of decades are now being effected in years, thus what is useful today could be obsolete tomorrow or at least next year. Are shop floor personnel aware of this acceleration, and would they accept radical changes in their long established work patterns, such as the integration of inspection into the production system? Would this lead to dissatisfaction and an increase in grievances at the hourly paid blue collar inspection levels?

7. The utilisation of high capital cost equipment is of paramount importance and a question is raised to determine what manning arrangements are made to provide the optimum service to the production operation.

8. The whole question of participation by employees in the functioning of the organisation has been discussed at great length in the literature but does this really take place or is it desirable from the viewpoint of shopfloor management? To ascertain this, a question was constructed to determine to what degree that the blue collar inspector was involved in the decision-making on the new measuring machines? After all, this inspector has probably more experience on the concept of measuring than all the levels of employees above him, but is this experience utilised or ignored and whichever way why? Perhaps related to the above is the question of labour problems which resulted

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in disputes due directly to the new technologies coming into the plant, did the other Caterpillar plants have any disputes?

9. The remaining questions developed in this section were concerned with learning curves, training media and back-up services for the planning and preparation of computer measuring programmes and tapes.

Nine Key Elements of Enquiry on Co-ordinate Measuring Machines.

The last section of the three part questionnaire was inevitably concerned with Co-ordinate Measuring Machines, the new technology central to this reseach project. This section as shown in Appendix K had a total of 29 individual questions and a possible maximum of 123 bits of data.

1. The initial questions in this section were concerned with the measuring machine hardware, what type and model of machine was used by each plant, why was this type selected, when was it selected? Of the equipment used what peripheral units were included to improve the output from the basic system? This data was important to the overall research in order that comparisons be made between Caterpillar as a multinational corporation, the actual sales made by suppliers of this new technology and the results obtained from the research on a much wider spectrum of users. Quite apart from the benefits of this research to other managements using or potentially using this equipment, the results of the above series of questions would be of vital importance to the suppliers and manufacturers of this equipment.

2. There has been some research in the literature concerned with determining how new technology gets into manufacturing industry. Does this come about by pressure from a parent organisation or is it one particular individual pushing for the new technology? How long does it take for the new technology to move from the concept stage to that of commissioning and installing in the plant? To what degree of investigation does a firm go to, to aid the decision-making for the capital investment - do they visit other users, several suppliers, seek advice from independent agencies such as governmental bodies?

3. Related to question 7 as detailed in the aforementioned questionnaire on People and Organisation,what have been the true results of utilisation of this new equipment? Have the two key advantages been obtained, that is a reduction in waiting time on production machine tools, and secondly, a reduction in the time required to perform the actual measure? What decisions were reached on the disposition of expensive gauge equipment made obsolete by the new technology? This second question was considered important to get some measure on the confidence of management by moving from a very long established technology to an entirely new technology together with the consequences of holding onto old methods. This again was reflected in the single

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manufacturing plant study at Caterpillar Glasgow where it was shown that due to early problems with the new N. C. drills, the line management insisted on the retention of the old radial drill equipment, this equipment is still in use today - See Chapter 3, Section 3.6 page 119

4. "Fringe technologies" such as measuring machines as compared with "central" technologies in terms of machine tools tend to receive less consideration in the overall planning strategy of the manufacturing sequence. This it is argued is primarily due to the fact that such fringe technologies do not add value to the product as for example by cutting, shaping or heat treating in order to change metallurgical properties of that product. The return on investment for the basic measuring machine has to be very carefully analysed and must obviously reflect itself in some improvement to the investment on the central technology of machine tools by, for example, extending the machine tools cutting time and therefore its productivity. It is therefore an even greater task for the advocate of new measuring machine technologies to justify the case for special shop floor conditions to house this new technology and indeed to seek the best location within the machine shop for the measuring machine.

   A question has been set up to attempt to establish how many plants in the multinational corporation were using special facilities for locating the CMM equipment and if the actual location is in the optimum position to gain maximum benefits.

5. Another important aspect of the research project was concerned with the early hour reliability of the equipment, in that how many hours of downtime were experienced after the new technology was first installed and what was the basic cause of this downtime?

6. Two of the most searching questions in the research project are those directly concerned with Contribution and Decision Factors for Investment. These questions were designed on a multi-choice basis with five factors of variance moving from major increase to major decrease over nine key items of contribution such as Profit, Productivity, Speed and others. The second question on Decision Factors consisted of five variables of rating from Vital Importance to Not Considered spread over thirteen key items related to the decision for investment, such as More Accuracy, Labour-Saving, Reduced Inventories and others. The results of both questions would give a pattern to management on the most common decision path to follow for acquisition of the new technology and secondly what degree of real contribution they should expect to gain when the new technology is in operation?

7. A group of question were set in an attempt to investigate the depth to which management had gone in long term planning of the optimum use of the new technology. For example, had they established which components at which point in the machining operation were to be measured over the measuring machine? Was this done on a high cost value basis, high volume and/or most critical components? Had management clearly determined how to load the new equipment to capacity?

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8. The accelerated pace of new technology could result in technological leapfrogging, for example, a measuring machine which was so accurate in measurement may suggest to some design engineers that tighter blueprint specifications are feasible but this could in turn result in the need for more accurate machine tools at higher capital costs to the firm, when the basic concept of fitness for use maybe perfectly adequate with the previous equipment for both measurement and machining. What and how are different plants doing to control this?

9. Several other questions in this final section of the questionnaire included items on maintenance policy to service the equipment, the possible use of the CMM for non-production components, and the whole question of justification of a fully automated co-ordinate measuring system.

The final design of the tripartite questionnaire was posted out to the 25 manufacturing plants of Caterpillar Tractor Company during January 1978. As previously stated all of the findings in the above research of the multinational have not been included in the text. Details more closely associated with the research objectives have been discussed in the text and a summary of all findings is given in Appendix D.

APPENDIX N

CATERPILLAR - THE MULTINATIONAL ORGANISATION

APPENDIX N

CATERPILLAR - THE MULTINATIONAL ORGANISATION.

In Chapter 3 the development and organisation of the Single Manufacturing Plant of Caterpillar Tractor Company, Limited at Glasgow was discussed in some detail. This was considered a necessary and important part of the research on the impact of new technology on the individual plant. In a similar manner, the pattern of the study on the multinational organisation of Caterpillar Tractor Company will start with a brief review of the company's history and current status as a worldwide enterprise.

For more than 50 years Caterpillar track-type tractors have been doing the world's work. The story of Caterpillar, however, is much more than the story of the crawler tractor, although this is the machine most readily associated with Caterpillar. Today Caterpillar's product line includes also wheel-type tractors, scrapers, track-type and wheel-type loading shovels, motor graders, bulldozers and rippers, industrial engines and agricultural tools and a range of fork lift trucks and other materials handling equipment. To find Caterpillar's origins it is necessary to look back one hundred years to the pioneering days of the American West. It was then that two young men, Best and Holt by name, first began to produce the machinery that led to the formation of the C.L. Best Tractor Co., and the Holt Manufacturing Co., who were the predecessors of Caterpillar Tractor Co. In the early days both Holt and Best produced agricultural machinery and it was their development of the combine harvester that brought them success. Combines grew larger and larger. Holt made one in 1893 with a 50-foot cut, the larger machines required as many as 40 horses to pull them and 6 men to operate them, but often the horses sank deeply into the soil and churned up the soft ground. Farmers wanted more power - compact power - that would ride on top of the yielding land. Was steam the answer? Best and Holt led the West Coast in the production of steam traction engines during the "Big Steam Era" of 1890-1910. Best sold his first "steamer" in 1889, Holt followed with his first machine in 1890, a tractor that operated winter and summer for the next quarter century. As capacity improved, weight increased, wheels

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sank still deeper into the soft earth. To combat this tendency and provide increased bearing area, both companies added larger and larger wheels, Holt built a monster with three 6-ft., wide wheels on either side, each being 7. ft. 6 ins., in diameter with the overall tractor width an enormous 45 ft. 8 ins.

The First Practical Crawler-Tractor.

In the first years of the twentieth century, Holt began to approach the traction problem from a different angle. The need for a prime mover of larger ground contact area, yet with high manoeuvrability, led him to the idea of a track-laying tractor. The concept of a machine that laid and picked up its own broad base as it went along was hundreds of years old, but the principle had never been applied on a commercially successful basis. Holt ingeniously combined old ideas and created new ones, mounting a pair of rough tracks on a steam engine from which the wheel had been removed, the result was the world's first practical crawler-tractor tested in 1904 in California. In 1906 gasoline power began to replace steam and the new carrier became more versatile and cheaper to operate. Though its first market was the farm it eventually became a time-saving tool for loggers and builders. In those days when motor trucking and road construction were still in their infancy, the crawler was much in demand for overland freighting as well. Later, as it helped construct the roads that made short haul freighting the exclusive province of the track, it literally built itself out of a market. In fact the crawler-tractor led to the road-making boom in the U.S.A., after World War 1.

Caterpillar Incorporated.

In 1925, the Holt and Best organisations combined to form Caterpillar Tractor Co., and because of geographical advantages, manufacturing was centered at Peoria, Illinois. The years immediately following the merger saw rapid development, not only in the crawler-tractor itself, but also in the equipment designed to work with it. New tools appeared in front, behind and on top of the tractor - rubber tyred wagons and scrapers, bulldozers, rippers, pipelayers, front-end shovels and a

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great variety of agricultural machinery. As time passed Caterpillar devoted more and more engineering and manufacturing to the needs of the construction man and the road builder.

New Power - Diesel

Meanwhile, in the late 1920's, Company engineers were thinking in terms of a new type of power - diesel. Over a million dollars were spent in research which preceded the first Caterpillar Diesel Tractor of 1931. Even in the throes of the Depression, reception was enthusiastic and news of diesel economy, the fact the new engines burned low cost fuel (and less of it) cutting fuel bills by 50-80%, spread rapidly. Because of the great demand, Caterpillar soon entered the diesel engine field, supplying diesel engines to sawmills, cotton gins, rock crushers, irrigation pumps, industrial plants and manufacturers of power driven equipment such as excavators, compressors, drill rigs and locomotives. Later special marine diesels and diesel electric sets were added to the fast growing line, and all over the world the new diesel crawler resulted in earthmoving costs going down. The beginning of World War II brought a new need for tractors and road machinery to build airports, military roads and war plants, to clear land and haul supplies, to hit the beach with the first waves of amphibious landings, a need for engines and electric sets to furnish light and power for advance bases, isolated locations and bombed-out areas. As in World War I, the Caterpillar track-type tractor became a familiar sight on Allied fighting fronts all over the world. Military construction men found it an indispensable tool, particularly for rapid schedule airfield and road construction needs.

Post War Expansion.

After the war Caterpillar launched a broad expansion programme to handle the increased demand for earthmoving equipment. This programme involved an investment of £130 million in new land, buildings, machinery and equipment in the 13 years 1946-1958. In 1945 Caterpillar's manufacturing facilities were limited to two plants in the United States, today Caterpillar has 56,000 employees and operates

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twelve manufacturing plants in the U.S.A., in addition to manufacturing facilities in Britain, Brazil, Australia, France, Canada, Belgium, India and Japan. An Industrial Engine Plant and a Technical and Research Center are among the new plants constructed in the United States. With the period of re-building and expansion that followed World War II, there was an increased need for Caterpillar equipment throughout the world. With world markets and the special needs of customers in the sterling areas in mind, the Company decided for the first time to establish manufacturing facilities outside the United States. The first to be formed was the British subsidiary - Caterpillar Tractor Co. Ltd., whose original purpose was to procure, inspect and distribute genuine Caterpillar parts. In addition to a parts depot at Leicester, British Caterpillar now has two manufacturing plants at Glasgow and Newcastle. The subsidiary in Brazil was formed in 1954. Its first task was also to act as a parts marketing organisation, but a manufacturing plant has now been built at Sao Paulo. The Australian subsidiary was formed in 1955 and has a plant at Melbourne. Other recent Caterpillar manufactring subsidiaries include the French company, formed in 1960 with a plant at Grenoble, and operations in Belgium and Japan. In 1965 Caterpillar acquired the Towmotor Corporation, a leading American manufacturer of fork lift trucks which are now marketed on a worldwide scale. Today Caterpillar employs some 83,000 men and women in over 50 facilities around the world - developing, testing, manufacturing and marketing Caterpillar products - and ensuring the availability of parts and service wherever these products are at work.

<u>New Technologies in Product and Process.</u>

To provide greater quantities of machines, engines and product support needed for the future, the company is carrying out the largest capital expansion programme in its history. Development, adaptation and refinement of new technology has always been a basic company strength from the development of the first practical track-type tractor by a predecessor company in 1904 to the introduction in 1977 of the world's largest and most technologically advanced crawler-tractor, the D10.

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Caterpillar's technological leadership is the primary responsibility of more than 4,700 engineers, scientists, technicians and supporting personnel, working in the Research Department exploring advanced technology related to the company's capabilities and using the technology developed by Research, engineering departments then design machines and components which are tested in the laboratory and on the job as they proceed towards production. This work is conducted at the Technical Center, at proving grounds and in the field and to a lesser degree in engineering departments at 17 manufacturing plants worldwide. Caterpillar's objective is to offer the most advanced, reliable and productive line of machines, engines and other products which represent maximum value to users.

Over 120 models of earthmoving, construction and materials handling machines are produced to meet almost any job requirement. These products include track-type tractors, track and wheel loaders, lift trucks, pipelayers, motor graders, wheel dozers, compactors, wheel tractor-scrapers, hydraulic excavators, skidders, off-highway trucks and tractors and related parts and equipment. Caterpillar Diesel and Natural Gas Engines meet power requirements from 85 to 1550 horsepower and from 50 to 900 kilowatts in generator sets and more than 1000 other manufacturers offer Caterpillar Engines in their equipment as the prime source of power. Caterpillar products are manufactured at 15 plants in the United States, at subsidiaries in Australia, Belgium, Brazil, Canada, France, Mexico and the United Kingdom and by affiliated companies in India and Japan. These facilities pursue technological leadership in quality control, metallurgy, machinery and tooling, use of computers, materials handling, environmental controls, energy conservation and other aspects of plant operations.

During the 1970s Caterpillar has made capital expenditures of $2.4 billion to build and expand facilities, provide for the manufacture of new and improved products, and instal new tooling and technology. Caterpillar now occupies 37.7 million square feet (3.5 million square meters) of manufacturing space, excluding the capacity of affiliated

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companies in Japan and India. This is an increase of approximately 36 percent over space existing at the end of 1973. Since the company's earliest days, Caterpillar products have been sold in countries around the world - today more than 50 facilities in 15 countries are involved in producing, marketing and supporting these products. The 83,000 people employed at the company's facilities come from dozens of national backgrounds and independent Caterpillar dealers employ an additional 70,000 people in more than 150 nations selling, servicing and maintaining the products. The company is owned by some 48,000 shareholders and to encourage broad ownership, the company lists its shares on stock exchanges in Belgium, France, the United Kingdom, Switzerland, West Germany and the United States.

See attached to this Appendix -

- o Basic Data on Caterpillar Plants Worldwide - Table No: N.1.
- o Caterpillar Tractor Company - Subsidiaries and Affiliates - Figure No: N.1.
- o Significant Financial Trends - Table No: N.2.

TABLE No:N. 1.

BASIC DATA ON CATERPILLAR PLANTS WORLDWIDE

Plant Name:	Year Founded:	Product Type:	Manufacturing Floor Area - Million Square Feet:
U.S. Plants:			
Aurora, Illinois.	1958	Track-type Tractors	4.1
Dallas, Oregon	1965	Lift Trucks	0.241
Davenport, Iowa	1956	Diesel Engine Parts	0.635
Decatur, Illinois	1955	Motor Graders	3.0
East Peoria, Ill.	1909	Track-type tractors	7.0
Joliet, Ill.	1951	Scrapers	3.2
Mapleton, Ill.	1967	Grey Iron Castings	2.2
Mentor, Ohio	1970	Lift Trucks	1.1
Milwaukee, Wisc.	1951	Components	0.492
Mossville, Ill.	1959	Diesel and Gas Engines	4.2
Pontiac, Ill.	1977	Engine Parts	0.137
San Leandro, Cal.	1886	Pumps	1.3
York, PA.	1953	Tractor Parts	1.5
	AVERAGE FLOOR AREA U.S. PLANTS =		2.238 64%
Outside U.S:			
Glasgow, Scotland	1958	Track-type Tractors	1.0
Gosselies, Belgium	1967	Wheel Loaders	2.4
Grenoble, France	1961	Track-type Tractors	1.1
Leicester, England	1953	Lift Trucks	0.569
Melbourne, Aust.	1957	Motor Graders	0.359
Monterrey, Mex.	1964	Parts	0.039
Newcastle, England	1956	Scrapers	0.744
Piracicaba, Brazil	1975	Wheel Loaders	0.678
Sao Paulo, Brazil	1960	Track-type Tractors	0.526
Toronto, Canada	1964	Motor Graders	0.191
Vernon, France	1974	Grey Iron Castings	0.180
Sagami, Japan	1965	Track-type Tractors	1.8
	AVERAGE FLOOR AREA OUTSIDE U.S =		0.798 36%
	AVERAGE ALL PLANTS =		1.518 M. Sq. Ft.

Oldest = 1886
Latest = 1977
Biggest Growth Period = 1955-60

FIGURE No: N.1.

CATERPILLAR TRACTOR CO., SUBSIDIARIES AND AFFILIATES

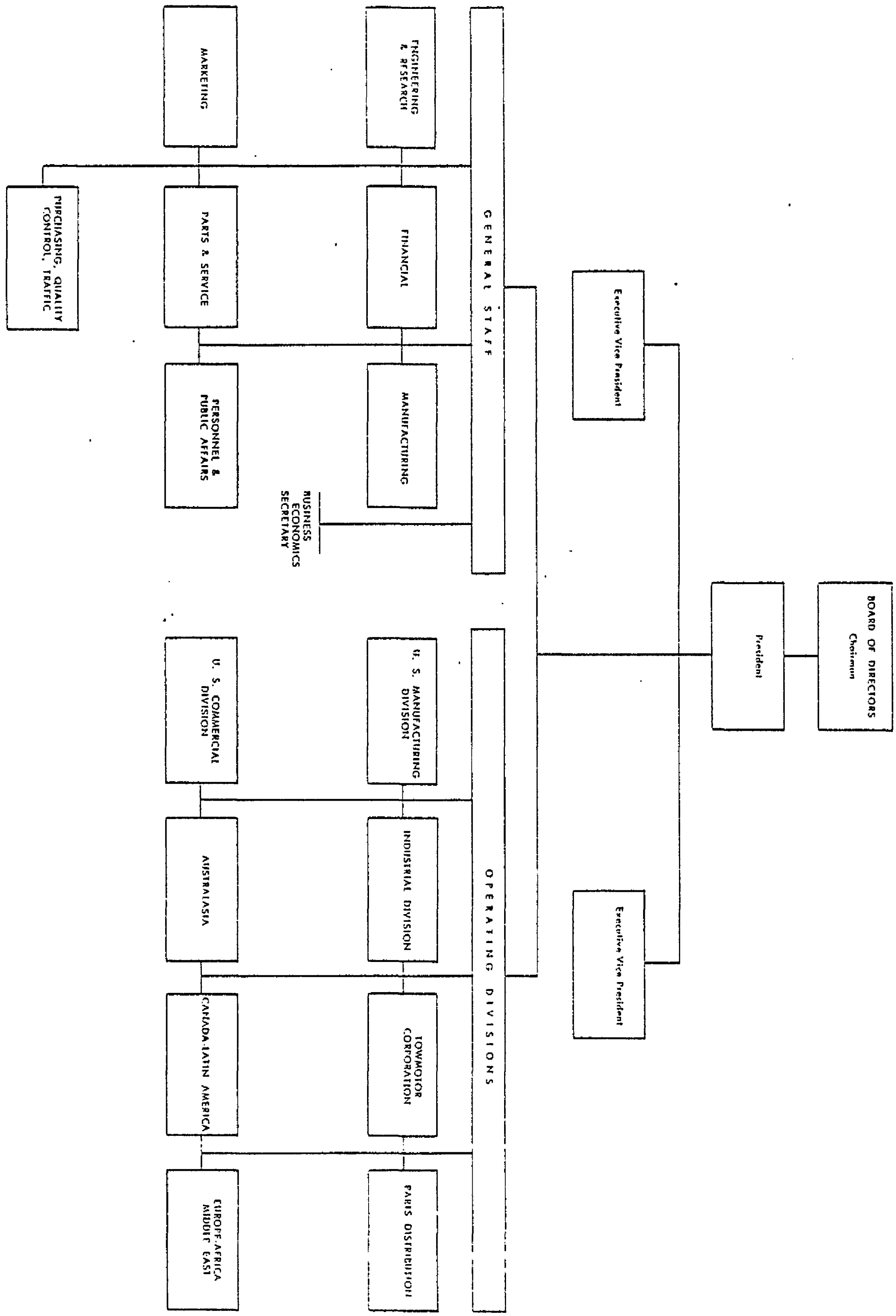

Table No: N. 2.

SIGNIFICANT TRENDS, 1968-77 (Dollar amounts in millions except those stated on a share basis)

	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Sales	5848.9	5042.3	4963.7	4082.1	3182.4	2602.2	2175.2	2127.8	2001.6	1707.1
Profit	445.1	383.2	398.7	229.2	246.8	206.4	128.3	143.8	142.5	121.6
Profit per share (1) (2)	5.16	4.45	4.64	2.67	2.88	2.42	1.50	1.69	1.67	1.43
Dividends per share (1)	1.58	1.46	1.23	1.10	1.00	0.93	0.90	0.80	0.80	0.80
Materials, supplies, services purchased	3047.9	2641.8	2703.2	2459.3	1701.1	1271.8	1063.2	1087.7	1064.3	845.6
Wages, salaries, employee benefits	1761.7	1561.3	1511.7	1327.4	1076.0	858.9	767.2	710.3	652.9	571.6
Taxes based on income	334.1	260.1	248.8	133.7	152.5	160.9	107.6	129.9	130.6	90.5
Capitalised expenditures	516.4	495.0	446.0	349.7	263.7	132.8	123.6	113.2	110.0	183.3
Depreciation and amortisation	210.5	184.1	156.4	125.5	106.4	100.8	99.7	99.5	95.9	82.2
Average number of employees	78565	77717	79393	76993	71028	62134	62528	66062	63939	59848
Number of shareholders, year-end	48313	46424	44697	45295	44331	44319	46726	48201	47178	48126

(1) After adjustment for stock splits and stock dividends.

(2) Computed on weighted average number of shares outstanding.

APPENDIX O

TRIPARTITE QUESTIONNAIRE TO CATERPILLAR PLANTS WORLDWIDE

APPENDIX O

TRIPARTITE QUESTIONNAIRE TO CATERPILLAR PLANTS - WORLDWIDE.

SECTION I.	PLANT AND MACHINE SHOP (10 Questions).
SECTION II.	PEOPLE AND ORGANISATION OF QUALITY CONTROL. (27 Questions).
SECTION III.	CO-ORDINATED MEASURING MACHINES. (29 Questions).

TOTAL: 66 Questions.

PLANT AND MACHINE SHOP

Glasgow figures in brackets

1. Approximately how many powered machine tools for machining, cutting or forming parts do you have in your machine shop? ________ (500)

2. How many of the above have numerical controls?
   A. Stand Alone N. C. ________ (20)
   B. Part of automated transfer line ________ (10)

3. What is the rough surface area of the machine shop? (Can you send me a small layout?) ________ (Plant = 5.4m. sq. ft). (M/c Shop = 423,000 sq.ft).

4. What is the surface area for the average sized machine tool? ________ (60 sq. ft.)

5. What surface area approximately is used by Inspection within this machine shop? (Including inspection machines, benches, cribs, etc). ________ (14,500 sq.ft)

6. What is the approximate power consumption for the machine shop monthly in kilowatt hours ________ (M/c Shop = 1.7m Kw hour per month).

   (Plant = 5m kw hour/mth).

7. What is the approximate annual cost of labour and material expense for the total Quality Control Department? ________ ($1.7m)

8. Have any production systems been changed or will be changed to suit inspection - example the installation of a new CMM may be more efficient if parts are routed to it rather than the gauging being done at the machine tool? Comment:-

____

____

____

____

/.....

9. Do you have a long term plan towards further automation of inspection by any of the following?

	Yes	No	Undecided
More automated CMM for inspection			
More automatic gauging integrated into machine tools			
Other			

10. It has been suggested that Automation and Advanced Technology of any kind will be resisted for various reasons some of which are as follows. Has this been your experience with inspection equipment in particular?

	Yes	Perhaps	No
Protection of inspectors current status or prerogative			
Protection of existing ways of doing inspection work			
Protection of handskills, experience and knowledge			
Protection of the job - security of employment			
To avoid scraping valuable assets such as gauging fixtures, etc.			
To avoid the need to alter other systems in harmony with inspection			
General fear of change			
To avoid conflict with organised groups			
Because it places inspection in too great a scientific and mysterious role upsetting relationships with other functions.			

PEOPLE AND ORGANISATION OF QUALITY CONTROL

(Glasgow figures in brackets)

1. Would you send me a copy of your current organisation structure from Quality Control Manager down to Inspector showing the number of co-ordinated measuring machine operators together with numbers of inspectors in each area. (A rough hand sketch would be sufficient).

2. What year was your plant opened? 19____ (1958)

3. What is the total personnel at this location approx? ____ (2500)

4. How many hourly paid employees approx? ____ (1500)
   -do- direct production? ____ (1100)
   inspectors? ____ (100)
   How many weekly paid inspection people? ____ (23)
   How many monthly paid inspection people (inc. management) ____ (22)

5. Manufacturers claim up to 90% faster inspection with co-ordinate measuring machines suggesting that fewer people would be required. Have you actually reduced your inspection manpower as a result of using these machines?

   Yes: ____ No: ____

   If yes, where did they go?

	Approx Nos:
Left company voluntarily	
Moved to Production Machines	
Moved to other Inspection work	
Moved to Office work	
Other	

6. Have you had to increase your planners and programmers designing tapes as a back-up to the CMM? Yes: ____ No: ____

   If so, how many ____ (2)

7. About what age are your CMM operators and approximately how many are there?

Age Years:	No:	Approx. Service Years:
20-24		
25-29	(1)	
30-34	(1)	

/.....

7. (Cont).

Age Years:	No:	Approx. Service Years:
35-39	(1)	
40-44	(1)	
45-49	(2)	
50-54		
55-59		
60-64		

8. What is the <u>average</u> age of your other inspectors? ____ years (41years)

9. What was the CMM operator's job title prior to working on the CMM? Quote numbers if possible.

TITLE:	Nos:
Surface Plate Inspector	(6)
Machine Operator	
Office Worker	
Labourer	
Maintenance man	
Toolmaker	
Other	
Other	

10. Did you make any changes in wage/skill grading for CMM operators?

Increased grade	
Remained same	(✓)
Reduced grade	

11. Since the introduction of the CMM how in your opinion has this affected the influence and power of the inspector/operator towards line management or production supervisors? (e.g. can he instruct production to stop?)

	Greatly Increased:	Increased:	No Change:	Reduced:	Greatly Reduced:
Influence:					
Power:					

/....

12. If the CMM operator has gained more or less power how has this affected his relationship with the line production supervisor?

	Greatly Improved:	Improved:	No Change:	Deteriorated:
Relationship:				

13. How have your production supervisors accepted results from CMM in comparison with surface plate results?

	Total Acceptance:	Accept:	Accept with qualifications:	Prefer surface plate check:
During early months of use:				
After six months:				

14. If CMM becomes an integrated part of in-line machining process and output data takes away human discretions, do you consider that the inspector should eventually become part of the production team?

Strongly Disagree:	Mildly Disagree:	Neither Agreement nor disagreement:	Mild Agreement:	Strong Agreement:

15. If the CMM tends to require less skill to operate do you think the inspectors of tomorrow will become dissatisfied with their work or not?

Strongly Disagree:	Mildly Disagree:	Neither Agreement nor disagreement:	Mild Agreement:	Strong Agreement:

16. Do you have any female CMM operators? Yes: _____ No: _____(✓)

If yes, how many? _______

What were their previous jobs in the plant?

Machine operator	
Office worker	
Inspectress	
Other	

/....

17. What effect has the introduction of CMM technology had on your inspection staff both CMM operators and other inspectors?

	CMM Operators:	Other Inspectors:
Feeling of increased self status		
Feeling of less self status		
Greater interest in work		
Less interest in work		
No change		

18. What reaction have you had with in-plant users of CMM output? For example - Production Supervisors, Machine Operators?

	First 3 mths:	Six mths:	One Year +
Pleasantly surprised at speed of measuring			
Distrust of first results & ask for plate check			
Prefer surface plate checks			
Do not understand print-out data			
Had to conduct classes of instruction			
No reaction			
Demand for further usage			

19. What are the major or most frequent complaints made by your CMM operator?

	Brief Outline
About CMM itself	
About work environment	
About job grading	
About other	

20. Have any of your CMM operators failed on the job? Yes: _____ No: _____

If yes, why did they fail? ________________

and what happened to the CMM operator(s) who failed?

Returned to previous job	
Went to other job	
Other	

/....

21. Do you normally operate your CMM on -

Single shift 8 hours	
Two shifts 16 hours	
Three shifts 24 hours	

22. What type of back-up do you have for preparation of CMM tapes and other planning work?

	No. of planners
Special CMM programmers group	
Existing N.C. mach. programmers	
Other	

Comment: ____________________

23. How did your planners learn CMM tape preparation?

Self taught from literature:	
Attended course by CMM builder	
Previous related experience	
Other	

24. Did you involve your CMM operator in the Planning and Purchasing decisions for your first CMM?

	Current CMMs	Will consider next time
No, not at all		
Kept advised		
Part of visit to other user		
Attended all planning meetings		

25. Have you experienced any labour problems in terms of disputes since the introduction of CMM? For example movement of work from one group to another. Concern about reduction of inspectors, etc. ____________________

/...

26. Some manufacturers of CMM claim that operators can be trained to operate a CMM in less than four hours. How long on average have your operators taken to competently operate your most advanced CMM?

_____ hours _____ days _____ weeks _____ months

Comment: ____________________

27. Do you use any particular training techniques for CMM operators, programme planners or others?

Film or videotape	
Programmed Learning	
Instruction by Manufacturer	
Self taught from literature	
Other	
Other	

Glasgow figures in brackets

CO-ORDINATED MEASURING MACHINES

1. What make of co-ordinate measuring machines (CMM) have you got or have in forecast for the future?

Type:	Models:	Reason for Choice*	Year of Purchase	
Ferranti/Bendix	(Saturn)	(Travel)		(1976)
D.E.A.	(Gamma)	(Accuracy)		(1976)
Hansford				
L.K. Tools				
NOTSA				
Zeiss				
S.I.P.				
Olivetti				
Portage				(1969)
Boyce				
Mitutoyo				
Other				

*Reasons = Cost, Accuracy, Travel, Table Size, etc.

2. From whom did you first learn about CMM?

	Approx. Year:	
Caterpillar G.O.		(✓) (1969)
Technical Press		
Conference - Exhibition		
CMM Manufacturers		(✓) (1973)
Other		

3. What type of peripheral equipment do you have for each CMM or in forecast?

	For Models	Glasgow
Manual system only		Cordax
Digital Readout x, y, z.		Portage
Calculator		Gamma/Saturn
Printer Teletype		Gamma/Saturn
Plotter		
Mini Computer		Gamma/Saturn
V.D.U.		
Full automatic system		
Other		

/....

4. Before buying a CMM did you visit any other organisation to see them in action? Yes: ______ No: ______

If yes, whom did you visit: ____________________

5. Since the introduction of CMM approximately what percentage time have you gained with the following in comparison with conventional inspection methods?

(✓) Glasgow

	10	20	30	40	50	60	70	80	90	100
Production machines awaiting inspection check reduction in time - percentage				(✓)						
Time to set-up part for checking - percentage							(✓)			

6. What did you do with your obsolete gauges and fixtures?

Scrap: ______ Store as Standby: ______ (✓) Sold: ______ Other: ______

7. How did you locate your CMM?

	Actual:	Preferred After Experience:
Special air conditioned clean room		
Wall partition with/without roof	(✓)	
Open workshop		
Inspection centre		(✓)
On--line with machining centres		
At final check-out		
Other		

8. Was this the best site for optimum inspection or only available site?
Comment: ____________________

9. Is your CMM softwear compatible with all other CMM in-plant? ( ) Glasgow

Yes: (✓) No: ______

/....

10. Did you experience installation and early teething problems with your CMM and what is the current status?
Comment: ______________________________

11. What contribution has the use of CMMs made to the following factors in your plant or inspection itself?

Contribution:	Major Increase	Some Incr:	Minor Incr:	Some Decrease:	Major Decrease:
Profit					
Productivity					
Cost Reduction					
Speed of checks					
Accuracy of checks					
Set-up times reduction					
Repeatability of checks					
Reliability of checks					
Calculating errors					

12. In your decision to invest in CMM what importance did you rate the following factors for your plant?

	Vital Impt	Very Impt	Import ant.	Unim-portant	Not Considered
Faster checking					
More accuracy					
Better repeatability					
Labour saving					
Less production m/c downtime					
Better data					
Reduced inventories					
Cost saving-gauges					
Keeping up to date with technology					
Ease of operating					
No need for special fixtures					
Safer					
Quicker detection of m/c tool variations.					

/....

13. What percentage of time are your CMMs used in a manual mode as opposed to using tapes to measure parts from the machine shop?

Manual mode: (20) Tapes: (80)

14. How many application tapes do you have currently for each CMM?

Model: (Saturn -215) (Gamma - 172) - please answer against the models quoted in question No: 1.

15. What are the approximate total number of components processed through your machine shop for machining purposes? ________ (1300)

16. What is the average machining operation per component? ______ (4)

17. What appropriate percentage of these above components are currently checked over the CMM? ______ (16%)

18. Are the balance of components checked by conventional inspection e.g. surface plate or hand gauges?

Yes: ______ (✓) No: ______

19. What percentage of time is spent on checking purchased finished items with CMM? ______ % time of CMM.

20. Do you have an optimum target for tapes per CMM in terms of current production or capacity of CMM?

Optimum targets: __________ (Saturn 550)
(Gamma 800)

21. Since the introduction and use of CMM in your plant and the possible improved accuracy of measuring to blueprint specification, do you now question the capabilities of your machine tools in terms of maintaining accuracy and repeatability?

Yes: ______ No: ______

Comment: ______________________________

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22. What servicing or maintenance policy fo you operate for your CMM?

	(✓)
In-house engineers	
Service Contract	
Combination of above	
Other	

23. Have you experienced a change in the following since the use of CMM? (Estimates will be sufficient).

	Prior to CMM.	Currently.	Time taken to notice change.
Scrap Cost			
Rework Labour			
Field Complaints			

24. Do you regularly use the CMM for checking other items in addition to components?

	Yes	No	Frequency
Gauging Fixtures			
Manufactring Fixtures			
Components only			
Other uses			

25. Any other general comments about your experience with Co-ordinated Measuring Machines or your opinion about the future of automated inspection in industry:

____

____

____

____

____

____

26. Would you send me any papers, literature, photographs, reports, magazines or books about co-ordinate measuring machines which I can copy and return to you if required? Yes: ______ No: ______

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27. How would you justify the investment of a fully automated CMM?

By measuring time taken to measure parts currently v's new system	
By production time lost awaiting measure	
By Labour Saving	
By Savings gained from less scrap and rework	
Other	
Other	

28. With the greater ability to measure very accurately, has this had any spin-off advantages to engineering design in terms of tolerance dimensioning or other aspects?

Yes: ______ No: ______

29. Do you have any suggestions to improve my questionnaire? (example questions to omit, add, change, etc.

APPENDIX P

A HISTORY OF COMPUTERISED CO-ORDINATE MEASURING MACHINES AT CATERPILLAR, WORLDWIDE.

APPENDIX P

A History of Computerised Co-ordinate Measuring Machines at Caterpillar Worldwide.

Caterpillar's history in computerised CMMs began with East Peoria Plant in 1970. As East Peoria's Quality Assurance personnel became more proficient in the use of CMMs, it became apparent that the computer programme, which was provided by the CMM manufacturer, was inadequate. Automatic alignment was available on the X-axis only; however parts manufactured at Caterpillar use a 2-axes (X-Y) alignment. Also, no translation (moving of origin) was available. This feature is very useful when the origin is in error but the inspection sequence is to be continued.

EPQA, by developing their own Master Control Programme (MCP) to provide these features increased the throughput by approximately a factor of 3.

In data processing terminology, the Master Control Programme could be described as a utility programme in that parameters are provided to it which instruct the computer to perform pre-determined calculations or functions. An example of these parameters are:

Command:	Nominals:	Function:
'A'	None	Reads X + Y co-ordinates.
'B'	XN, YN e.g. (6.83, 5.56)	Compare Xs + Ys
'O'	Comments	Computer to print comments or instructions.

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There are now two Master Control Programmes maintained by EPQA. The original MCP was designed to operate in 4K of core memory. The expanded MCP needs 8K of core memory. When ever a new CMM, with different electronics or features is purchased, EPQA modifies one of their MCPs and generates a unique version to be used with it. There are presently 19 versions maintained by EPQA.

As other plants became interested in computerised CMMs, East Peoria Quality Assurance was contacted for assistance. East Peoria Quality Assurance would then create a Master Control Programme for each unique brand of CMM and send a copy of the programme to the requesting plant. The source programme deck and listing was retained in East Peoria Quality Assurance. Any questions pertaining to the Master Control Programme would, by necessity, be directed to East Peoria Quality Assurance.

The statistics regarding CMM usage at Caterpillar.

Plant:	No. of CMM.	Computer:	No. of Application Programmes:
Aurora	4	DEC PDP/8	1650
Basic Engine	9	DEC PDP/8	2100
Davenport	6	DEC PDP/8	530
Decatur	3	DEC PDP/8	1610
Ind. Div.	1	DEC PDP/8	9
Joliet	4	DEC PDP/8	1784
Milwaukee	0		
Morton	1	DEC PDP/8	3
East Peoria	17	DEC PDP/8	3440
Towmotor Mentor	1	DEC PDP/8	330
Towmotor Dallas	0		
San Leandro	1	DEC PDP/8	400
York	2	DEC PDP/8	70
Glasgow	2	DEC PDP/8	181
Gosselies	2	DEC PDP/8	316
Grenoble	1	DEC PDP/8	75
Japan	1	DEC PDP/8	100
Total 15	55		12,568
* San Leandro	2	IBM S/7	780
** Mapleton	1	IBM 1800	108

APPENDIX Q

CATERPILLAR WORLDWIDE CASE STUDY - COLLATED RESPONSES FROM INTERNATIONAL QUESTIONNAIRE.

APPENDIX Q

CATERPILLAR WORLDWIDE CASE STUDY

Collated Responses from International Questionnaire.

Question No: Introductory Section:	Comment:
1. Caterpillar Tractor Company.	
2. 26 Manufacturing Plants Worldwide plus 2 affiliated companies.	
3. Major products are earthmoving equipment such as tractor bulldozers, heavy trucks and motor graders also diesel engines for trucks, marine and generating set applications, Lift trucks are also part of the product line.	
4. Headquarters in Peoria, Illinois, U.S.A.	
5. Production type ranges from small batch to large batch although some of the component producing plants and foundries in the U.S.A. could now be verging on the mass production type.	
6. Caterpillar have invested approximately $2.4 billion during the 1970s to build and expand their plants worldwide. Currently a complete model change is taking place in preparation for the 1980s.	Changes involve automation, transfer systems, robotics and much computer control on shop floor.
7. Changes will be slow to affect production systems but it is anticipated that wide changes will be necessary in the late 1980s.	See model of Technical changes and production systems.
8. Caterpillar have several on-going plans for automation in various spheres of their business i.e. manufacturing, assembly, etc. Currently there are approx. 404 N.C. machines in the company worldwide.	
9. Approximately 20,500 powered machine tools worldwide not counting many indirect powered machine tools.	
10. Approximately 404 N.C. machine tools.	

/.....

Question No:	Introduction Section:	Comment:
11.	As of the beginning of 1978 Caterpillar occupies 37.7 million square feet of manufacturing space worldwide.	
12.	Machine tools range from 10 sq.ft up to 120 sq.ft. in area.	
13.	Inspection tend to occupy about 3% to 5% of the total machine shop area. Much depends upon the nature of manufacturing i.e. assembly or machine cutting shops.	
14.	There was insufficient data available to record the exact consumption for power in each Caterpillar plant.	
15.	All Quality Control Managers report to the Plant Manager who is the most senior executive at each Caterpillar facility.	
16.	Organisation: Board Level Caterpillar Caterpillar Tractor Co. Ltd. Caterpillar Tractor Co. Ltd. Glasgow	
17.	Caterpillar Tractor Company was founded in 1925 but the earliest production was in 1886 at San Leandro, California by one of the founder members of Caterpillar.	
18.	There is a total of 83,000 employees in the worldwide organisation - January 1979.	
19.	Total hourly payroll is 76.1% of total Total weekly payroll is 11.2% of total. Total monthly payroll is 12.7% of total. Quality Control represent 5.32% of total employees and this is broken down as shown in table 5.	These percentages apply to American plants only but are near enough for total world figures.
20.	All forms of inspection are practiced worldwide.	
21.	Caterpillar has been growing in employment over the last 10 years but the concept used and encouraged by the corporation would be to use: 1. Normal Wastage. 2. Retrain for other skills	

Question No:	Introduction Section:	Comment:
22.	Approximately £55 million for worldwide quality control budget covering labour and material expense.	
23.	Results of this survey are given separately.	
24.	Specific plans have been drawn up and are on-going.	

Question No. Co-ordinate Measuring Machine Section:	Comment:

1.
Caterpillar Worldwide currently have 59 co-ordinate measuring machines.

2.
Various sources were used but Caterpillar East Peoria had acquired co-ordinate measuring machines as early as 1962. (The first machines ever designed were made in 1959-60). Transfer of information from plant to plant on these measuring machines has been remarkably slow.

3.
In most plants the Quality Control Manager was the major promoter of the need for this equipment. His service with the Company varies considerably plant to plant but it would be unusual to have a Quality Control Manager with less than 10 years service mainly due to the Company policy of promotion from within the organisation.

4.
The Corporation have a formal project approval system through which all capital expenditure above a specific value must go. This system can take up to 3 months to go the full route. Adding on the time to acquire a new CMM from the supplier of at least one year, then considering the decision time prior to raising the project we could have a total of two years time lag.

5.
Each plant is left with its own decision on visits to users and suppliers, but generally there are three main theatres - U.S.A., Europe and the Far East. Each group of plants in these areas generally co-operate to check one CMM against another. (The range of product produced in each plant is different, therefore there is no competition which could cause resistance to exchange technology).

6.
Two major studies have been conducted in the corporation to determine improvements one at Glasgow Plant which is reported in the Case Study at Glasgow, the second study was made at East Peoria Plant.

Glasgow = 70% improvement.
East Peoria = 75% improvement.

Question
No:

Co-ordinate Measuring Machine Section:	Comment:

7.
Caterpillar is a very conservative organisation and in this respect have a gauge policy which encourages a 5-year retention of obsolete gauges therefore most plants will have retained gauges after the new technology has been installed.

8.
Initially, the General Office headquarters instructed that co-ordinate measuring machines should be located in the open workshop. However most new installations, especially in the U.S. are now being housed in special air conditioned clean rooms.

9.
Large components encourage planners to minimise transporting and therefore many CMMs are correctly located in or near the point of manufacture. With small components the general corporate philosophy is to locate measuring equipment at the end of the manufacturing lines for most optimum use.

10.
All worldwide facilities use compatible software in order that maximum flexibility and exchange can be achieved.

11.
Most Caterpillar Plants experienced electronic problems mainly due to overheating and dirt. (Hence the move toward encasing the CMM in an air controlled room).

12.
There have been no co-ordinated results on the contribution from all the factors listed. Headquarters tend to encourage audits for utilisation measures but these are rather vague.

13.
Decision factors for investment in CMM technology are centred around "Faster Checking" "More Accuracy" and less "Downtime of production machines".

14.
Caterpillar are concerned about "technological leap-frogging" due to the improved nature of measuring. Machine tool accuracy is constantly under review.

15.
A combination of "In-house Maintenance" and "Service Contracts" are employed in all Caterpillar Plants. A close analysis of faults is maintained worldwide by the headquarters group.

...

Question No: Co-ordinate Measuring Machine Section:	Comment:
16. Caterpillar introduced a unique system of Quality Indicators in 1976 part of which is the measurement of scrap and rework hours lost. In addition to this a measure of field failures is maintained. Only the Glasgow Plant have attempted with success to correlate these figures to the introduction of co-ordinate measuring machine technology.	
17. Caterpillar has at present only one fully automated CMM in operation. This machine is part of a computer controlled transfer line. To justify other similar installations one would require similar machining investment. Therefore the major concern would be to justify the CMM via less production machine downtime.	
18. Worldwide concern is to increase the utilisation of what CMM exist currently in each plant and to consider integrating gauging systems into machine tools as a means to minimise the high expenditure on co-ordinate measuring machine technology.	
19. No figures have been published as yet showing a downtime of inspection manning worldwide due to the use of co-ordinate measuring machines. Generally the belief is that more work is now being inspected than ever before.	
20. Planners have been increased in all Caterpillar Plants very slightly as the existing N.C. machine tool programmes have been used together with the aforementioned master programming service from the East Peoria Plant.	
21. There are approximately 104 CMM operators in the Caterpillar Worldwide Quality Control functions. The average age of these operators is between 40 and 44 years and again on average they have 12 years of service with the Company. It is interesting to note that the U.S. Plants on their own have 65 operators with average age 50 to 54 and 16 years service. This is due to the longer established plants.	

Question No: Co-ordinate Measuring Machine Section:	Comment:

22.
The average age of inspectors in U.S. based Caterpillar Plants is 43 years while other Caterpillar Plants are 37 years giving an overall average of 40 years.

23.
In all cases the 104 CMM operators were previously employed as surface plate inspectors.

24.
The Major Survey gave a 14% "Increased Grade" and 86% "Remained the Same". Caterpillar U.S. Plants were 25% "Increased Grade" and 75% "Remained the Same" while Caterpillar other worldwide plants had 28% "Increased Grade" and 72% "Remained the Same". The majority of firms seem to get away with pushing in new technology without paying higher rates for it.

25.
This question was asked to determine if any behavioural changes had taken place with the inspector's influence and power on the shop floor. Caterpillar Worldwide claim increased Influence in 85% of Plants against a 44% claim from the "Major Study". However the responses for Increased Power were 22% major study against 38% for Caterpillar.
Overall Caterpillar report greater gain with influence and power than the Major Survey.

26.
Has the relationship between the Production Supervisor and the CMM Operator improved? 75% of the Caterpillar Plants say "Improved" and 10% say "Greatly Improved" while the 150 firms in the Major Survey have 40% "Improved" and 2% "Greatly Improved". 57% of the Major Survey claim "No Change".

27.
Will technology eventually integrate the inspection role and the production role? Interesting results from both Caterpillar and the Major Survey as Caterpillar were almost 50-50 in both directions i.e. strongly agreeing and strongly disagreeing. The Major Survey had a similar trend but not to the same extremes.

28.
What could very advanced technology do to the inspector, make him dissatisfied? Both the Major Survey and the Caterpillar Worldwide response in the main disagreed with this possibility. Again there were firms who strongly agreed with the suggestions.

Question No: Co-ordinate Measuring Machine Section:	Comment:

29.
This question tries to determine the effect on the CMM operator resulting from the new technology also was there a "Hawthorn" type rub off. Caterpillar saw an 80% "Increased Self Status" and a 15% "Greater Job Interest". The major survey said 50% of firms "Increased Status" and 26% Greater Work Interest but 23% said "No Change".

The Major Study claimed a No Change on other inspectors for 62% of firms but 13% said they had "Increased Status" and 20% "Greater Job Interest". Caterpillar said that almost half of the plants claimed "Increased Self Status" for the other inspectors.

30.
Much discussion has taken place on the learning curve of the co-ordinate measuring machine operator to gain overall competence. The Caterpillar world survey which has several actual time studies gave a result of 8.1 weeks, while the Major Study of 150 user firms gave an average of 9 weeks.

31.
Selling the new technology to the Shop Floor is of vital importance, to what extent do firms involve shop floor operators? Caterpillar said 65% no involvement" and 35% "Kept Advised". Major Survey claimes 61% of firms said "No" and 32% "Kept Advised", 6% "Part of Visit" and 3% actually "Attending Planning Meetings".

When asked about future involvement, the Caterpillar plants moved for more involvement and so did the Major Survey firms but not to the same degree.

32.
Each firm was asked if any of their CMM operators had failed on the assignment? 55% of Caterpillar Plants said they had had failures caused mainly by "Lack of Confidence" 30% of this sample Returned to Previous Job and 20% Went to Other Work. Only 17% of the Major Survey claimed failures and most of these were again put down to "Lack of Confidence" 2 out of 3 "Went Back to Previous Job".

33
The final questionnaire of the survey tried to determine if any "Labour Problems" had resulted with the introduction of CMM technology. 73% of the Major Survey said "No Problems" 12% had wage claims and 14% were anticipating further problems. Caterpillar had a 40% "No Problems" 30% "Wage Claim" and 30% Concern for future changes.

APPENDIX R

ORGANISATION STRUCTURES - LIST OF SHEETS

APPENDIX R

ORGANISATION STRUCTURES

SUMMARY OF CONTENTS

/...

1	2	3	4	5	6	7	8	9
Business Activity/ Employee Size	Employee Size:	No: Position Titles:	No. of Levels:	Director Span of Control:	No. of Divisions:	Division Span of Control:	No. of Sections:	No. of CMM Sections:
Employee Size								
User		6.3	3.6	3.2	3.2	3.7	8.0	1.25
Non User		4.1	2.9	2.98	2.63	1.75	6.04	0.0
Business Activity								
User	2054	6.3	3.67	3.19	3.51	4.28	9.15	1.0
Non User	930.8	3.81	2.75	2.58	2.19	2.05	6.43	0.0
All Firms								
User		6.64	3.95	3.18	3.6	3.82	9.2	1.36
Non-User		3.82	2.66	2.62	2.02	1.84	5.72	0.0

INDEX A: SUMMARY OF ALL USER AND NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY EMPLOYEE SIZE AND BUSINESS ACTIVITY.

Sheet 1: of 2:

10 Mgr. Qual. Cont.	11 Asst. Q.C. Mgr.	12 Chief Insp.	13 Asst. Chief.	14 Tech. Mgr.	15 Superin-tendent.	16 Foreman	17 Asst. F'man.	18 Qual. Engr.	19 Co-ord:	20 Head of Lab:	21 Test Mgr:	22 Rel'bty Mgr:	23 Quality Assur. Mgr:
6.1	0.57	2.71	0.42	0.57	1.43	5.4	1.57	3.43	1.57	2.1	1.0	1.14	3.57
4.0	0.28	3.42	1.42	0.57	1.0	4.5	0.14	2.42	0.71	0.71	0.85	0.14	1.28
1.65	0.1	1.0	0.15	0.25	0.15	1.2	0.20	1.4	0.55	0.9	0.4	0.35	1.0
1.8	0.03	1.7	0.75	0.35	0.55	2.35	0.10	1.2	0.35	0.35	0.35	0.5	0.7
0.75	0.08	0.52	0.10	0.08	0.10	0.56	0.06	0.62	0.18	0.40	0.14	0.16	0.40
0.56	0.04	0.48	0.18	0.06	0.10	0.64	0.04	0.36	0.10	0.10	0.14	0.02	0.24

INDEX A. SUMMARY OF ALL USER AND NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY EMPLOYEE SIZE AND BUSINESS ACTIVITY.

Sheet 2 of 2:

1 Business Activity/ Employee Size	2 Employee Size:	3 No: Position Titles:	4 No. of Levels:	5 Director Span of Control:	6 No. of Divisions:	7 Division Span of Control:	8 No. of Sections:	9 No. of CMM Sections:
User								
10- 49		4.0	3.0	3.0	3.0	4.0	5.0	1.0
50- 99		5.75	3.2	3.0	3.0	4.0	5.0	1.0
100- 499		5.6	3.3	2.6	2.5	2.8	7.0	1.0
500- 999		4.4	3.3	2.6	3.4	3.3	7.7	1.0
1000-1999		8.8	3.9	3.25	2.8	4.3	8.4	1.25
2000-4999		7.2	4.4	3.7	3.8	4.0	8.0	1.8
5000 plus		8.4	4.2	3.2	4.0	3.7	15.0	1.7
Average		6.3	3.6	3.2	3.2	3.7	8.0	1.25
Non-User								
10- 49		2.6	2.0	2.0	1.0	1.0	2.0	0.0
50- 99		2.75	2.25	2.25	1.25	1.0	3.25	0.0
100- 499		3.6	2.5	2.4	1.7	1.96	5.7	0.0
500- 999		3.87	2.6	2.75	2.0	1.6	4.6	0.0
1000-1999		6.0	3.5	3.0	3.0	3.25	10.25	0.0
2000-4999		5.0	3.5	3.5	3.5	1.5	8.5	0.0
5000 plus		5.0	4.0	5.0	6.0	2.0	8.0	0.0
Average		4.1	2.9	2.98	2.63	1.75	6.04	0.0

Sheet 1 of 3.

INDEX B - USER AND NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY EMPLOYEE SIZE.

	10 Mgr. Qual. Cont.	11 Asst. Q.C. Mgr.	12 Chief Insp.	13 Asst. Chief.	14 Tech. Mgr.	15 Superin-tendent.	16 Foreman	17 Asst. F'man.	18 Qual. Engr.	19 Co-ord:	20 Head of Lab:	21 Test Mgr:	22 Rel'bty Mgr:	23 Quality Assur. Mgr:
	5.0	0.0	0.0	0.0	0.0	6.0	7.0	2.0	0.0	0.0	0.0	0.0	0.0	4.0
	6.0	0.0	0.0	0.0	0.0	1.0	3.0	5.0	0.0	0.0	0.0	0.0	1.0	5.0
	4.0	1.0	5.0	0.0	0.0	0.0	2.0	0.0	2.0	3.0	1.0	2.0	0.0	2.0
	10.0	0.0	5.0	1.0	1.0	1.0	9.0	1.0	7.0	1.0	3.0	2.0	0.0	4.0
	7.0	1.0	5.0	1.0	3.0	1.0	6.0	1.0	8.0	2.0	5.0	1.0	2.0	3.0
	4.0	0.0	3.0	0.0	0.0	1.0	4.0	1.0	4.0	3.0	3.0	2.0	3.0	5.0
	7.0	2.0	1.0	1.0	0.0	0.0	2.0	1.0	3.0	2.0	3.0	0.0	2.0	2.0
Av.	6.1	0.57	2.71	0.42	0.57	1.43	5.4	1.57	3.43	1.57	21.	1.0	1.14	3.57
	2.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
	10.0	1.0	14.0	6.0	2.0	1.0	21.0	0,0	8.0	1.0	1.0	4.0	1.0	8.0
	6.0	0.0	5.0	1.0	0.0	2.0	3.0	0.0	1.0	3.0	1.0	1.0	0.0	1.0
	2.0	0.0	3.0	1.0	1.0	2.0	3.0	1.0	3.0	0.0	2.0	0.0	0.0	0.0
	2.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	2.0	0.0	1.0	1.0	0.0	0.0
	2.0	1.0	0.0	1.0	0.0	1.0	2.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Av.	4.0	0.28	3.42	1.42	0.57	1.0	4.5	0.14	2.42	0.71	0.71	0.85	0.14	1.28

Sheet 2 of 3.

INDEX B. USER AND NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY EMPLOYEE SIZE.

	24	25	26	27	28	29	30
	Ratio Hourly Inspector to Total Hourly	Ratio Hourly Inspector to Total Dir./Prod.	Ratio Weekly Inspector to total personnel.	Ratio Monthly Inspector to total personnel.	Ratio all Inspection to total personnel.	Budget per head of inspection personnel (x 1000)	Budget per head of total personnel (x 1000)
	7.22	11.71	1.90	1.82	8.0	7.92	0.48
	7.63	3.18	1.47	10.43	16.0	6.66	0.23
	8.94	14.91	1.94	2.80	10.0	6.85	0.54
	6.66	10.22	1.67	1.20	6.0	6.67	0.32
	9.06	16.65	2.02	1.13	8.0	9.45	0.64
	4.67	7.54	1.83	1.14	6.0	8.07	0.45
	6.70	11.04	2.58	0.80	7.0	9.47	0.56
M.	7.25	11.73	1.95	1.84	8.0	7.92	0.49
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N.	109	120	130	132	128	85	86
	1.97	18.81	2.93	4.02	9.9	2.89	0.42
	4.54	6.23	2.80	1.92	8.6	5.22	0.44
	4.50	6.66	1.98	1.51	6.8	5.64	0.31
	4.34	6.04	0.92	0.81	4.8	7.41	0.31
	6.41	9.51	2.46	1.01	6.0	15.82	0.97
	11.30	27.77	0.18	0.67	4.3	3.75	0.03
	0	0	1.0	0.75	7.0	0.92	0.04
M.	4.63	8.68	2.04	1.65	6.9	6.41	0.38
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N.	130	130	131	131	130	84	86

Sheet 3 of 3

INDEX B. USER AND NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY EMPLOYEE SIZE.

1 Business Activity/ Employee Size	2 Employee Size:	3 No: Position Titles:	4 No. of Levels:	5 Director Span of Control:	6 No. of Divisions:	7 Division Span of Control:	8 No. of Sections:	9 No. of CMM Sections:
User								
Defence	2362	5.5	3.75	3.75	3.0	4.0	10.0	1.75
Aircraft	5531	10.5	5.0	3.2	3.5	3.5	13.7	2.28
Tools	1800	4.0	3.0	2.0	2.0	2.0	4.0	2.0
Machining	1200	12.0	4.0	5.0	5.0	6.0	12.0	1.0
Engines	1320	4.6	3.6	3.0	3.6	4.0	9.0	1.6
Pumps	1450	5.0	4.0	2.5	5.0	3.0	9.0	1.0
Truck/Track	4500	12.0	4.0	6.0	6.0	6.0	13.0	1.0
Food Proc.	1250	4.0	3.0	3.0	3.0	4.0	11.0	1.0
Telec	3797	4.5	3.0	2.0	4.0	4.0	9.0	1.5
Elec.	792	6.6	4.0	3.25	3.5	3.0	7.5	1.0
M/c Tool	584	4.0	2.5	2.5	2.5	3.0	6.5	1.0
Controls	1800	4.0	3.0	3.0	3.0	7.0	12.0	1.0
Castings	2700	11.0	4.5	4.0	4.0	3.0	8.0	1.0
Auto	2833	6.0	5.0	3.0	4.0	4.0	8.0	1.0
Misc.	995	4.0	4.0	2.5	4.0	4.0	4.5	1.0
R. & D.	6000	5.0	4.0	3.0	2.0	3.0	6.0	1.0
Plastics	2053	6.64	3.9	3.2	3.6	3.8	9.2	1.3
M/H	1000	8.0	4.0	5.0	5.0	10.0	20.0	1.0
Instr.	683	7.0	3.3	3.0	2.6	3.3	5.6	1.0
Dom P.	500	2.0	2.0	1.0	1.0	5.0	5.0	1.0
TOTALS	41097	126.3	73.55	63.9	70.3	85.6	183.0	
AVERAGE	2054	6.3	3.67	3.19	3.51	4.28	9.15	1.0

Sheet 1 of 3.

INDEX C - USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITIES.

10 Mgr. Qual. Cont.	11 Asst. Q.C. Mgr.	12 Chief Insp.	13 Asst. Chief.	14 Tech. Mgr.	15 Superin-tendent.	16 Foreman	17 Asst. F'man.	18 Qual. Engr.	19 Co-ord:	20 Head of Lab:	21 Test Mgr:	22 Rel'bty Mgr:	23 Quality Assur. Mgr:
2.0	0.0	1.0	0.0	0.0	0.0	2.0	1.0	0.0	2.0	2.0	1.0	2.0	2.0
4.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	3.0	1.0	4.0	0.0	1.0	3.0
1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	2.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
2.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	2.0	1.0	2.0	0.0	0.0	1.0
0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0
2.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
1.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0
5.0	1.0	2.0	0.0	1.0	1.0	4.0	2.0	5.0	2.0	1.0	5.0	0.0	6.0
2.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	1.0	0.0	1.0	1.0	1.0	0.0	1.0	1.0	2.0	0.0	1.0	1.0
4.0	0.0	3.0	1.0	0.0	1.0	3.0	1.0	4.0	0.0	2.0	0.0	0.0	1.0
3.0	0.0	1.0	1.0	0.0	0.0	3.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0
1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0
1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0
1.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	2.0	1.0	0.0	2.0
1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33.0	2.0	20.0	3.0	5.0	3.0	24.0	4.0	28.0	11.0	18.0	8.0	7.0	20.0
1.65	0.1	1.0	0.15	0.25	0.15	1.2	0.20	1.40	0.55	0.9	0.4	0.35	1.0

Sheet 2 of 3.

INDEX C. USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITIES.

	24 Ratio Hourly Inspector to Total Hourly	25 Ratio Hourly Inspector to Total Dir. Prod.	26 Ratio Weekly Inspector to total personnel.	27 Ratio Monthly Inspector to total personnel.	28 Ratio all Inspection to total personnel.	29 Budget per head of inspection personnel (x 1000)	30 Budget per head of total personnel (x 1000)
	5.73	9.29	3.65	0.73	7.6	9.91	0.60
	6.67	10.67	3.08	2.15	8.5	6.28	0.57
	4.76	6.72	0.95	0.81	5.1	4.78	0.20
	12.23	8.39	3.90	2.34	13.7	2.85	0.25
	7.66	15.29	1.18	1.75	8.3	14.06	0.96
	9.42	13.5	1.92	4.96	12.6	3.80	0.36
	5.29	9.0	1.11	1.17	5.9	13.15	0.65
	4.08	3.05	0.75	0.86	3.9	7.74	0.30
	13.01	19.11	0.77	0.56	8.4	9.24	0.79
	9.17	12.09	1.46	1.84	7.5	8.20	0.55
	4.19	8.83	1.47	0.50	4.9	4.23	0.19
	4.80	27.53	2.69	1.10	6.9	3.64	0.25
	9.35	17.95	3.20	0.34	10.4	4.39	0.35
	6.99	10.55	3.30	0.087	9.4	3.93	0.39
	9.19	9.33	3.17	0.79	8.2	8.24	0.45
	7.25	23.48	1.95	0.59	1.9	1.66	0.05
	9.04	13.44	1.25	0.50	7.7	2.85	0.28
	20.83	26.32	1.95	3.67	17.5	9.43	0.48
	7.42	7.88	1.63	8.57	12.2	9.43	0.44
	1.83	2.39	0.88	0.70	2.9	3.02	0.07
M.	7.25	11.67	1.95	1.84	8.02	7.92	0.48
N.	111	122	130	132	150	86	150

Sheet 3 of 3
INDEX C - USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITIES.

1 Business Activity/ Employee Size	2 Employee Size:	3 No: Position Titles:	4 No. of Levels:	5 Director Span of Control:	6 No. of Divisions:	7 Division Span of Control:	8 No. of Sections:	9 No. of CMM Sections:
Non-User.								
Defence	257	3.0	2.5	1.5	1.0	1.5	5.0	0
Aircraft	215	3.0	2.0	2.0	1.0	3.0	4.0	0
Tools	300	3.0	3.0	1.0	0.0	0.0	6.0	0
Machining	157	3.0	2.5	2.3	1.75	1.25	3.3	0
Engines	2500	3.0	2.5	2.0	1.0	2.0	5.0	0
Pumps	60	2.0	2.0	2.0	0.0	0.0	2.0	0
Truck/Tr.	1215	5.0	4.0	2.5	2.5	4.0	7.0	0
Food Proc.	998	4.0	3.0	3.0	3.0	3.0	10.0	0
Telecom.	106	5.0	3.0	4.0	4.0	2.0	20.0	0
Elect.	445	4.25	2.75	2.8	2.3	2.0	5.25	0
M/c Tool	1172	5.2	3.0	3.4	2.8	2.4	9.6	0
Controls	210	3.5	2.5	2.0	2.0	2.5	7.0	0
Castings	315	4.0	3.0	1.5	0.0	0.0	4.0	0
Auto	5000	6.0	5.0	8.0	10.0	2.0	10.0	0
Misc.	369	2.9	2.0	2.7	1.6	1.4	4.8	0
R. & D.	400	4.0	2.0	2.0	2.0	1.5	4.0	0
Plastics	585	5.5	3.0	2.0	1.0	2.5	4.5	0
M/H	3419	4.0	3.0	2.3	2.3	2.0	5.6	0
Inst.	312	3.0	2.3	1.6	1.6	3.0	5.6	0
Dom P.	581	3.0	2.0	3.0	4.0	5.0	6.0	0
TOTALS:	18616	76.35	55.05	51.6	43.85	41.05	128.65	
AVERAGES:	930	3.81	2.75	2.58	2.19	2.05	6.43	0

Sheet 1 of 3
INDEX D. NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITY.

10 Mgr. Qual. Cont.	11 Asst. Q.C. Mgr.	12 Chief Insp.	13 Asst. Chief.	14 Tech. Mgr.	15 Superin-tendent.	16 Foreman	17 Asst. F'man.	18 Qual. Engr.	19 Co-ord:	20 Head of Lab:	21 Test Mgr:	22 Rel'bty Mgr:	23 Quality Assur. Mgr:
0	0	2	1	1	0	2	0	1	1	0	0	0	0
0	0	1	1	0	0	1	0	1	0	0	0	0	0
0	0	1	0	1	0	1	0	0	0	0	0	0	0
3	0	5	3	0	0	3	0	2	0	1	0	0	2
1	0	3	2	1	0	2	0	1	0	0	0	0	1
1	0	0	0	0	0	1	0	0	0	0	0	0	0
1	0	0	0	0	2	1	1	2	1	1	0	0	0
1	0	0	0	0	1	1	1	1	0	1	0	0	0
0	0	0	0	0	0	1	0	0	1	0	0	1	1
6	0	3	3	0	1	6	0	4	0	0	4	0	2
3	0	3	1	0	0	3	0	2	1	2	1	0	1
1	0	2	0	0	0	2	0	0	0	0	0	0	0
2	2	1	1	0	1	3	0	1	0	0	0	0	0
1	1	0	0	0	1	1	0	1	0	0	0	0	1
3	0	5	1	3	1	5	0	2	1	1	0	0	3
2	0	4	1	1	1	4	0	1	1	1	0	0	1
2	0	1	0	0	0	0	0	1	0	0	0	0	1
3	0	1	1	0	1	3	0	1	1	0	1	0	0
3	0	1	0	0	0	3	0	1	0	0	0	0	0
3	0	1	1	0	2	4	0	2	1	0	1	0	1
36	3	34	15	7	11	47	2	24	7	7	7	1	14
1.8	.03	1.7	0.75	0.35	0.55	2.35	0.10	1.2	0.35	0.35	0.35	0.05	0.70

Sheet 2 of 3.
INDEX D.

NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITY

	24 Ratio Hourly Inspector to Total Hourly	25 Ratio Hourly Inspector to Total Dir. Prod.	26 Ratio Weekly Inspector to total personnel.	27 Ratio Monthly Inspector to total personnel.	28 Ratio all Inspection to total personnel.	29 Budget per head of inspection personnel (x 1000)	30 Budget per head of total personnel £ (x 1000)
	4.58	8.57	2.02	2.39	7.7	6.33	0.39
	0.89	0.91	9.73	5.10	15.29	3.87	0.70
	5.01	4.78	2.03	2.39	8.5	4.22	0.38
	4.19	6.00	1.63	1.66	6.5	3.92	0.25
	7.46	8.59	1.43	0.32	5.7	3.27	0.16
	2.01	2.57	2.90	1.88	6.1	8.611	0.56
	3.29	8.64	1.91	0.76	5.16	23.32	0.94
	4.58	8.57	2.02	2.39	7.7	6.33	0.38
	0.36	0.71	1.42	3.83	5.56	3.64	0.18
	5.67	7.79	1.30	1.88	6.26	13.74	0.93
	3.22	5.29	1.20	0.54	4.23	3.65	0.16
	3.02	3.62	3.96	1.94	7.94	4.06	0.31
	5.02	7.74	3.39	1.74	9.58	3.37	0.33
	3.45	10.74	6.83	0.86	13.08	1.41	0.15
	6.65	17.98	1.79	2.52	10.10	3.37	0.26
	0	0	0.74	17.73	18.47	7.50	0.14
	3.22	1.47	2.20	0.60	4.95	4.86	0.22
	3.52	4.82	0.69	0.91	3.95	5.07	0.16
	7.42	15.4	1.81	0.67	4.31	3.60	0.14
	7.92	11.23	0.91	1.27	8.00	2.95	0.23
M.	4.58	8.57	2.02	2.39	7.70	6.33	0.38
N.	132	132	132	132	137	86	137

Index D
Sheet 3 of 3.

NON-USER FIRMS OF ADVANCED MEASURING TECHNOLOGY.
DISPLAYED BY BUSINESS ACTIVITY.

1 Business Activity/ Employee Size	2 Employee Size:	3 No: Position Titles:	4 No. of Levels:	5 Director Span of Control:	6 No. of Divisions:	7 Division Span of Control:	8 No. of Sections:	9 No. of CMM Sections:
U.S. FIRMS								
Users:								
Defence	4700	4	3	5	2	5	9	1
Aircraft	8750	12	5	3	5	3	28	1
Aircraft	8000	6	3	4	3	3	6	1
Aircraft	8500	11	4	4	4	3	19	3
Engines	1300	5	4	4	4	8	20	2
Pumps	200	7	3	3	2	2	10	1
Track/Truck	4500	12	4	6	6	6	13	1
Food Proc.	600	4	3	3	3	6	17	1
Elect.	550	3	2	2	2	2	4	1
Miscellaneous	1800	7	3	4	4	2	4	1
R & D	6000	5	4	3	2	3	6	1
M & H	1000	8	4	5	5	10	20	1
TOTAL	45900	84	42	46	42	53	156	15
Average:	3825	7	3.5	3.8	3.5	4.4	13	125

INDEX E - U.S. FIRMS USING ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITY AND EMPLOYEE SIZE (Sheet 4).

Sheet 1: of 4.

	10 Mgr. Qual. Cont.	11 Asst. Q.C. Mgr.	12 Chief Insp.	13 Asst. Chief.	14 Tech. Mgr.	15 Superin-tendent.	16 Foreman	17 Asst. F'man.	18 Qual. Engr.	19 Co-ord:	20 Head of Lab:	21 Test Mgr:	22 Rel'bty Mgr:	23 Quality Assur. Mgr:
	1	-	-	-	-	-	-	-	-	1	1	-	1	1
	1	-	-	-	-	-	-	-	1	1	1	-	1	-
	1	-	-	-	-	-	-	-	1	-	1	-	-	1
	1	-	-	-	-	-	-	-	-	-	1	-	-	1
	-	-	1	-	1	-	-	-	-	-	1	-	1	-
	1	-	1	-	-	-	1	-	-	1	1	-	-	-
	-	-	1	-	-	-	1	-	1	1	-	-	1	1
	1	-	-	-	-	-	-	-	1	-	-	-	-	-
	1	-	-	-	-	-	1	-	-	-	-	-	-	-
	1	-	1	-	-	-	1	-	-	-	1	-	-	-
	1	-	-	-	-	-	-	-	1	-	-	-	1	-
	1	-	-	-	-	-	1	-	1	1	1	-	-	-
T.	10	-	5	-	1	-	5	-	6	5	8	-	5	4
Av.	0.83	-	0.41	-	0.08	-	0.41	-	0.5	0.41	0.66	-	0.41	0.33

Sheet 2 of 4.
INDEX E -

U.S. FIRMS USING ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITY AND EMPLOYEE SIZE (Sheet 4).

	24 Ratio Hourly Inspector to Total Hourly	25 Ratio Hourly Inspector to Total Dir. Prod.	26 Ratio Weekly Inspector to total personnel.	27 Ratio Monthly Inspector to total personnel.	28 Ratio all Inspection to total personnel.	29 Budget per head of inspection personnel (x 1000)	30 Budget per head of total personnel (x·1000)
	5.7	7.8	2.95	0.54	6.46	12.77	0.76
	6.67	13.3	1.89	1.03	7.01	7.63	0.71
	6.67	13.3	1.89	1.03	7.01	7.63	0.71
	6.67	13.3	1.89	1.03	7.01	7.63	0.71
	8.8	18.4	2.10	1.29	9.70	22.81	1.51
	6.39	10.7	1.18	0.97	6.32	14.72	0.85
	5.01	10.46	0.56	0.52	4.94	18.31	0.86
	5.4	4.57	1.00	0.56	4.61	8.68	0.40
	3.7	6.0	0.0	2.09	5.09	4.17	0.09
	7.3	8.9	1.18	0.09	4.97	22.46	1.11
	6.3	7.0	1.00	0.97	0.42	14.71	0.85
	20.83	26.32	1.36	5.00	17.50	14.00	0.85
M.	6.4	10.71	1.18	0.97	6.32	14.72	0.85
N.	34	34	35	35	35	24	23

Sheet 3 of 4.
INDEX E.

U.S. FIRMS USING ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITY AND EMPLOYEE SIZE (Sheet 4)

American Users by Size:	Ratio Hourly Inspector to Total Hourly:	Ratio Hourly Inspector to Total Dir. Prod.	Ratio Weekly Inspector to total personnel:	Ratio Monthly Inspector to total personnel:	Budget per head of inspection personnel: (x 1000)
10- 49	0	0	0	0	0
50- 99	3.7	4.6	0	1.28	7.00
100- 499	5.2	6.6	0.75	0.85	16.80
500- 999	4.5	4.0	0.04	1.35	11.74
1000-1999	10.9	15.06	0.71	1.23	20.43
2000-4999	5.9	11.51	1.04	0.74	15.43
5000+	6.35	12.07	2.10	0.94	14.39
Mean:	6.35	10.77	1.18	0.97	14.99
N.	33	33	35	35	23

Sheet 4 of 4:
INDEX E. U.S. FIRMS USING ADVANCED MEASURING TECHNOLOGY DISPLAYED BY BUSINESS ACTIVITY AND EMPLOYEE SIZE (Sheet 4).

APPENDIX S

EIGHTEEN PAIRED ORGANISATION CHARTS

APPENDIX S

EIGHTEEN PAIRED ORGANISATION CHARTS ILLUSTRATED.

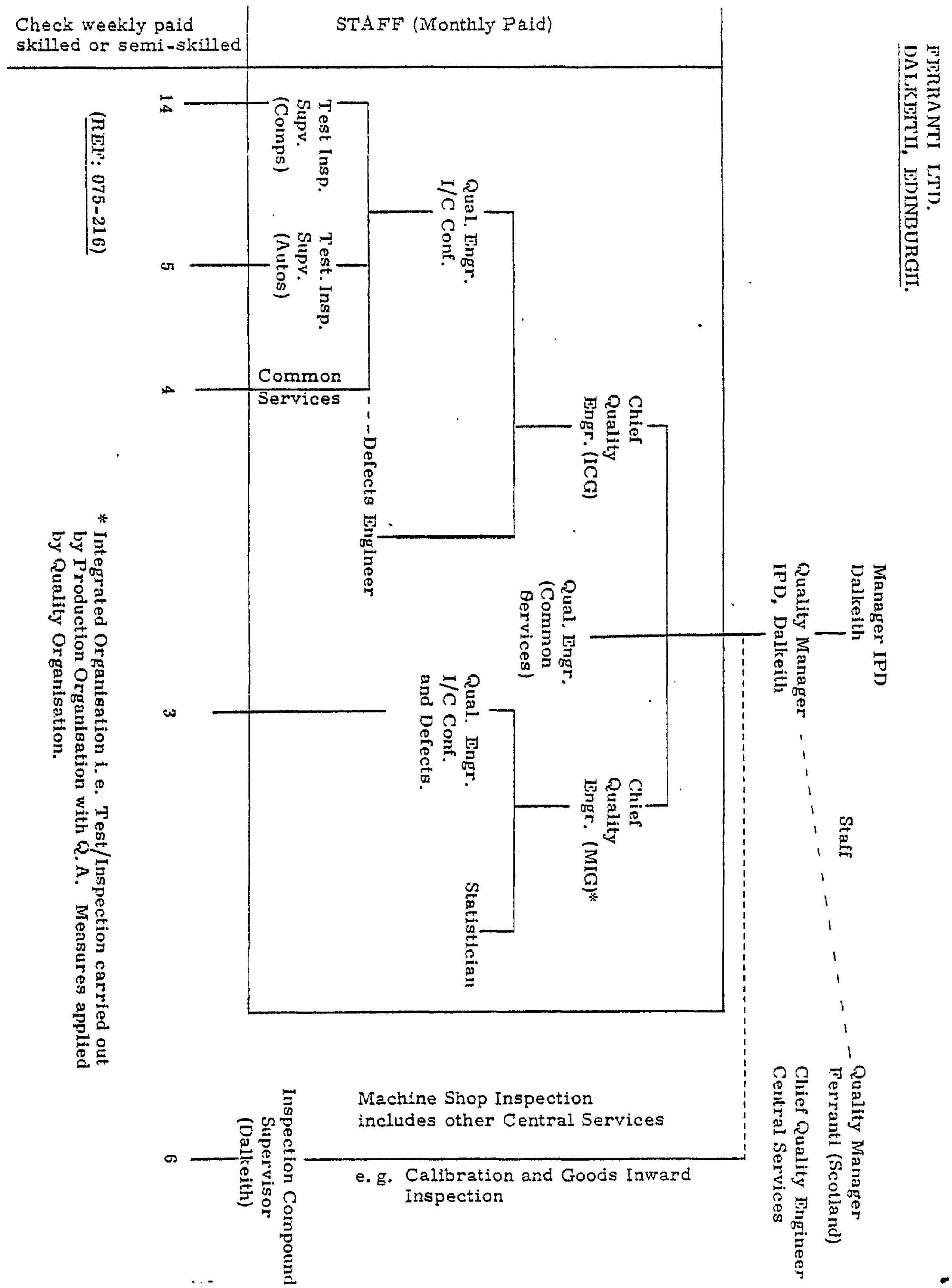
(NOTE: The front summary of Table No: 6.6 also appears in Chapter 6 where the text of the Chapter discusses these organisations).

Table No: 6.6.

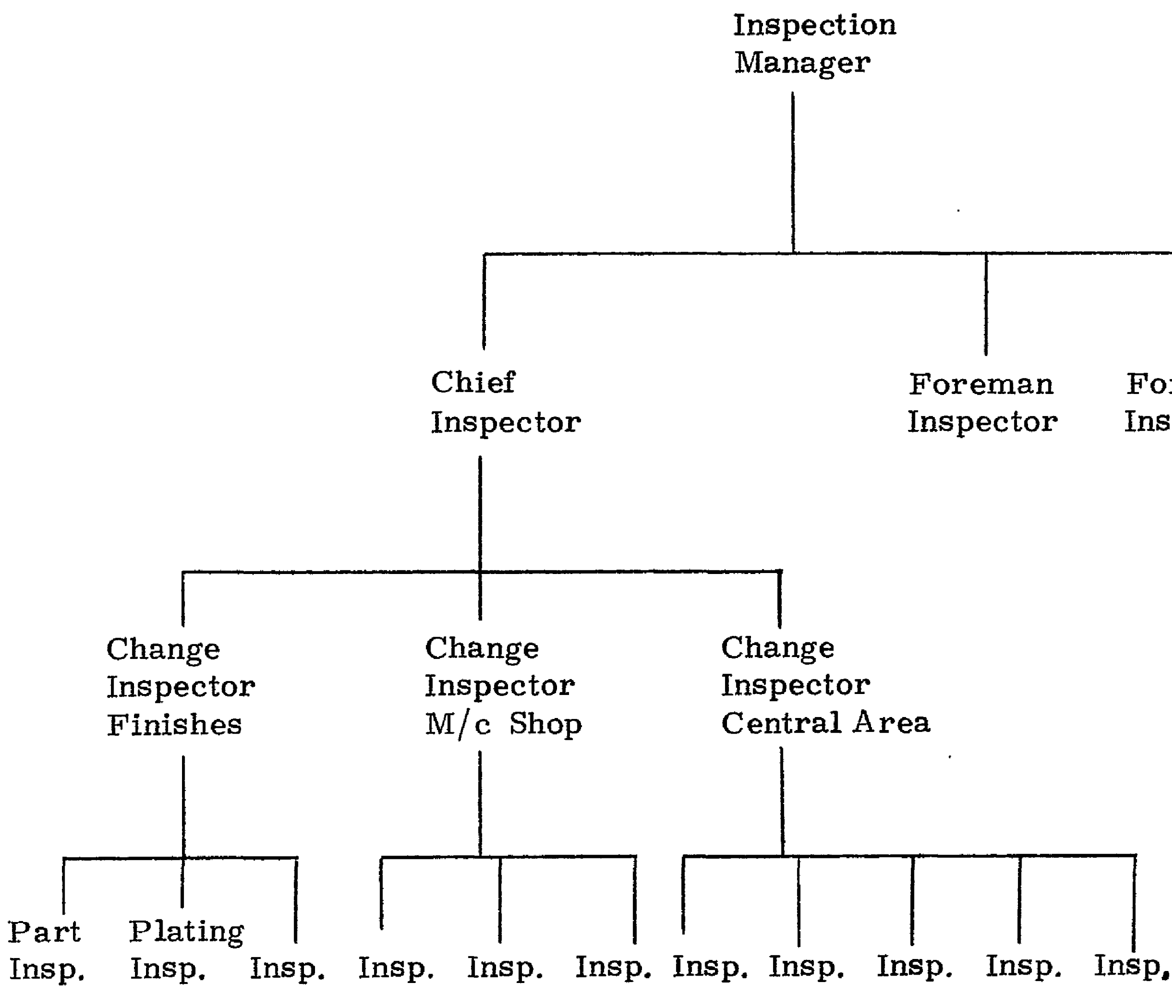
ORGANISATION CHARTS ILLUSTRATED

(K=000's)

1 Ref No:	2 Firm Name:	3 User or Non-user of advanced Technology:		4 Business Activity:	5 Total Empl's:	6 Total Insp. Empl's:	7 % of Total:	8 Total Budget for Inspection: (£)	9 Per Head of Employee: (£)
075	Ferranti Ltd.	User	(UK)	Electronics	454	45	10	--	--
216	GEC Measurements	Non user	(UK)	Electronics	1600	111	7	N.A.	--
026	Fairbanks Morse	User	(US)	Engines	1300	69	5	502K	386
106	Cummins Engine	User	(UK)	Engines	2200	N.A.	-	N.A.	-
270	Anderson Strathclyde	Non user	(UK)	Med/hvy Engr.	2000	89	4	N.A.	-
108	Doncaster Monk Bridge	User	(UK)	Cast/F'ging	1000	250	25	600K	600
066	Rolls Royce	User	(UK)	Aero Engines	1200	316	26	757K	630
044	Westinghouse	User	(US)	Med/hvy Engr.	1000	175	17	N.A.	-
032	Litton Microwave	User	(US)	Food Proc.	600	22	4	250K	416
264	EMI	Non user	(UK)	Electronics	700	26	4	300K	428
001	Alvis Ltd	User	(UK)	Defence	2000	153	8	850K	425
167	Robophone	Non user	(UK)	Telecom.	106	7	7	16K	151
096	John Deere	User	(US)	Truck/track.	4500	164	4	N.A.	-
170	Sperry New Holland	Non user	(UK)	Truck/track.	930	32	3	191-6K	206
086	British Aerospace	User	(UK)	Aircraft	3373	153	5	N.A.	-
009	Boeing (Washington)	User	(US)	Aircraft	8500	180	2	N.A.	-
076	B.L. Cars	User	(UK)	Motor	7500	866	12	46K	6
207	Alfred Herbert	Non user	(UK)	Machine Tool	1830	48	3	N.A.	-


FERRANTI LTD.
DALKEITH, EDINBURGH.
Check weekly paid
skilled or semi-skilled
STAFF (Monthly Paid)
Manager IPD
Dalkeith
Quality Manager
IPD, Dalkeith
Staff
Quality Manager
Ferranti (Scotland)
Chief Quality Engineer
Central Services
Chief
Quality
Engr. (ICG)
Qual. Engr.
(Common
Services)
Chief
Quality
Engr. (MIG)*
Qual. Engr.
I/C Conf.
Test Insp.
Supv.
(Comps)
Test. Insp.
Supv.
(Autos)
Common
Services
Defects Engineer
Qual. Engr.
I/C Conf.
and Defects.
Statistician
14
5
4
3
6
Machine Shop Inspection
includes other Central Services
e.g. Calibration and Goods Inward
Inspection
Inspection Compound
Supervisor
(Dalkeith)
(REF: 075-216)
* Integrated Organisation i.e. Test/Inspection carried out
by Production Organisation with Q.A. Measures applied
by Quality Organisation.

G. E. C. MEASUREMENTS LTD.



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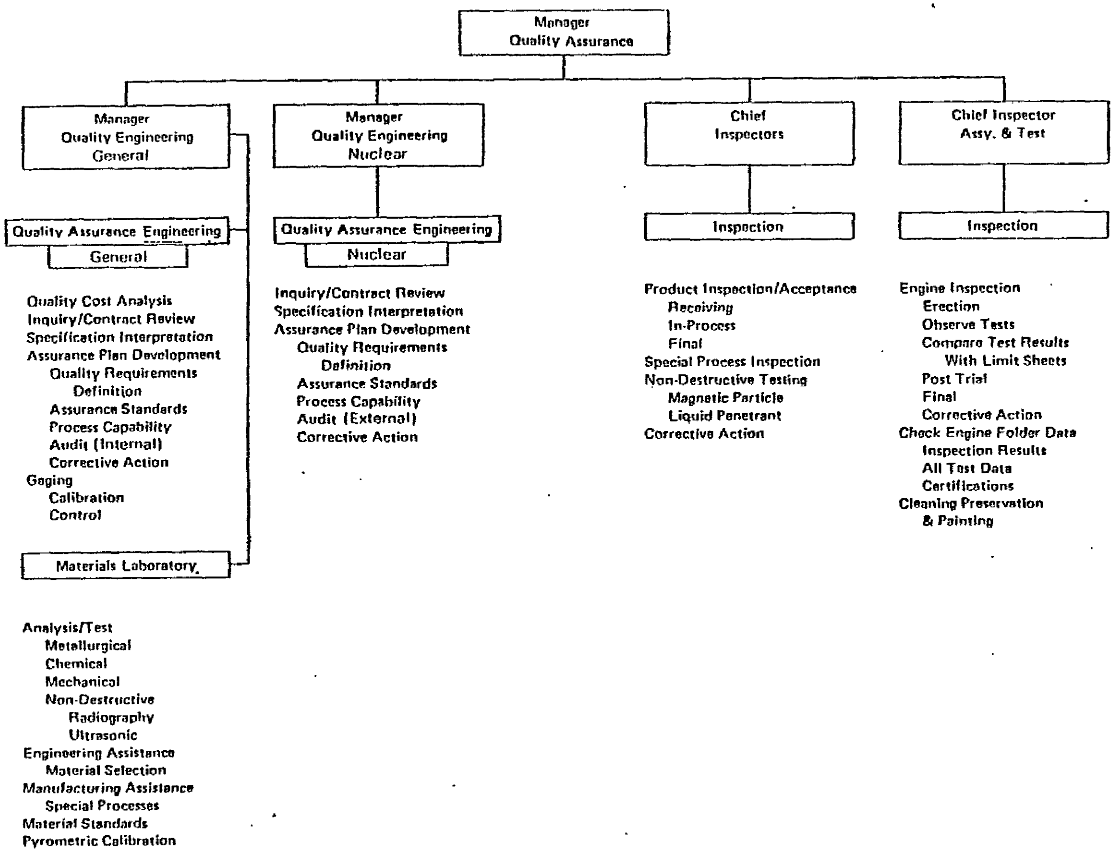
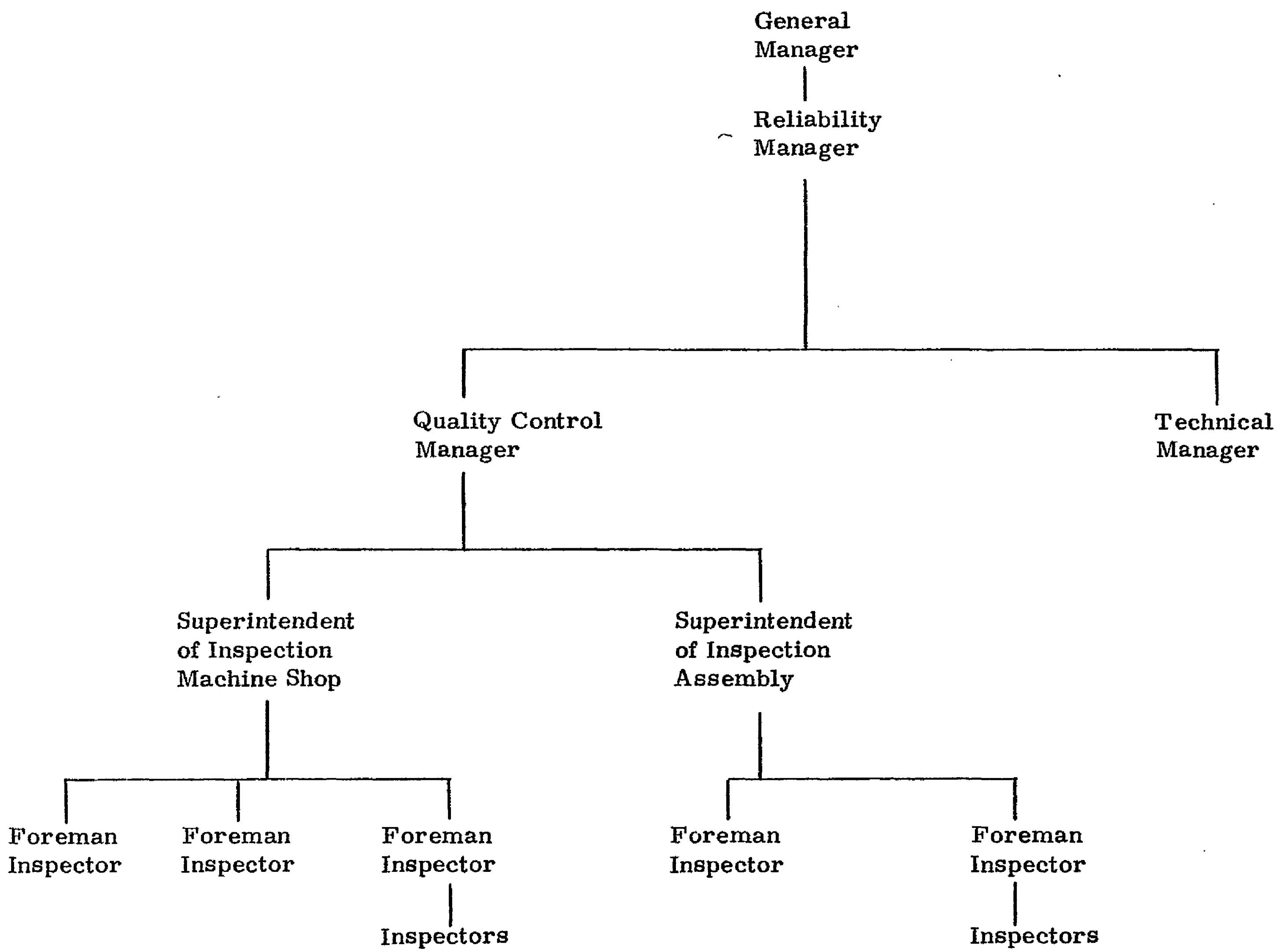


Fig. 1.2 Organization Chart

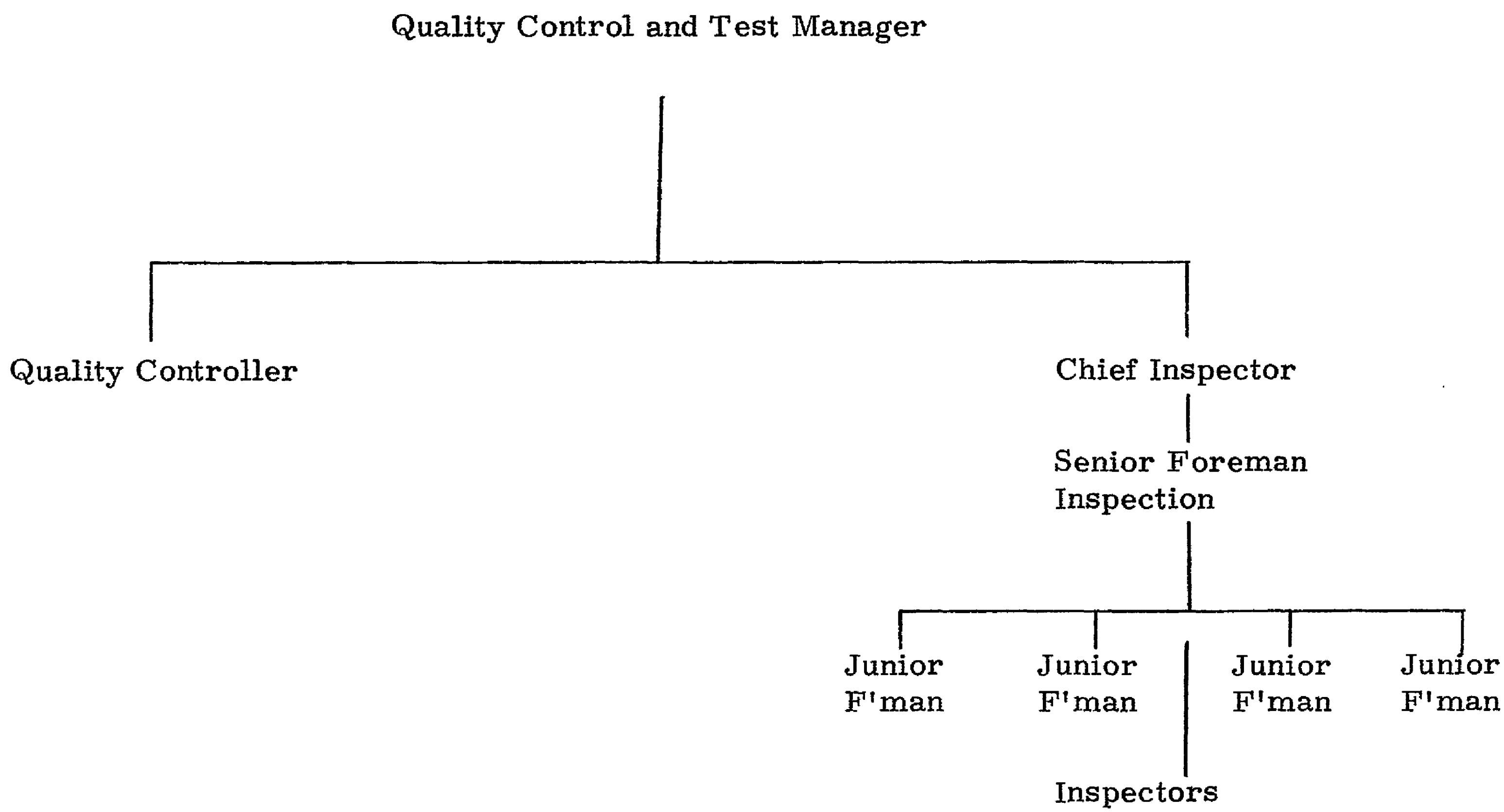
(REF. 026-106)

CUMMINS ENGINE CO. LTD.



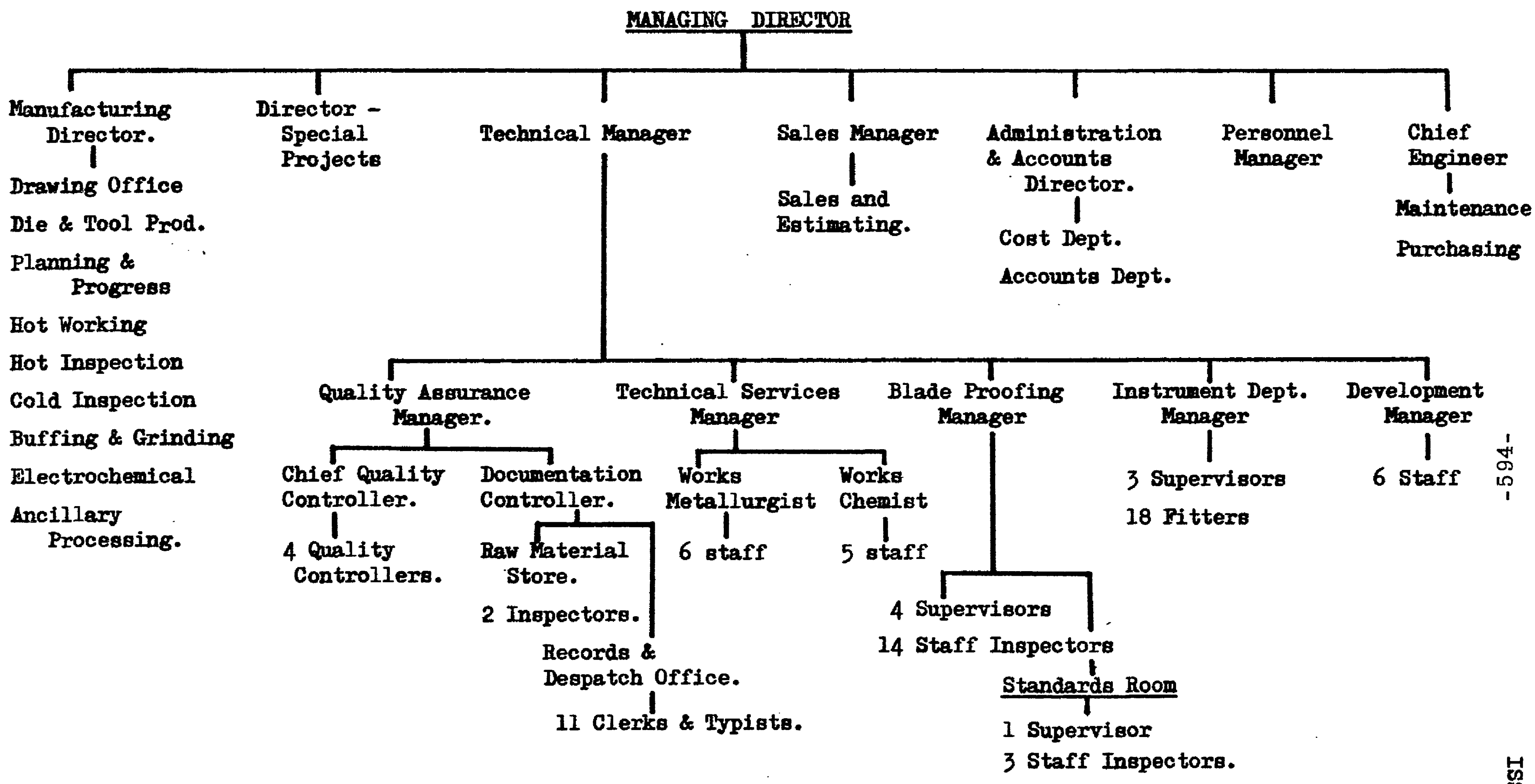
(REF: 106-026)

ANDERSON STRATHCLYDE

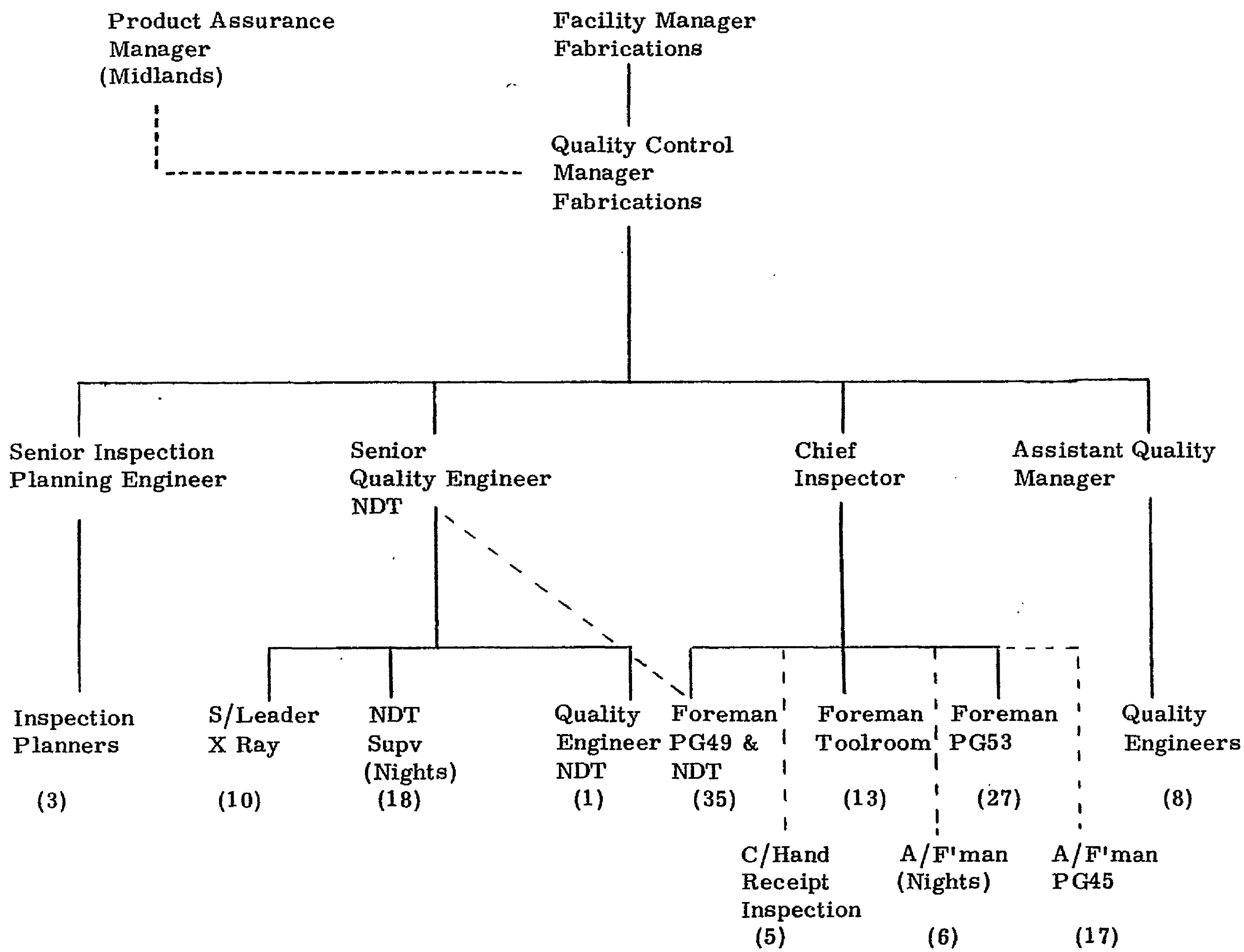


(REF: 270-108)

DONCASTERS MONK BRIDGE LIMITED

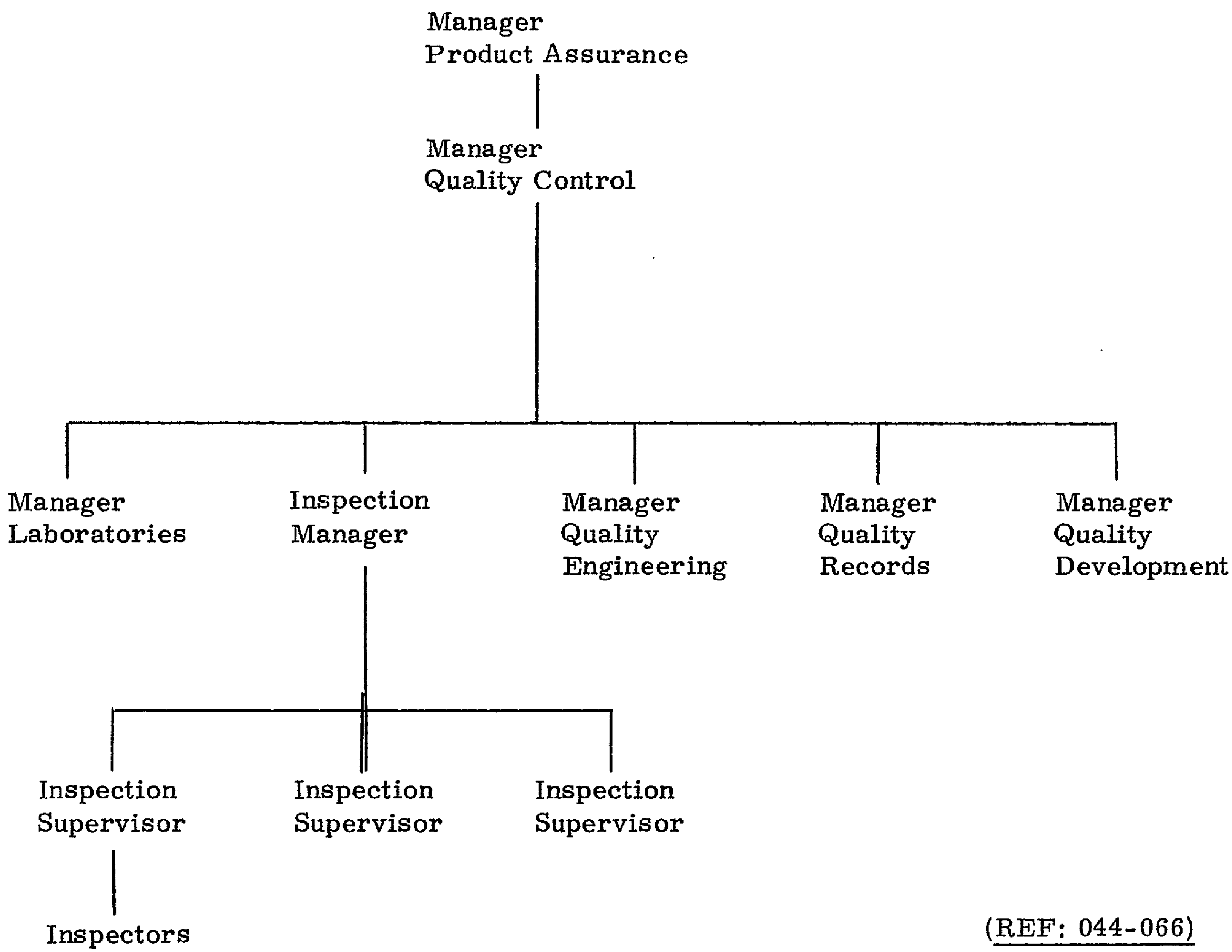


ROLLS ROYCE LTD., LOUGHBOROUGH.



(REF: 066-044)

WESTINGHOUSE N. F. D.
COLUMBIA, S. C.



(REF: 044-066)

LITTON MICROWAVE RANGE

QUALITY DEPARTMENT ORGANIZATION

Organization at 22 Heads
Effective 2-20-78

RANGE QUALITY MGR.
R.L. ZIMMERER

SECRETARY
J. FOX

SR. QUALITY ENGR.
FABRICATION/PAINT
T. THOMPSON

Fab Insp.	(6)	
Paint Ins.	(2)	
Dave Bowman	1st Fab (SR)	
John Erntson	1st Fab	
Kim Pearson	1st Fab	
Bernie Froberg	1st Fab	
Al Emig	2nd Fab (SR)	
John Phillips	2nd Fab	
Sandra Wycough	1st Paint	
Juanita Ditsch	2nd Paint	

SR. QUALITY ENGR.
RECVG. INSP.
W. REED

Receiving Insp (3)

- Bill Bell
- Matt Hessburg
- Norma Molvig

SR. QUALITY ENGR.
ASSEMBLY/
CUSTOMER AUDIT
J. GRAHAM

Assembly Insp (5)
Customer Audit/
Ship Test (1)

- Kent Konieczny (Sr. & Subs.)
- Sharon Hill (Cavities)
- Rhonda Nitschke (Doors/tops)
- Linda Veldheusen (Main Line)
- Audrey Huntington (Final)
- Mike Koplin (C/A and T&V)

2/13/78

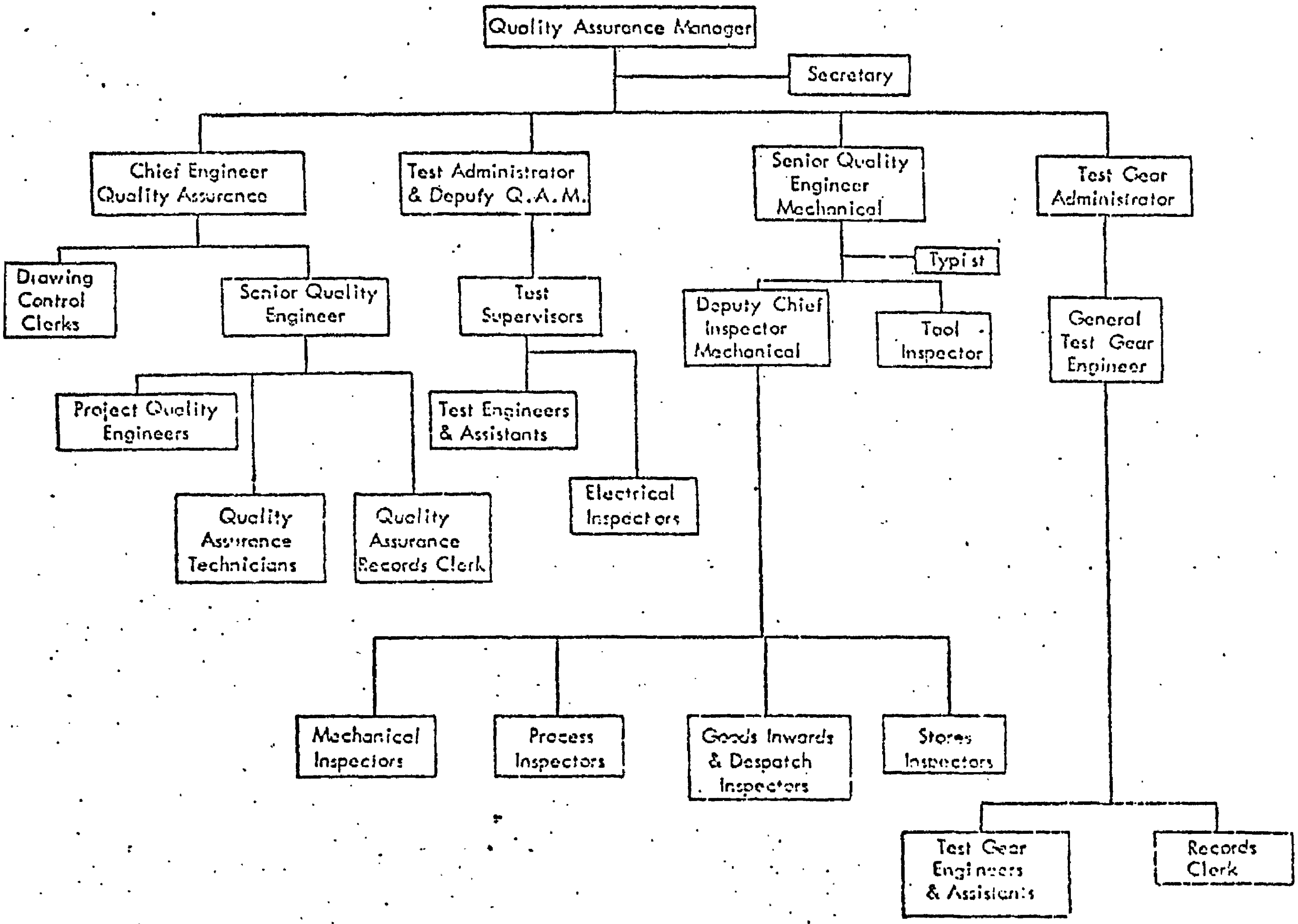


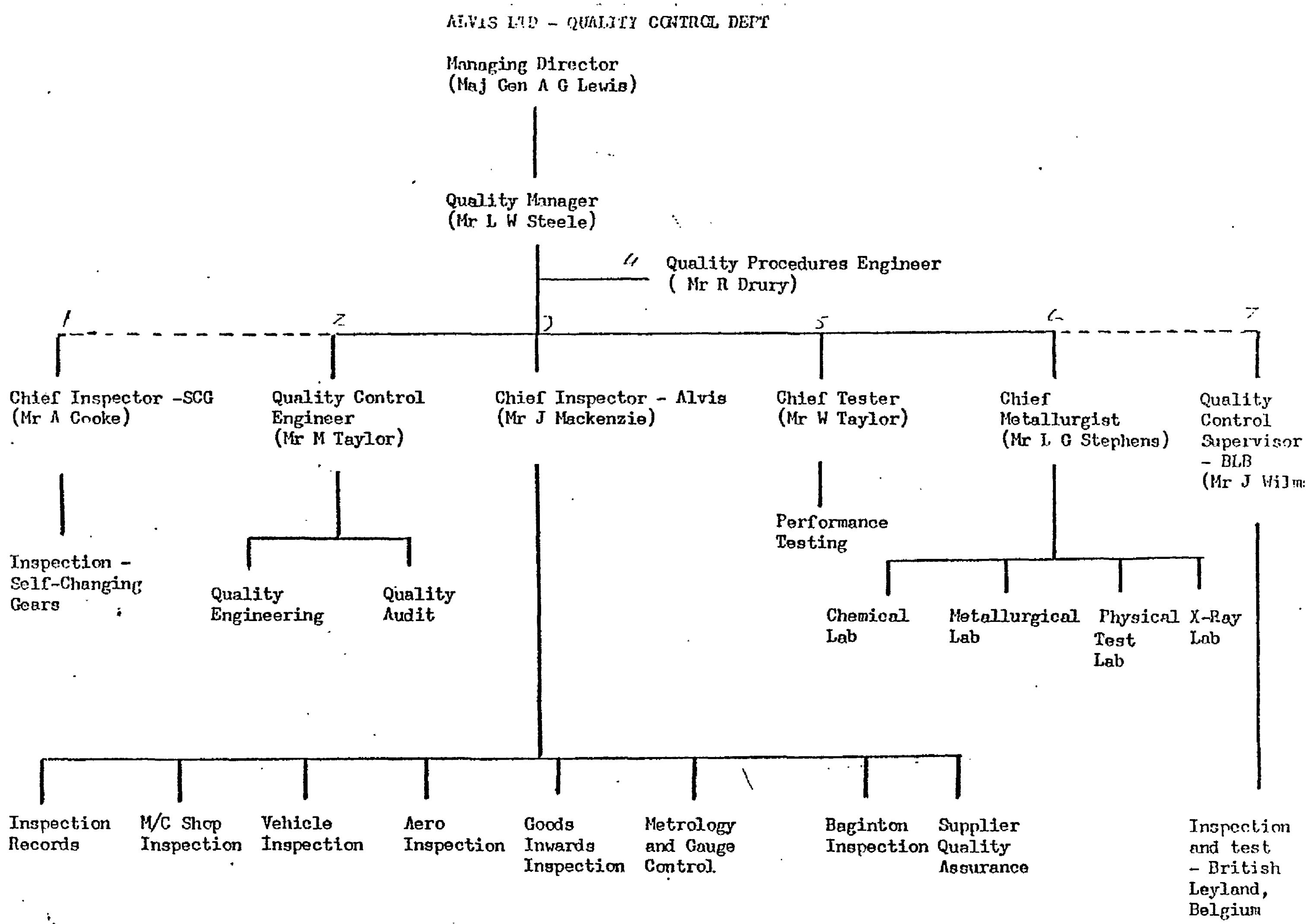
CHART 3C3

E.M.I.

QUALITY ASSURANCE DEPARTMENT - WELLS LOCATION

(REF- 264-032).

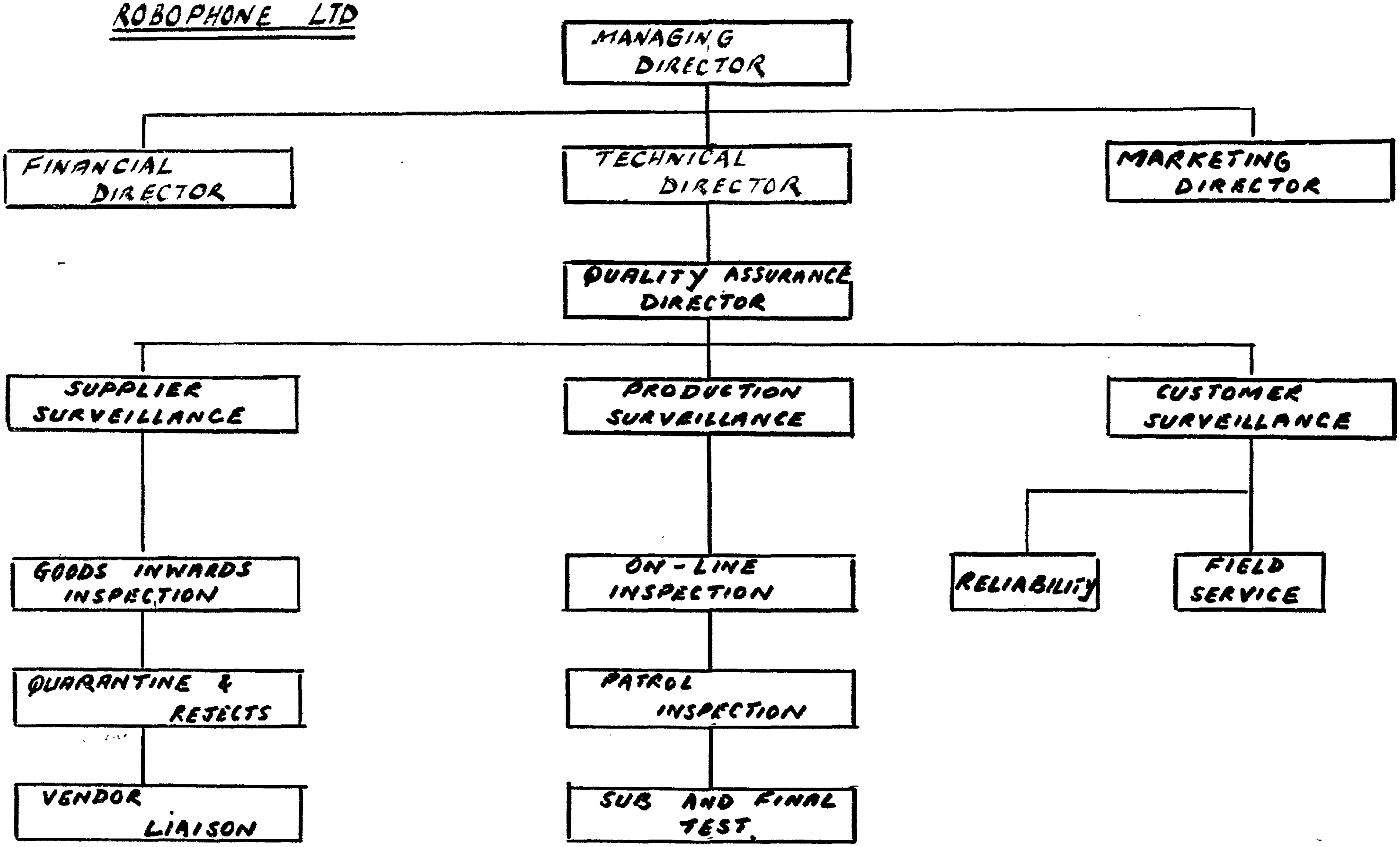
(Ref: 001-167)



(REF. 001 - 167)

REF. 167.001

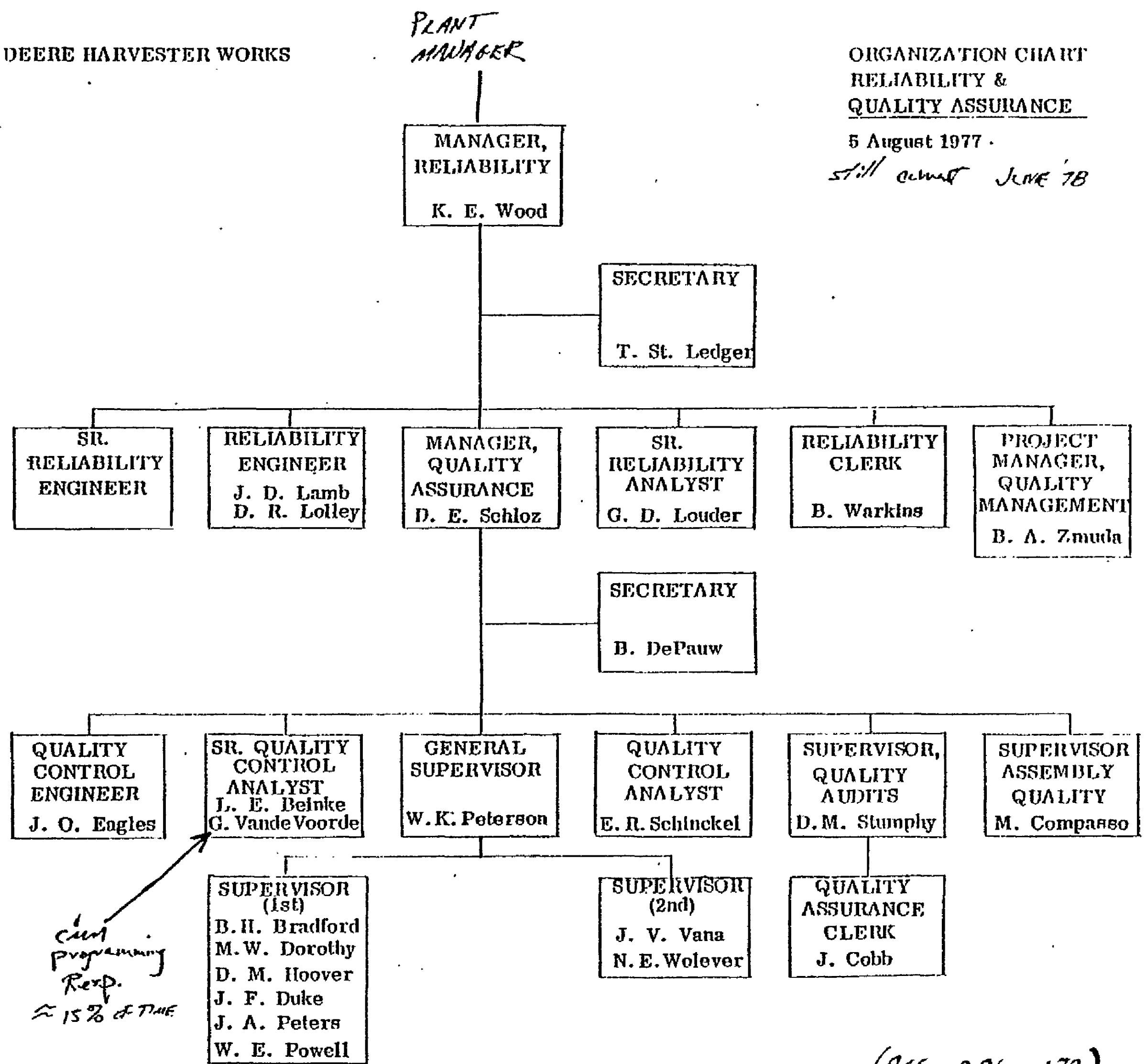
ROBOPHONE LTD



JOHN DEERE HARVESTER WORKS

ORGANIZATION CHART
RELIABILITY &
QUALITY ASSURANCE

5 August 1977.
still current June '78

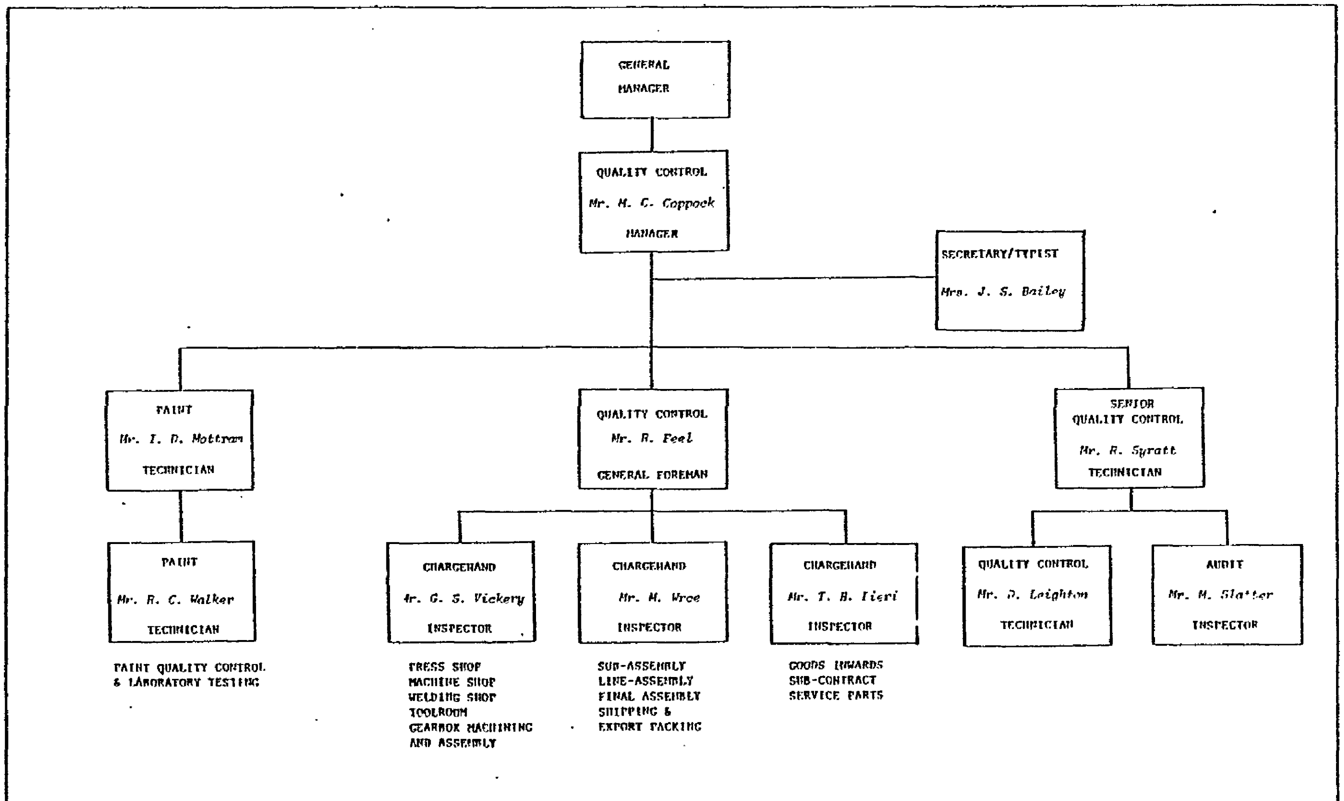


(Ref. 096 - 170)

Mr. M. C. Coppock

SPERRY NEW HOLLAND
AYLESBURY PLANT

ORGANIZATION CHART



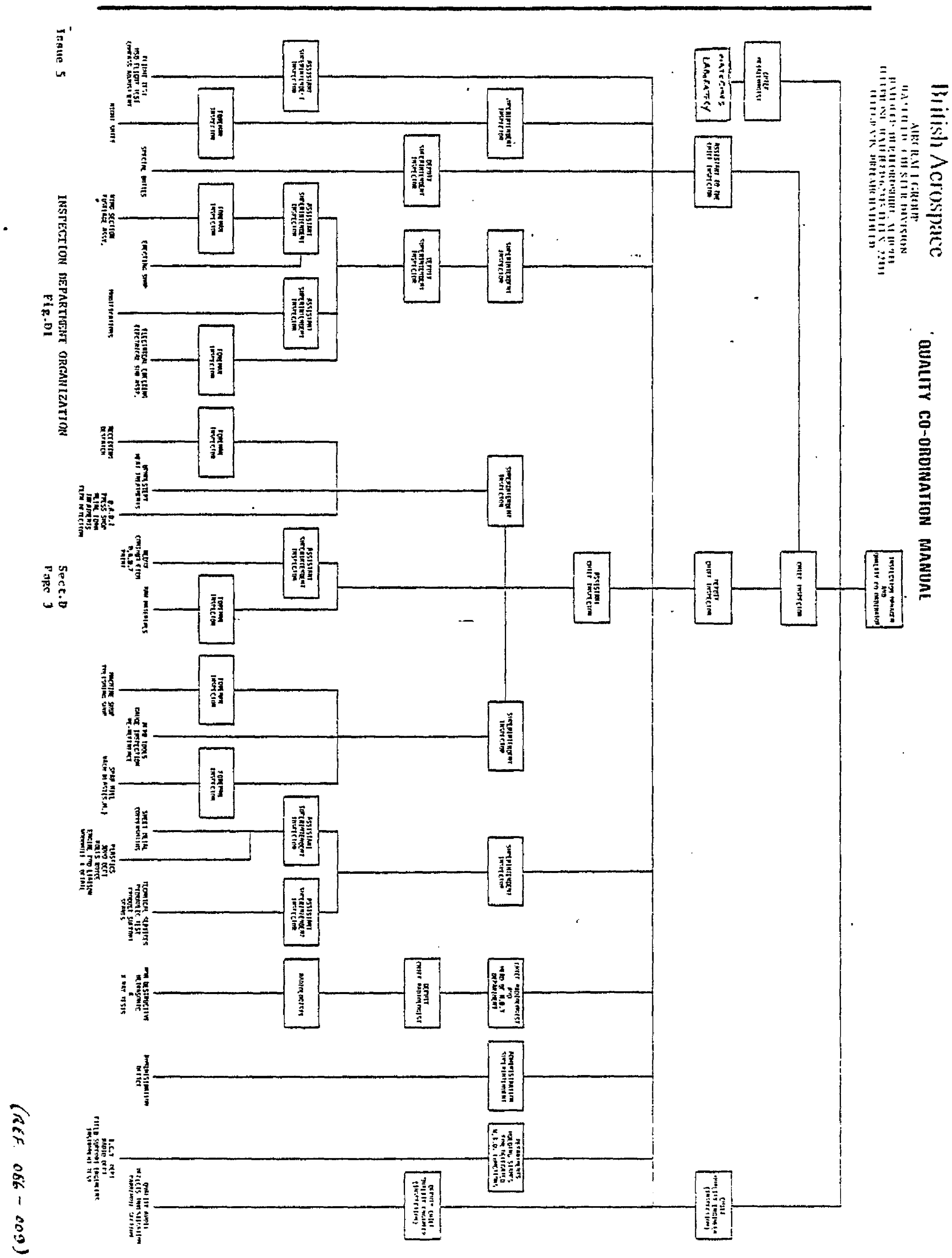
APPROVAL	APPROVAL	ORGANIZATION	EFFECTIVE DATE	LOCATION	CHART NUMBER
	Coppock	QUALITY CONTROL	5th April 1978	Aylesbury	Q.C. 1.

NH455

C4-1503.

(REF- 170 - 096)

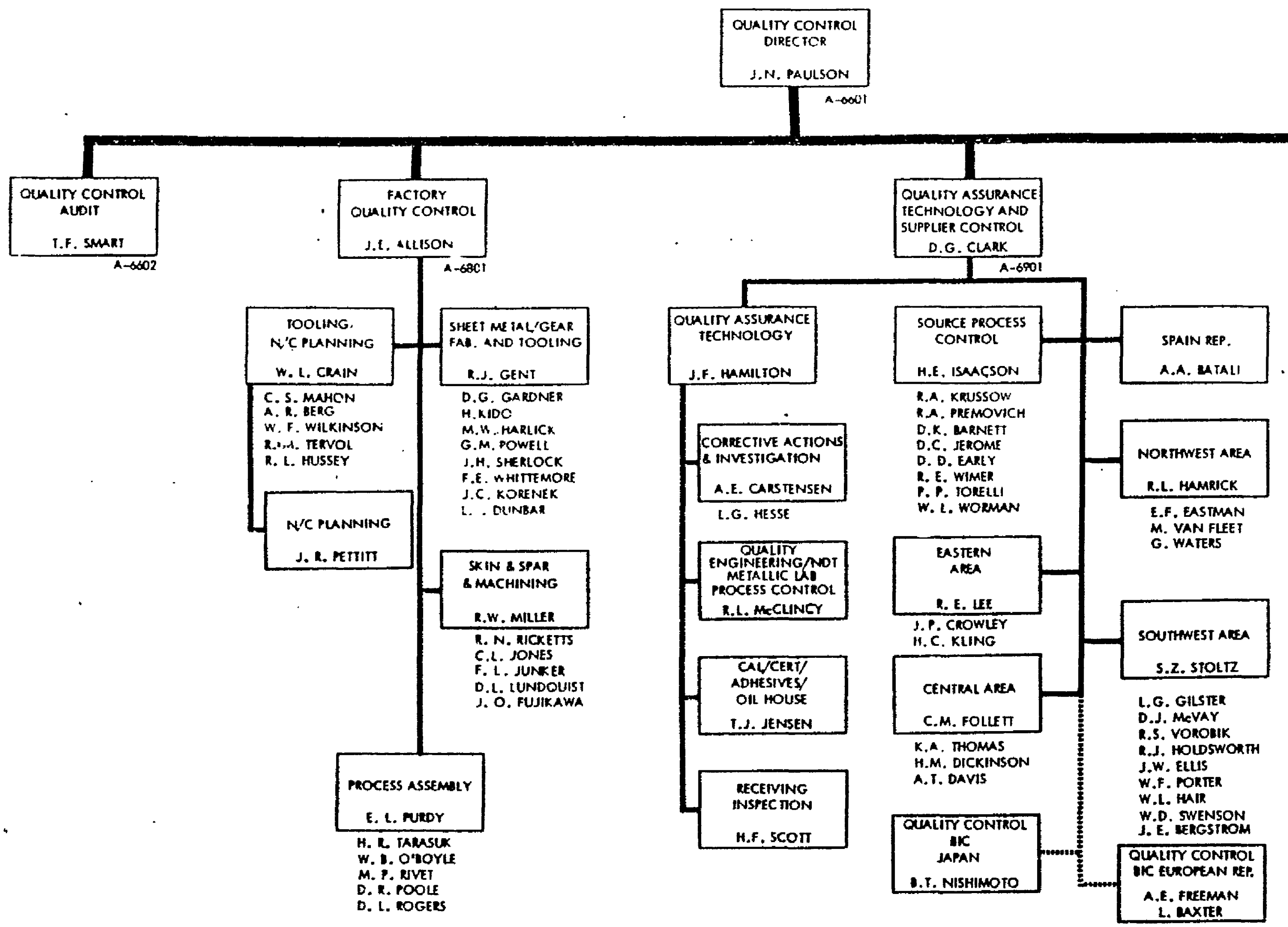
(Ref: 086-009)


British Aerospace
QUALITY CO-ORDINATION MANUAL
INSPECTION DEPARTMENT ORGANIZATION
Fig.D1
Issue 5
Sect.D
Page 3
(REF 086 - 009)

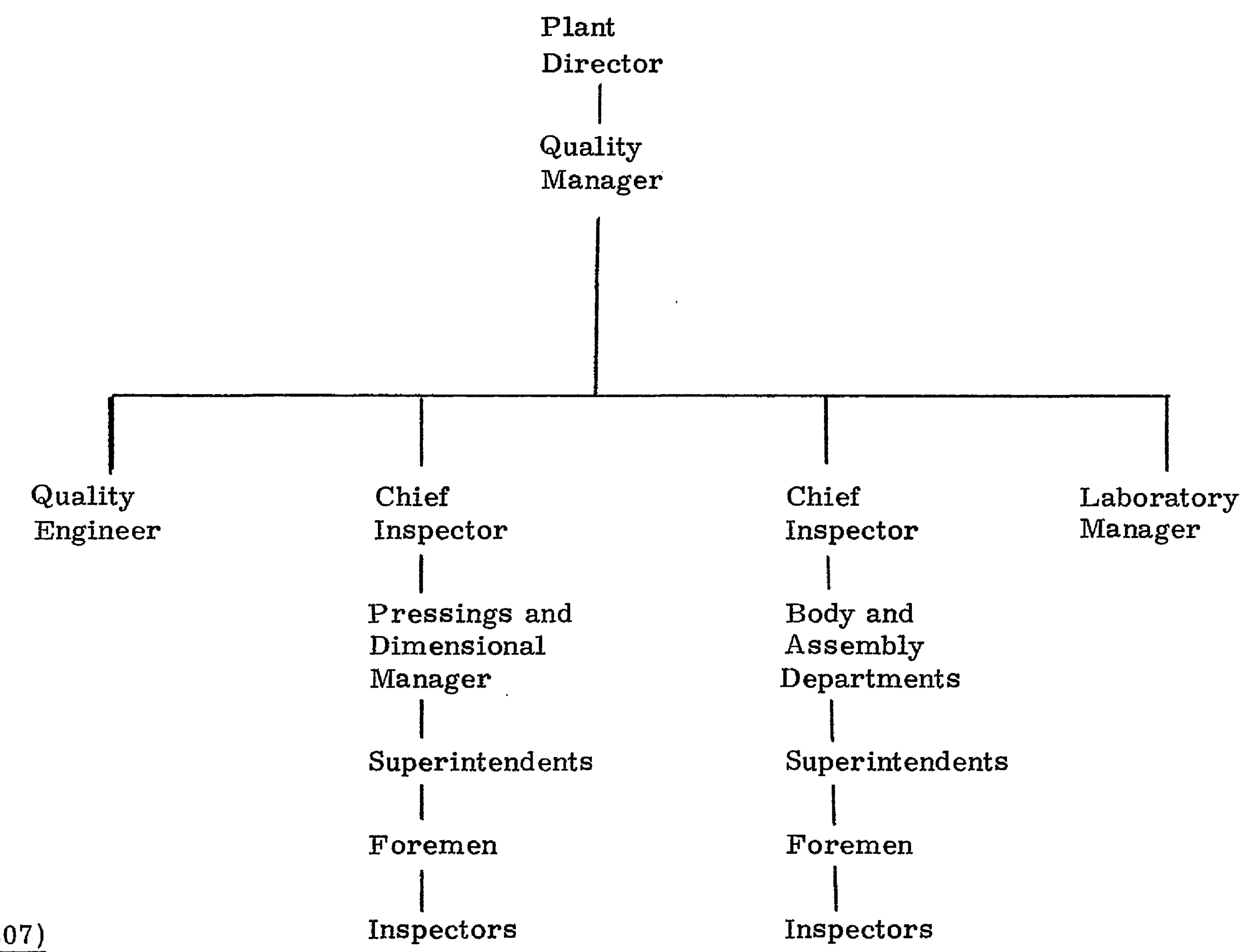
BOEING AIRCRAFT.

FABRICATION DIVISION

OPERATIONS **QUALITY CONTROL**



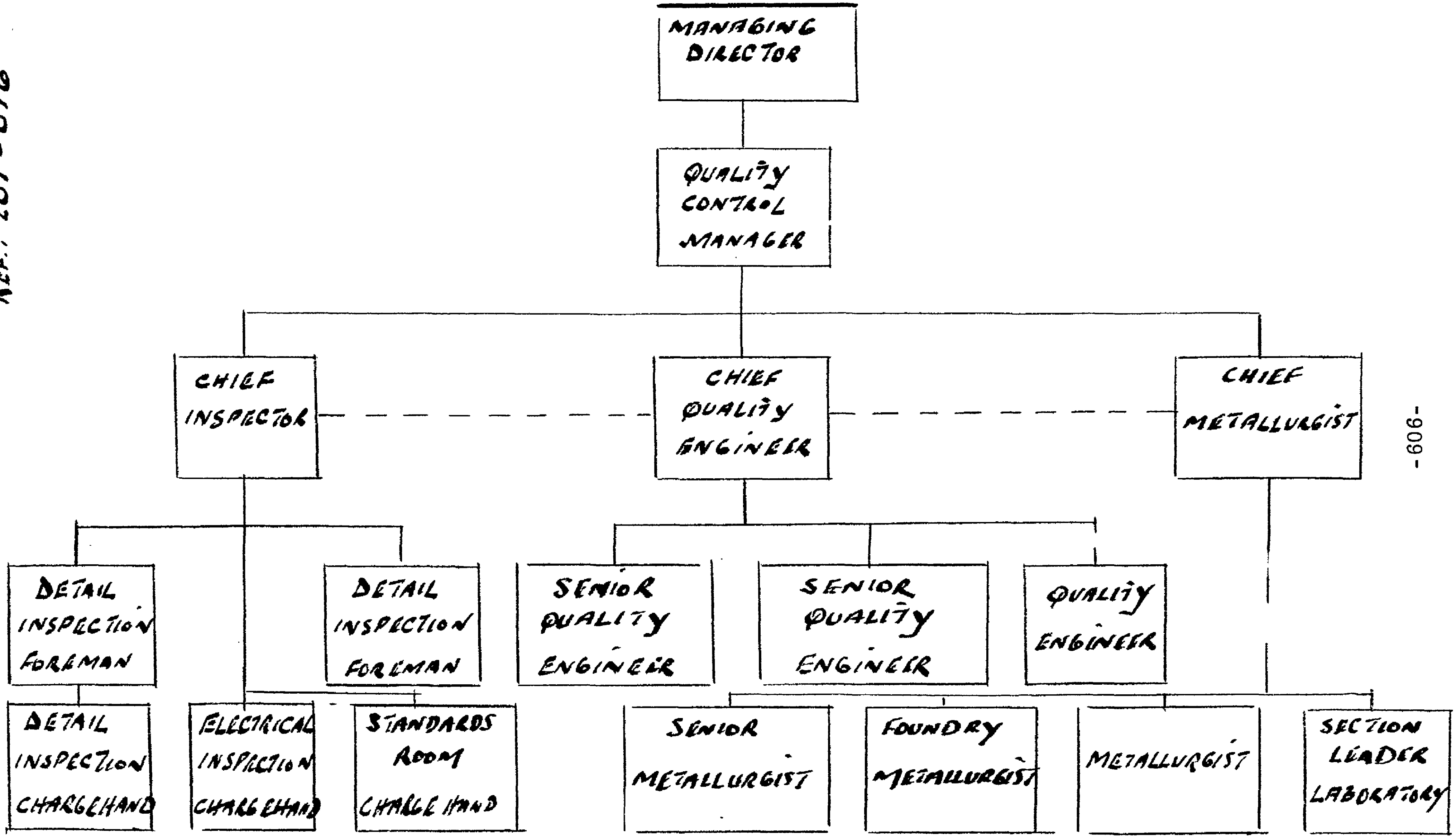
B.L. CARS, BIRMINGHAM.



(REF: 076-207)

REF.: 207 - 076

ALFRED HERBERT QUALITY CONTROL ORGANISATION



APPENDIX T

INTERNATIONAL COMPARATIVE STUDY OF QUALITY CONTROL ORGANISATIONS

UNIVERSITY OF GLASGOW

DEPARTMENT OF
MANAGEMENT STUDIES

ADAM SMITH BUILDING

GLASGOW, G12 8RT
Tel. STD 041-339 8855
Extension

The Quality Control Manager or (Chief Inspector)

Dear Sir,

Inspection equipment has become very advanced in recent years and many firms have been sufficiently foresighted enough to keep up with this progress. I am interested in getting information about this new technology then sharing it with you if you so desire.

In particular I am examining Co-ordinate Measuring Machines and would be most interested in obtaining the views of people using this equipment; equally I want to hear from people who do not have co-ordinate measuring machines in their organisation. I trust you will assist me by answering some questions, which will take you on average only 15 minutes to complete.

I can guarantee anonymity. Nothing you complete will be traceable to you or your Company as it will be used as the basis for a thesis within the University.

Yours faithfully,

S P Black

SAM P. BLACK
University of Glasgow
Glasgow.

International Comparative Study of Quality Control Organisations

BRITAIN, U.S.A., GERMANY.

QUESTIONNAIRE

Project Co-ordinator
SAM P. BLACK

Department of Management Studies
Adam Smith Building
University of Glasgow
SCOTLAND.

INSTRUCTIONS:

1. Please complete the INTRODUCTORY PART whether you have Co-ordinate Measuring Machines or not.

2. Complete the section on Co-ordinate Measuring Machines - first question is for Plants with no Co-ordinate Measuring Machines.

3. Return completed questionnaire to Sam P. Black.

4. Tick if you want a copy of summary findings. ☐

INTRODUCTORY SECTION:

(✓) or delete as necessary.

1. Company Name: ____________________

2. Location: ____________________

3. Nature of Product or Service: ____________________

____

4. Are you a Subsidiary at this location? Yes: ___ No: ___

   If yes, who is your Parent Company and where is their location?

   Parent: ____________________

   Location: ____________________

/......

5. Is production predominantly -

Single Simple Articles	
Prototypes	
Large equipment, built-in stage	
Jobbing	
Small batches	
Large batches	
Mass production	
Continuous flow	

6. Have any major technical changes taken place with your plant equipment in the last two years or are any such changes contemplated? (e.g. introduction of numerical controlled machines, transfer machine systems, co-ordinate measuring machines, etc?) Yes: ___ No: ___

   If yes, brief description: ______________________________

   ____

   ____

7. If any changes were or will be made, will the nature of the production system be affected? Yes: ___ No: ___

   If yes, comment: ______________________________

   ____

   ____

   ____

   ____

   ____

8. Does your Company have a long term plan towards automation of the factory or inspection equipment?

Have complete long term plan	
Have planned for specific items only, e.g. transfer machines, N.C. machines	
Have looked only at fringe technology, e.g. co-ordinate measuring machines	
Does not apply to our organisation or product	

/...

9. Approximately how many powered machine tools for machining, cutting or forming parts do you have in your machine shop? ________

10. How many of the above have numerical controls?
    A. Stand alone N. C. ________
    B. Part of automated line ________

11. What is rough floor area of the machine shop? ________

12. What is the floor area for the average sized machine tool? ________

13. What floor area approximately is used by Inspection within this machine shop? (including inspection machines, benches, cribs, etc) ________

14. What is the approximate power consumption for the machine shop monthly in kilowatt hours? ________

15. To whom is the head of inspection of Quality Control responsible? ________________

16. Would you send me a copy of your current organisation structure from Quality Control Manager down to Inspector? (a rough hand sketch would be sufficient).

17. What year was your plant opened? 19______

18. What is the total personnel at this location approx? ________

19. How many hourly paid employees approx? ________
    -do- direct production? ________
    -do- inspectors? ________
    How many weekly paid inspection people? ________
    How many monthly paid inspection people (inc. management) ________

20. Which of the following forms of inspection are used in your plant?

Shop Floor	
Centralised	
Mixed	
Other	

/....

21. How would you plan to take care of your people as you move more towards more automation and less labour intensive equipment?

By normal wastage	
By re-training to other remaining skills	
By a phased redundancy policy	
No particular plan - let it happen	
Shorter working week	
Other	

22. What is the approximate annual cost of labour and material expense for the total Quality Control Department?

____

23. It has been suggested that Automation and Advanced Technology of any kind will be resisted for various reasons some of which are as follows. Has this been your experience with inspection equipment in particular?

	Yes	Perhaps	No
Protection of inspectors current status or prerogative			
Protection of existing ways of doing inspection work			
Protection of handskills, experience and knowledge			
Protection of the job - security of employment			
To avoid scraping valuable assets such as gauging fixtures, etc.			
To avoid the need to alter other systems in harmony with inspection.			
General fear of change			
To avoid conflict with organised groups			
Because it places inspection in too great a scientific and mysterious role upsetting relationships with other functions.			

24. Do you have a long term plan towards further automation of inspection by any of the following?

	Yes	No	Undecided
More automated CMM for inspection			
More automatic gauging integrated into machine tools			
Other			

CO-ORDINATE MEASURING MACHINES SECTION:

Question for plants with no Co-ordinate Measuring Machines (CMMs).
Why do you not have a CMM in your plant?

Not required for our product/service	
Too Expensive	
Current Gauging Equipment adequate	
Have no knowledge of these machines	
Other reason	
Other reason	

1. What make of co-ordinate measuring machines have you got or have in forecast for the future?

Type:	Models:	Reason for Choice*	Year of purchase
Ferranti/Bendix			
D. E. A.			
Hansford			
L. K. Tools			
NOTSA			
Zeiss			
S. I. P.			
Olivetti			
Portage			
Johannson			
Mitutoyo			
Brown/Sharpe			

* Reasons = Cost, Accuracy, Travel, Table Size, etc.

2. From whom did you first learn about CMM?

	Approx Year:
Headquarters	
Technical Press	
Conference-Exhibition	
CMM Manufacturers	
Other	

/.....

3. Before buying CMM was there a single manager in your Company strongly in favour of CMM use?

Yes: ___ No: ___

If yes, what was his position? ______________________

How long has he been with the Company? ______________________

4. Can you estimate the time lag between your first knowing about CMM and the installation of your first machine?

____ years ____ months

5. Before buying a CMM, did you visit any other organisation to see them in action?

Yes: ___ No: ___

If yes, whom did you visit? ______________________

____

6. Since the introduction of CMM, approximately what percentage time have you gained with the following in comparison with conventional inspection methods?

		10	20	30	40	50	60	70	80	90	100
Production machines awaiting inspection check reduction in time-percentage	%										
Time to set-up part for checking percentage	%										

7. What did you do with your obsolete gauges and fixtures?

Scrap: ____ Store as Standby: ____ Sold: ____ Other: ____

8. How did you locate your CMM?

	Actual:	Preferred after Experience
Special air conditioned clean room		
Wall partition with/without roof		
Open workshop		
Inspection centre		
On-line with machining centres		
At final check-out		
Other		

9. Was this the best site for optimum inspection or only available site?

Comment: ______________________________

____

____

10. Is your CMM softwear compatible with all other CMMs in-plant?

Yes: _____ No: _____

11. Did you experience installation and early-teething problems with your CMM and what is the current status?

Comment: ______________________________

____

____

____

____

12. What contribution has the use of CMMs made to the following factors in your plant or inspection itself?

Contribution:	Major Increase	Some Incr:	Minor Incr:	Some Decrease:	Major Decrease:
Profit					
Productivity					
Cost Reduction					
Speed of checks					
Accuracy of checks					
Set-up times reduction					
Repeatability of checks					
Reliability of checks					
Calculating errors					

/....

13. In your decision to invest in CMM what importance did you rate the following factors for your plant?

	Vital Impt	Very Impt	Import ant	Unim-portant	Not considered
Faster checking					
More accuracy					
Better repeatability					
Labour saving					
Less production m/c downtime					
Better data					
Reduced inventories					
Cost saving-gauges					
Keeping up to date with technology					
Ease of operating					
No need for special fixtures					
Safer					
Quicker detection of m/c tool variations.					

14. Since the introduction and use of CMM in your plant and the possible improved accuracy of measuring to blueprint specification, do you now question the capabilities of your machine tools in terms of maintaining accuracy and repeatability?

Yes: ___ No: _____

15. What servicing or maintenance policy do you operate for your CMM?

In-house engineers	
Service Contract	
Combination of above	
Other	

16. Have you experienced a change in the following since the use of CMM? (Estimates will be sufficient). E. g. higher, lower, no change.

	Prior to CMM.	Currently:	Time taken to notice change.
Scrap Cost			
Rework Labour			
Field Complaints			

/....

17. How would you justify the investment of a fully automated CMM?

By measuring time taken to measure parts currently v's new system	
By production time lost awaiting measure	
By labour saving	
By savings gained from less scrap and rework	
Other	
Other	

18. Any other general comments about your experience with co-ordinated measuring machines or your opinion about the future of automated inspection in industry:

____

____

____

____

____

19. Manufacturers claim up to 90% faster inspection with co-ordinate measuring machines suggesting that fewer people would be required. Have you actually reduced your inspection manpower as a result of using these machines?

Yes: ____ No: ____

If yes, where did they go?

	Approx Nos:
Left company voluntarily	
Moved to production machines	
Moved to other inspection work	
Moved to office work	
Other	

20. Have you had to increase your planners and programmers designing tapes as a back-up to the CMM?

Yes: ____ No: ____

/....

21. About what age are your CMM operators and approximately how many are there?

Age Years:	No:	Approx. Co. Service yrs.
20-24		
25-29		
30-34		
35-39		
40-44		
45-49		
50-54		
55-59		
60-64		

22. What is the average age of your other inspectors? ______ years.

23. What was the CMM operators' job title prior to working on the CMM? Quote numbers if possible.

Title:	Nos:
Surface plate inspector	
Machine operator	
Office Worker	
Labourer	
Maintenance man	
Toolmaker	
Other	
Other	

24. Did you make any changes in wage/skill grading for CMM operators?

Increased grade	
Remained same	
Reduced grade	

25. Since the introduction of the CMM, how in your opinion has this affected the influence and power of the inspector/operator towards line management or production supervisors? (e. g. can he instruct production to stop?)

	Greatly Increased:	Increased:	No Change:	Reduced:	Greatly Reduced:
Influence:					
Power:					

26. If the CMM operator has gained more or less power how has this affected his relationship with the line production supervisor?

	Greatly Improved:	Improved:	No Change:	Deteriorated:
Relationship:				

27. If CMM becomes an integrated part of in-line machining process and output data takes away human discretions, do you consider that the inspector should eventually become part of the production team?

Strongly Disagree:	Mildly Disagree:	Neither Agreement nor Disagreement:	Mild Agreement:	Strong Agreement:

28. If the CMM tends to require less skill to operate do you think the inspectors of tomorrow will become dissatisfied with their work or not?

Strongly Disagree:	Mildly Disagree:	Neither Agreement nor Disagreement:	Mild Agreement:	Strong Agreement:

29. What effect has the introduction of CMM technology had on your inspection staff both CMM operators and other inspectors?

	CMM operators:	Other Inspectors:
Feeling of increased self status		
Feeling of less self status		
Greater interest in work		
Less interest in work		
No change		

30. Some manufacturers of CMM claim that operators can be trained to operate a CMM in less than four hours. How long on average have your operators taken to competently operate your most advanced CMM?

_____ hours _____ days _____ weeks _____ months

/.....

Comment: ____

____

____

____

31. Did you involve your CMM operator in the Planning and Purchasing decisions for your first CMM?

	Current CMMS	Will consider next time:
No, not at all		
Kept advised		
Part of visit to other user		
Attended all planning meetings		

32. Have any of your CMM operators failed on the job? Yes: _____ No: _____

Is yes, why did they fail? ____

____

____

and what happened to the CMM operator(s) who failed?

Returned to previous job	
Went to other job	
Other	

33. Have you experienced any labour problems in terms of disputes since the introduction of CMM? For example, movement of work from one group to another, concern about reduction of inspectors, etc.

____

____

____

APPENDIX U

PRODUCTION TYPES FOUND IN STUDY OF FIRMS

PRODUCTION TYPE BY EMPLOYEE SIZE
USERS OF ADVANCED TECHNOLOGY

Employee Size:	PRODUCTION TYPE Single Art		Prototype		Large Equipment		Jobbing		Small Batch		Large Batch		Mass Production		Continuous Flow		TOTAL	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes		%
10- 49	1	0	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0.7
50- 99	4	1	5	0	3	2	3	2	2	3	5	0	5	0	5	0	5	3.6
100- 499	32	0	26	6	31	1	31	1	9	23	19	13	30	2	26	6	32	23.2
500- 999	22	1	18	5	20	3	17	6	9	14	17	6	17	6	23	0	23	16.7
1000- 1999	22	1	18	5	17	6	20	3	10	13	16	7	16	7	20	3	23	16.7
2000- 4999	32	2	29	5	26	8	31	3	23	11	16	18	21	13	32	2	34	24.6
5000-80000	18	2	15	5	17	3	19	1	13	7	9	11	7	13	16	4	20	14.5
Total:	131	7	111	27	115	23	122	16	67	71	83	55	97	41	123	15	138	
Percent	95	5	80	20	84	16	88	12	48	52	60	40	70	30	89	11		100%

PRODUCTION TYPE BY EMPLOYEE SIZE
NON-USERS OF ADVANCED TECHNOLOGY

Employee Size:	PRODUCTION TYPE Single Art No	Single Art Yes	Prototype No	Prototype Yes	Large Equipment No	Large Equipment Yes	Jobbing No	Jobbing Yes	Small Batch No	Small Batch Yes	Large Batch No	Large Batch Yes	Mass Production No	Mass Production Yes	Continuous Flow No	Continuous Flow Yes	TOTAL	%
10- 49	9	4	8	5	11	2	11	2	3	10	10	3	13	0	13	0	13	9.8
50- 99	14	2	12	4	14	2	15	1	4	12	11	5	16	0	15	1	16	12.1
100- 499	62	7	53	16	59	10	56	13	26	43	46	23	61	8	63	6	69	52.3
500- 999	12	3	14	1	11	4	12	3	8	7	9	6	11	4	11	4	15	11.4
1000- 1999	12	1	11	2	12	1	12	1	6	7	7	6	9	4	9	4	13	9.8
2000- 4999	4	0	4	0	4	0	4	0	2	2	3	1	3	1	3	1	4	3.0
5000-80000	2	0	2	0	1	1	2	0	2	0	1	1	2	0	2	0	2	1.5
Total:	115	17	104	28	112	20	112	20	31	31	87	45	115	17	116	16	132	
Percent:	87	13	78	22	84	16	84	16	38	62	66	34	87	13	88	12		100%

PRODUCTION TYPE BY BUSINESS ACTIVITY
USERS OF ADVANCED MEASURING TECHNOLOGY.

	PRODUCTION TYPE																	
Business Activity:	Single Art		Prototype		Large Equipment		Jobbing		Small Batch		Large Batch		Mass Production		Continuous Flow		TOTAL	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes		%
Defence	6	1	4	3	6	1	6	1	4	3	4	3	6	1	6	1	7	(4.7)
Aircraft	10	3	6	7	7	6	10	3	4	9	7	6	9	4	10	3	13	(8.8)
Tools	4	0	4	0	4	0	3	1	3	1	2	2	2	2	4	0	4	(8.7)
Machining	4	1	3	2	3	2	4	1	0	5	3	2	5	0	4	1	5	(3.4)
Engines	11	0	9	2	10	1	10	1	9	2	5	6	6	5	9	2	11	(7.4)
Pumps	8	0	8	0	7	1	8	0	4	4	5	3	6	2	6	2	8	(5.4)
Tractors	19	0	19	0	18	1	19	0	16	3	7	12	11	8	18	1	19	(13.)
Food Proc.	4	0	4	0	3	1	3	1	2	2	3	1	3	1	3	1	4	(2.7)
Telecom.	4	0	4	0	3	1	3	1	1	3	2	2	3	1	4	0	4	(2.7)
Electron	17	0	13	4	16	1	15	2	4	13	11	6	14	3	17	0	17	(11.5)
M/c Tools	9	0	8	1	7	2	5	4	1	8	8	1	8	1	8	1	9	(6.1)
Controls	5	0	5	0	5	0	5	0	1	4	4	1	4	1	5	0	0	(3.4)
Castings	4	0	2	2	4	0	2	2	1	3	2	2	3	1	4	0	4	(2.7)
Motor	10	0	8	2	9	1	10	0	6	4	6	4	3	7	8	2	10	(6.8)
Misc.	9	1	8	2	8	2	10	0	7	3	7	3	6	4	9	1	10	(6.8)
R & D	3	0	0	3	3	0	3	0	1	2	3	0	3	0	3	0	3	(2)
Plastics	3	0	3	0	3	0	3	0	2	1	1	2	2	1	3	0	3	(2)
M & H	2	1	3	0	1	2	3	0	1	2	2	1	3	0	2	1	3	(2)
Instrum	6	1	7	0	5	2	7	0	2	5	7	0	6	1	7	0	7	(4.7)
Dom.Prod.	2	0	2	0	2	0	2	0	2	0	2	0	0	2	2	0	2	(1.4)
Total:	140	8	120	28	124	24	131	17	71	77	91	57	103	45	132	16	148	
Percent	94	6	81	19	84	16	88	12	48	52	61	39	69	31	89	11		(100%)

PRODUCTION TYPE BY BUSINESS ACTIVITY NON-USERS OF ADVANCED MEASURING TECHNOLOGY.

Business Activity:	Single Art No	Single Art Yes	Prototype No	Prototype Yes	Large Equipment No	Large Equipment Yes	Jobbing No	Jobbing Yes	Small Batch No	Small Batch Yes	Large Batch No	Large Batch Yes	Mass Production No	Mass Production Yes	Continuous Flow No	Continuous Flow Yes	TOTAL	%
Defence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(0)
Aircraft	2	0	2	0	2	0	2	0	0	2	2	0	2	0	2	0	2	(1.5)
Tools	4	1	3	2	4	1	5	0	2	3	2	3	5	0	5	0	5	(3.6)
Machining	16	4	12	8	17	3	12	8	7	13	13	7	17	3	18	2	20	(14.6)
Engines	3	0	3	0	1	2	2	1	0	3	3	0	3	0	3	0	3	(2.2)
Pumps	2	2	3	1	1	3	3	1	0	4	3	1	4	0	4	0	4	(2.9)
Tractors	8	0	8	0	7	1	8	0	6	2	3	5	8	0	8	0	8	(5.8)
Food Proc.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(0)
Telecom.	3	0	3	0	3	0	3	0	1	2	3	0	3	0	2	1	3	(2.2)
Electron.	15	1	15	3	15	1	16	0	5	11	8	8	13	3	13	3	16	(11.7)
M/c Tools	10	1	8	3	5	6	8	3	3	8	9	2	11	0	11	0	11	(8)
Controls	3	1	3	1	3	1	3	1	1	3	3	1	2	2	3	1	4	(2.9)
Castings	7	0	5	2	7	0	4	3	3	4	4	3	7	0	6	1	7	(5.1)
Motor	4	0	4	0	4	0	4	0	4	0	1	3	3	1	3	1	4	(2.9)
Misc.	22	3	24	1	29	1	29	1	10	15	15	10	20	5	19	6	25	(18.2)
R & D	4	2	1	5	6	0	6	0	6	0	6	0	6	0	6	0	6	(4.4)
Plastics	2	1	3	0	3	0	2	1	2	1	1	2	2	1	3	0	3	(2.2)
M & H	4	3	4	3	4	3	5	2	3	4	6	1	6	1	5	2	7	(5.1)
Instrum.	7	1	6	2	8	0	8	0	1	7	8	0	8	0	8	0	8	(5.3)
Dom. Prod	1	0	1	0	1	0	1	0	1	0	1	0	0	1	1	0	1	(0.7)
Total:	117	20	106	31	115	22	116	21	55	82	91	46	120	17	120	17	137	
Percent.	85	15	77	23	84	16	85	15	40	60	66	34	88	12	87	13		(100%)