IMPLEMENTATION OF COMPUTER AND MICROPROCESSOR BASED CONTROL SYSTEMS

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SUMMARY

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'Implementation of computer and microprocessor based control systems'

This research examines the problem of introducing a new technology (microcomputers) into the manufacturing process of a small company. In particular it examines the difficulties that can arise when using external consultants to bring about the introduction.

Two detailed case studies form the basis for the research. The first was monitored and brought to a successful conclusion after fifteen months. Following analysis, a list of twelve factors associated with success was produced. The second case study was then planned taking these factors into account and was also brought to a successful conclusion. Throughout the case studies, the researcher was involved as an engineer and because of this, very detailed accounts of the projects are presented. This represents an uncommon approach to innovation research where the norm is to carry out research, using interview techniques, several years after the innovation has been completed. It is suggested that the action research approach to innovation research produces both useful results and practical achievements in an area where success is normally limited.

It was found that most, if not all, of the problems identified could be overcome by the addition of one individual. This individual had to be familiar with the new technology and based within the small company. Further examination showed that his major role was the communication of technical information. The presence of key individuals or 'champions' in the innovation process has been noted in previous innovation research. The research reported here describes in detail one important role of the champion figure and its relevance to innovation success.

Because the research has a practical bias, it is hoped that the findings will be of interest to the management of small companies as well as to innovation researchers.

Key Words

Management of Innovation | Implementation

Small Company | Action Research

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CHAPTER 1

INTRODUCTION

Rothwell (1977) describes technological innovation as "...a complex technico/socio/economic process which involves an extremely intricate web of interactions...". Researchers have been examining and analysing the innovation process for over thirty years and have concentrated on producing lists of factors associated with either success or failure. The factors themselves tend to be far too general in nature to be of any practical use. The normal research method is to identify a number of successful examples of innovation and then analyse them looking for common factors; this produces factors associated with successful innovation. Analysing failed examples produces factors associated with failure.

The research reported in this thesis takes a different view of innovation research, and has as its main aim the achievement of successful innovation. If, by the involvement of the researcher, an innovative project can be brought to a successful conclusion, then not only can the factors associated with success be identified but also the means of achieving them.

The research was carried out under the Interdisciplinary Higher Degrees (IHD) Scheme of the University of Aston in Birmingham and this scheme specialises in applying post-graduate research to real problems with a view to producing a practical solution.

The particular problem that is the subject of this research is that of introducing a new technology into the manufacturing processes of a small company.

Chapter 2 provides the background to the project by describing the IHD Scheme, the company and its problem, and the research method adopted.

Chapters 3 and 4 describe in detail the two case studies which were examples of introducing the new technology (microcomputers) into manufacturing processes.

The first part of chapter 5 analyses the case study described in chapter 3 and produces a list of factors and a preferred approach in the form of a research hypothesis. This approach is used to plan the second case study and its performance is analysed in the second part of chapter 5.

Chapter 6 restates the aims and achievements of the research project, and discusses the research findings. This discussion leads to the concept of the internal consultant, and the roles of this individual are examined using a simple model.

Chapter 7 lists the achievements and conclusions and suggests the direction of further research work. Appendix A contains a list of books, papers and articles that were referred to during the research project; not all of them are referred to in the text. Appendix B contains a glossary.

The hypothesis which this thesis supports is as follows:-

> An effective way of introducing a new technology into a small company with limited resources is to use an internally based consultant and a combination of internal and external resources.

The following are suggested as possible contributions to knowledge.

- the use of action research methods to influence technological innovation.
- the reporting of 'live' case studies from the viewpoint of a long term participant.
- the translation of innovation success factors into a practical approach.
- implementing and monitoring the performance of that approach.
- gaining an insight into the role of the champion figure.
- the development of the concept of the internal consultant.
- the development of the four stage information flow model.

CHAPTER 2

The Background to the Research Project

2.0 Introduction

The purpose of this chapter is to inform the reader of how the project came into being, the major aims of the project, and the manner in which the project was carried out.

2.1 The I.H.D. Scheme

The project was carried out under the Interdisciplinary Higher Degrees (IHD) Scheme of the University of Aston in Birmingham. Because of this the project has certain features which separate it from normal postgraduate research studies.

As the title implies, the Scheme is interdisciplinary and as such the projects normally involve more than one discipline. The project reported here required the two major disciplines of Engineering and Management. The researcher joined the scheme as a graduate of the former discipline and gained an understanding of the latter during the course of the project. The broadening of knowledge is an important part of the postgraduate training provided by the I.H.D. Scheme but perhaps not the most important. (Montgomerie 1977).

2.1 Unlike most postgraduate training, the IHD Scheme places the researcher in industry to work on a genuine problem, and it is this aspect of the Scheme that provides the most valuable training opportunities. The aim of the Scheme is for the collaborating company and the University to work together towards finding a solution to the company's particular problem. In this joint effort the researcher is the main link between the company and the University and his efforts are supervised by a team made up of University lecturers and company executives.

To back up what is normally a practical project, the University provides monthly lectures on subjects other than the researcher's main discipline. However, the emphasis is on applying knowledge gained rather than learning only to pass exams.

2.2 <u>The Collaborating Company</u>

The project was carried out at J & J Cash Limited in Coventry. The company is a small manufacturing concern perhaps best known for the 'Cash's Woven Nametape' used to label the clothes of schoolchildren since the turn of the century. Their other woven products include labels, badges, ribbon, webbing and woven silk gifts (See Appendix G). The sales turnover for 78/79 was £2.9m.

The company is normally described as small, although over 300 people were employed in 1978, and it is part of Jones Stroud Holdings.

2.2 The company specialises in Jacquard weaving and it is in this area where most of its expertise lies. In 1978 the company did not employ a single graduate engineer or scientist.

2.3 The Company's Problem

The company had been manufacturing woven nametapes since the turn of the century and had introduced some automation in 1968. They wanted to improve the reliability and flexibility of this automation and it was thought that the microcomputer could provide the solution. However, as stated above, they employed no qualified engineers and had no engineering development capability. The engineering skills they did possess were limited to maintaining the existing machinery. The 1968 development had been done by an external engineering company, but in 1978 that approach was too expensive.

Put simply, the problem was that the company wanted to introduce microcomputer technology into the name-tape manufacturing process, but they had neither the in-house expertise nor the funds to pay full-time consultants to carry out the development work.

Expressed in this way it is likely that other small companies have had a similar problem and as such the research effort was considered to be justified.

2.3 The aims of the research were to investigate and solve the problem and also to implement the microcomputer technology. The way in which the company approached the problem and the eventual involvement with the IHD Scheme is described in Chapter 3.

2.4 <u>The Research Method</u>

The literature relevant to the area covered by the project comes under the general heading of Mangement of Innovation. Interest in innovation has been growing steadily since the 1950's, and the volume of literature on the subject has grown accordingly. As an example of the growth, a study of innovation bibliographies by Robertson (1977), refers to a 1975 report on 4000 books and papers. There was one aspect in particular that attracted the attention of innovation researcher's back in the 1950's and it continues to demand attention today. This is the search for the key to successful innovation.

Because all the research studies are looking for this key to successful innovation, they have all adopted a very similar research method. This method involves collecting research data about successful innovations, normally by interview or questionnaire, and then analysing the data to produce conclusions in the form of a factor or factors associated with successful innovation.

2.4 One of the early books on innovation and a clear example of this approach was by Carter and Williams (1957). Their work examined 152 cases of successful innovation and they produced a list of 24 characteristics associated with the technically progressive firm. Another study a few years later used essentially the same approach except that both successful and unsuccessful cases were examined. Burns and Stalker (1961) concluded that there was one major factor associated with both success and failure, and that was adaptive management. A willingness to adapt is associated with success, unwillingness to adapt with failure.

The two studies referred to above seemed to set the pattern of innovation research with all later researchers using more or less the same method. Some examples of the later studies using the Case Studies - Analysis - Factors approach are Langrish (1972) and Layton (1972). Freeman (1972) tried the novel approach of analysing matched pairs of successes and failures. All three studies produced factors associated with successful innovation. Langrish identified the need for a 'Top Person', Layton a need for qualified scientists and engineers, and Freeman a need for attention to market requirements.

2.4 The findings of nine examples of innovation research (including Carter and Williams, Langrish and Freeman mentioned above) were summarised by Rothwell (1977), and his lists of factors associated with success and failure in innovation are shown in Exhibits 2.1 and 2.2 at the end of this chapter.

Factors expressed in general terms such as 'good internal and external communication' are of only limited use to industry if there is no indication of how the good communication was achieved, and it is suggested that the research methods adopted are responsible for producing results of this type.

Many of the studies have opted for quantity in the case studies rather than quality. For example, the work by Langrish (1972) examined eighty four innovations that won Queen's Awards and identified the following seven factors associated with success.

1. Top person: the presence of an outstanding person in a position of authority.
2. Other person: some other type of outstanding individual.
3. Clear identification of a need.
4. The realisation of the potential usefulness of discovery.
5. Good co-operation.
6. Availability of resources.

2.4 7. Help from government sources.

However, the innovations were examined several years after they were completed, and the research data was collected mainly via interviews. This approach must lead to much of the detail being lost because the data collection relies to a great extent on human memory. If this data is then analysed and generalised to produce just seven factors, how useful can those factors be? For example, do all seven factors have to be present to achieve success and how were those factors brought about? The answers to questions such as these can only be found in the detail that was either missing from the raw data or discarded during the generalisation, and clearly the research method described above cannot change this situation.

Langrish himself criticised the research method at an innovation conference (Langrish 1979), claiming that the matched pairs methodology of Freeman did not represent an improvement. Langrish also criticised the 'after the event' analysis, and in particular the fact that the researchers decided what constituted a success and used this as their basis for analysis. He went on to say that past studies had established the anatomy of innovation but tended to ignore the mind.

2.4 Some innovations succeed because of pure good fortune, others because of enthusiasm and determination. Factors such as these can only be found by the researcher getting much closer to the innovation process and recording events as they happen. This approach will not only produce more detailed factors but also information on how each favourable factor came to be present. The current literature is particularly weak on the last point; the factors are presented, but not the methods for achieving them, and without the methods it is extremely difficult to apply favourable factors to future innovation projects.

The work reported in this thesis had a strong practical bias and therefore the research method chosen had to produce results that could be put into use. For this reason a long term study of a single case study was the approach adopted. Using this approach, the researcher can make a positive contribution to the innovative project while at the same time keeping a record of events and decisions. This approach is not new, it has been used by behavioural scientists to bring about and study organisational change since the 1940's; in this context the approach is known as Action Research. Warr (1977) describes the features of action research as follows:-

2.4 1. Action research is change-oriented. Action research has a strong emphasis on intervention to alter and improve an operational system. This is in order to achieve practical goals but also for scientific reasons, to learn more about people and organisations through the manipulation of variables.

2. The action researcher is closely involved in the change process, he is where the events are taking place and he may help them along in various ways.

3. The action researcher gains knowledge which is otherwise unavailable to him. By this close involvement in what is going on the action researcher is able to acquire knowledge and understanding which otherwise would not be obtainable.

4. Action research is theory - oriented. The action researcher is not only a person trying to help change a situation; he wants to learn and generalise from that process.

5. Roles and relationships change over time. The roles of the researcher and the subjects of his research will change and may even reverse with the subjects carrying out research.

2.4 6. Action research creates tension. Any attempt to change things creates tension and there will inevitably be differences of opinion between the action researcher and the subjects of the research.

7. Action research reduces the gap between research and its application. The research is directly and immediately applied with the goal of learning and doing at the same time.

All the above features are describing action research as applied to organisational change, however, it is suggested that they are also applicable to research into innovation in industry. The procedures described by Warr are more specific to organisational change however, they do have some relevance to innovation. Warr suggests the following eight activities for the action researcher bringing about organisational change:-

1. Gathering and interpreting research data.

2. Educational, training or counselling activities.

3. Process consultation.

4. Data feedback procedures.

5. Intergroup communication meetings.

2.4 6. Problem-solving meetings.

7. Assistance with the development of plans and policies.

8. Establishment of longer-term structures.

Action research is not without its problems and Warr suggests four areas of difficulty all of which would apply to innovation research as well as to organisational change.

1. To whom is the action researcher responsible? The action researcher is responsible to himself to maintain professional standards and he must be careful not to appear to represent particular subgroups.

2. Where is the boundary of the project? The aim should be to study the entire organisation but the operational problems are larger and less easy to solve. The smaller the project the better the chances of success.

3. How can dependence be handled? If an action researcher is too involved in the change programme and is exceptionally willing to help and give advice, there is a danger that members of the organisation will adopt a passive, dependent role, relying on him for initiatives, advice and decisions. On the other hand, if the researcher avoids all forms of advocacy and advice, he may find that action fails to occur since change is typically resisted

2.4 3. and some encouragement is usually required. Some dependence is inevitable, but this must be reduced as the project develops towards its conclusion.

4. Action versus research. There is inevitably some tension between the requirements of research and those of action.

With innovation research the problem of dependence is likely to be the most prevalent, and is most likely to occur if the researcher becomes involved with the solution of technical problems.

Warr concludes that although the action research method can be fraught with difficulties, the benefits outweigh the problems.

An attempt to use the action research approach for the long term study of an innovative project was reported by Bessant (1978). In this study, Bessant joined a chemical company as a temporary employee in order to study their innovative performance from within. He terms his method Participant Observation rather than action research, because he observed the innovative performance of the R & D laboratory from the point of view of a participating chemical engineer, and the emphasis was on observation rather than participation. This is the opposite to the approach used for the research in this thesis where the emphasis is on participation and action by the researcher, with observation and research going on in the background.

2.4 This is not to say that observation and research aspects are unimportant, for without them the results of the action and participation cannot be used to determine the next course of action. Also without adequate documentation, the results of the action cannot be passed on to other researchers and used to increase the level of knowledge. It is the reporting aspect that separates action research from applied research where the results are seldom reported. Clark (1972) agrees with the above when he states that "...action research must possess an aspect of direct involvement in organisational change, and simultaneously it must provide an increase in knowledge.".

The great strength of an action research type of approach is the ability to take advantage of opportunities that present themselves. It was this ability to alter the research method to suit the circumstances that enabled the researcher to take advantage of an unexpected train of events. From the last statement it is clear that the research project followed events rather than a definite plan and as such is very different from the projects that examine completed innovations. This ability to adapt is the key to action research methods with each step forward depending on the results of the previous step. What follows is an outline of the research method and it must be remembered that this method is unique because it was adapted to suit the events.

2.4 When the researcher joined the company, the development described in Chapter 3 should have been in its final stages. The intention was for the researcher to join the project team and both contribute to and monitor the final stages of development and implementation; this was expected to take about seven months. During the first seven months, the researcher contributed very little to the development but it was monitored. The monitoring showed that instead of being on the verge of completion, the development was in fact several months behind schedule. Following these findings, the researcher's technical involvement was increased and changes were made that eventually brought the development to a successful conclusion. The fact that the development fell behind schedule presented a unique opportunity for the researcher to intervene and change factors while the development was in progress. A purely passive research method could have only produced predictions, action research implemented changes and monitored the results.

The next stage of the project was to analyse the data collected from the development project and to produce a list of factors so that the findings could be compared with the existing literature. The factors were produced, complete with details of methods of achieving them in a small company, and at the same time an opportunity arose to test the factors on another development project.

2.4 A project plan was produced, taking into account all the factors, and was approved by the company. The project was carried out and brought to a successful conclusion on schedule. The second development project is described in Chapter 4 and the factors and project plan in Chapter 5. The second development project was also monitored in order to produce further data for analysis.

The above method still uses the basic Case Study - Analysis - Factors approach but there are significant differences. There was initially only one case study, but this was monitored while it was still in progress over a period of some 15 months by someone involved with the technical development. It is suggested that this produced far more accurate and meaningful data for the later analysis. Only a long term study of this kind can offer the opportunity of intervention which may affect the outcome of the development. Both the analysis and the resulting factors have a practical bias, and because much of the analysis is done during the development, when the outcome is unknown, there is a reduced tendency to produce factors that are only associated with success or failure. The practical bias assures that not only factors, but methods of achieving them come from the analysis.

2.4 The second part of the method moves away from recognised techniques by continuing beyond the list of factors which are normally the end product of innovation research. The factors are implemented in the form of a project plan and then tested on a second case study which is in turn monitored and analysed. The approach can be summarised as Case Study - Analysis - Factors - Project Plan - Case Study - Analysis - Factors. This approach is clearly cyclical and in that form can be used to clarify both the factors and the methods of achieving those factors. Certainly converting factors into a plan and a successful case study is far more use to industry than an endless list of factors with no means of achieving them.

2.5 Conclusions

The research project had very practical aims and this is reflected in the way the project was set up and carried out. It is this feature that separates IHD Scheme research from normal post-graduate research and the feature that makes it more appropriate to university/industry collaboration.

EXHIBIT 2.1 : Factors associated with innovation success (based on Rothwell, 1977).

(a) Good internal and external communication

- 'use of outside technology and scientific advice'
- survey of potential ideas
- better contacts with the scientific community in the specific area associated with the innovation
- a willingness to share knowledge (not secretive)
- the information system which is at the disposal of the enterprise is associated with success - both good internal and external information are associated with high profitability
- communication outside the firm played an important role in the projects studied. Outside consultants more often used by successes
- good internal and external communication important to success. External communication particularly important for firms attempting radical innovations
- high quality of incoming information. Better contacts with outside establishments

(b) Collaboration with outside agencies

- successful innovators collaborate with potential customers during the development
- an element of success was the ability of a research unit to improve scientific and technological co-operation with extramural scientific and technological organisations
- readiness to co-operate with outside agencies
- collaboration with customers and suppliers
- successful innovators collaborated with external agencies from an early stage in the innovation process. Collaboration occurred most frequently with customers and other private industry
- frequent contact was maintained with customer
- external information is not obtained from symposia. A great deal of information results from personal contacts within and outside the company and from captive know-how and experience
- personal contacts and personal experience are best information sources for successful innovations

(c) Good integration and co-operation

- successes, on average, out perform failures in all areas of competence encompassed by the innovation
- harmonious co-operation between research, development, production and financial organisations contributed to success
- good internal co-ordination and co-operation
- innovation management is a corporate task, not Research and Development in isolation. Cannot be left to one functional department
- good intra-firm co-operation
- the balance of functions of production, marketing and Research and Development is an element in the success of an enterprise over the long term. It is a question not only of quantitative balance but also of a balance in quality. The firms which have the highest economic successes are those which attain a high quality simultaneously in these three major functions
- successful firms took steps to co-ordinate the effects of various functional departments. More progressive firms formulated a corporate strategy. Innovation is a corporate-wide task and success cannot be explained in terms of one or two factors only. On average successful firms out performed failures right across the board

(d) Effective development work

- successful innovators perform development work more efficiently and eliminate technical defects before commercial launch. In successful innovations there were fewer unexpected adjustments to production
- success was greatly facilitated by the adequate preparation of works for solving emergencies in the course of pilot production. Success was furthered considerably if the enterprise succeeded in overcoming the different operational problems
- good consciousness in research
- successful firms performed their development work more efficiently than failures. Successful firms eliminated technical bugs before commercial sales

(e) Good financial control

- the drawing up of a preliminary budget
- quantified investment decisions
- budget for market and development available
- most innovations were formally budgeted for at the start. This was particularly the case with incremental innovations

(f) Use of management and planning policy/strategy

- successful innovators undertook a deliberate search for the innovation. Successful innovators took a more serious approach to planning. In successful firms the Research and Development programme was systematically and periodically considered
- good use of management techniques
- innovative capacity is associated with an active policy in finding and developing new products
- planning was more highly structured and sophisticated in the successful cases
- the majority of successful innovators claimed to have an explicitly formulated policy towards innovation and also, to formulate in writing the objectives and plans of their development efforts. This was particularly true for radical innovators. Growing use of technico-economic analysis of new innovations in the more progressive firms

(g) Scientists and managerial positions

- did not discriminate. The successful Chief Executive was often a graduate scientist or engineer
- scientists and technologists on the board
- senior staff are mostly engineers but other graduates are also included
- in the case of radical innovators, 70% of Chief Executives possess a technical qualification, 35% were graduates. In the case of incremental innovators, 60% possessed a technical qualification, 26% were graduates

(h) Marketing contact and orientation

- marketing was the most important SAPPHO discriminator. Successful innovators understood user needs better. Successful firms pay more attention to marketing publicity and sales. Successful innovations arise in response to a market need
- an effective selling policy
- recognition of demand is a more frequent factor in successful innovation than the recognition of a technical potential
- clear identification of a need. Realisation of potential usefulness of a discovery
- the product policy aims essentially at orientating the resources of the enterprise towards the most profitable opportunities
- need recognised among users. Need recognised before technical solution. Project intended for specific user or end-product

(h) - an active attitude towards the market. Anticipation of a future market demand. Recognition of an existing demand
- knowledge of consumer demand is an important factor in success. Where no deliberate marketing was practised in the interests of successful development, this circumstance had a decisive role in failure. If the innovation formed an integral part of the marketing policy of the enterprise, the chances of success improved significantly
- the great majority of successful innovations arise in order to meet a customer need. This is particularly true for incremental innovations. Successful innovators interact strongly with customers during development. Successful firms have a 'market' rather than a 'technical' orientation. Most progressive firms possess a formal marketing policy

(i) <u>Good technical service</u>

- the avoidance of technical after-sales problems by good development work is important to success. Successful firms pay more attention to user education
- successful operations were furthered by the adequate preparation of consumers
- good technical service to customers
- successful firms had no initial difficulty in marketing the product
- successful firms provide an efficient and reliable after-sales maintenance service. Successful firms mount comprehensive operator training courses. These factors are particularly critical in the case of radical innovations

(j) <u>Forecasting</u>

- in successful innovations systematic sales forecasting was undertaken. Successful firms rated the prospects of technical success lower
- prior to introducing the new product, predictions were made regarding the new product
- a readiness to look ahead
- in the majority of successful radical innovations systematic sales forecasting was involved in the decision to add the innovation to the firm's product lines

(k) <u>Technical and power promotors</u>

- the executive in charge of success has more responsibility, higher status, higher authority, more enthusiasm, more involvement.

(k) Associated with success there is clearly identifiable technical innovator. In successful firms there is a product champion

- an element of success is if the head of the Research and Development department had considerable experience and his sphere of interest in Research and Development management has been increased. The same is true for the project manager. In successful projects, the project manager had more commitment
- outstanding person in a position of authority who makes special contribution to the innovation. Other person, e.g. a 'mechanical genius' or someone who possesses a unique form of knowledge that would otherwise not have been at the disposal of the firm - he is particularly important in innovations embodying large technological change
- project was initiated by firms top management
- success is promoted by enthusiastic top management. Enthusiasm, technical innovators and product champions have played decisive roles in fostering success. These individuals are particularly effective when the management structure is horizontal and decentralised and when management style is open and consultative. The clear will of management to innovate is important

EXHIBIT 2.2 : Factors associated with innovation failure (based on Rothwell, 1977)

(a) Market related factors

- made no enquiries of users
- made too few or wrong kind of enquiries, picked a typical user
- made enquiries but ignored answers
- misinterpreted or misunderstood answers
- committed to a preconceived design
- made user enquiries but no on-the-spot investigations
- market research neglected or ignored
- neglect of publicity or underinvestment in marketing effort
- failure to educate users
- unforeseen changes in the market (e.g. demand falls, price falls, low cost substitutes etc.)
- competitors developed new products much faster
- inadequate information about competitors
- defective marketing activity
- too expensive to be competitive
- potential market too small
- insufficient marketing and servicing resources available

(b) Technical factors

- poor or incomplete development work
- over-dependence on outside technology, lack of in-house capability
- insufficient resources for development work
- unexpected superior competitive technology
- belated supply of materials and parts
- lack of contact with research and production
- impractical design, technically 'nice' but lacks commercial performance
- incorporation of unnecessarily complex features
- competitors patents too strong
- problems with new production techniques

(c) Management factors

- project not taken seriously by top management or not integrated into company strategy
- inadequate project evaluation or control
- failure to communicate with critically important outside interests
- business innovator too junior, weak, inexperienced or not present

(c)
- powerful committed but mistaken product champion
- few development personnel with experience in determining economic factors
- potential not recognised by management
- remote, uninvolved business innovators
- secretive inventor/hostile business innovator
- general lack of experience in new area
- poor internal/external communication
- overattachement to old, traditional designs on behalf of management

CHAPTER 3

Introducing Microcomputers into Nametape Weaving

3.0 Introduction

The case study described in this chapter shows how a small company approached the problem of introducing a new technology into a production process. The study is divided into three sections. The first describes the background to nametape weaving and the development that took place before microcomputers were introduced. The second section describes the development and implementation of the microcomputer system and the involvement of the researcher. The final section examines the effects of introducing the new system from the points of view of system performance, the end users and the nametape customer.

3.1 Background

The company began producing woven nametapes (See Appendix G) at the beginning of this century and it was this product that made Cash's a household name. The nametape was woven on a Jacquard shuttle loom (See Plate 3.2) and the weaving pattern was determined by Jacquard cards.

For weaving nametapes, a single Jacquard card controls eighty warp threads and determines which of two shuttles inserts the weft thread. Producing individual nametapes from Jacquard cards was a laborious business for each letter of the name required typically thirty cards laced together to form a set.

3.1 To make up a complete name the sets of cards for each letter were taken from a library, arranged in the correct order and laced together to form a continuous set of cards. The complete set of cards was then fitted to the loom and the name woven; this would take about three minutes for a ten letter name. The complete set of cards then had to be removed from the loom, broken down into its individual letter sets and returned to the card library.

The above method had several shortcomings, the most obvious being the disparity between the card preparation time (10 minutes) and the weaving time (3 minutes). This was compensated for by employing large numbers of staff for card preparation which made the whole nametape operation labour intensive. The other shortcoming was the stop start operation of the loom which was necessary because of the continual card changing. The same method was still in use in the mid 1960's when the company was approached by an inventor who suggested an alternative method; that invention was to revolutionize the nametape department and make it the most profitable part of the company.

3.1.1 <u>Early Technical Development (1966-1968)</u>

The invention made it possible to do away with the sets of Jacquard cards and replace them with an electromechanical device. Instead of each warp thread being controlled by a hole in a Jacquard card, it was now controlled by an electrical solenoid.

3.1.1 The invention presented the company with a problem, it could see the potential but it simply did not have the engineering skills necessary to turn an invention into a production unit. There were other problems; the electromechanical device was no use without some form of electronic controller, and the company had no experience whatsoever in the field of electronics. There were various avenues open, the company could have recruited the necessary experts, or it could have brought in consultants. The company finally decided to approach a small engineering company with a view to a joint development project. The engineering company would provide the technical skills and resources and Cash's would provide the weaving knowledge.

The development took about two years to complete and was a tremendous success. The engineering company produced nineteen electromechanical units (normally referred to as a 'Loom Head') and nineteen electronic controllers. The controllers were operated by paper tape and one hole in the tape controlled one solenoid at the loom head. Using this method of control, the thirty Jacquard cards needed to weave one letter were replaced by a strip of paper tape about half a metre in length. For making up a complete name, a tape reader and punch were used to copy the individual strips onto a continuous length of paper tape, each strip taking only two or three seconds to copy.

3.1.1 This system overcame the major shortcomings of using Jacquard cards simply by reducing the time needed to prepare each name order. The example quoted earlier of a ten letter name, could be prepared in about thirty seconds and would require about five metres of paper tape; the weaving time of three minutes remained unchanged. The reduction of name preparation time made it possible to process the same number of orders with less staff, and had that reduction not taken place, it was almost certain that the company would have stopped making nametapes because of rising labour costs. The new system also made it possible to run the looms continuously because several names could be prepared one after another on a continuous reel of paper tape. The new system overcame all the shortcomings of the Jacquard card method and was without doubt an outstanding example of innovation in a small company.

3.1.2 Some Comments on the 1966 Development

Before moving on to the later development of the nametape system, it is worth examining the way in which the companies collaborated to bring about the technical success.

The major theme of this thesis is that of introducing a new technology into a small company using external skills and resources. The above project was the first of many, and being a success, should show some guidelines for projects of this type.

3.1.2 Perhaps the major problem to be overcome is that of bringing together the two technologies, and in particular bringing together the experts from each technology. In the above example, Cash's knew very little about electronic technology and the engineering company knew nothing about weaving technology. However, one factor did make the marriage of the technologies much easier; weaving information is by definition digital in that the warp thread is either up or down. Digital information could be understood by the electronic engineers and could be implemented using digital electronics, so there was at least a basis for communication between the two technologies.

In a project such as this, information flow should be biased towards the external company for it is essential that the external company fully understands the problem it is trying to solve. On the other hand the user of the new machine only needs sufficient information to enable him to use and maintain the machine. It will be shown later that this is a minimum requirement and does not represent the ideal.

From talking to people who were involved with the project, there appeared to be five key figures in the project organisation. From Cash's they were the Development Manager, the Works Electrician and the Nametape Supervisor and from the engineering company, the Director and the Electronics Engineer.

3.1.2 Each played a role in the project organisation. The Director managed the project, the Manager provided the weaving knowledge and the Engineer provided the electronic knowledge. The Electrician and the Supervisor were more concerned with the practicalities of bringing the system into the factory for between them they were to operate the new system. The Supervisor also made a major contribution to the project by manually preparing all the master strips of tape for the woven letters.

When the Electrician is talking about the project there is continual reference to when he visited the engineering company and what he and the Engineer worked on together at Cash's. This suggests that the continual interchange between the two companies may have been a factor in bringing the project to a successful conclusion. What is more important is that the interchange took place at all levels, and as the project progressed the end users were involved to a greater and greater extent. This point will be raised again when other projects are examined.

3.1.3 Further Development (1972-1973)

The nametape system, which came to be known as the CASHMATIC system, was improved one stage further in 1973 by the addition of a main frame computer which was to handle all the incoming orders and punch out the tape for the electronic loom controllers.

3.1.3 The nametape system had progressed from a library of Jacquard cards to a library of strips of paper tape, the next stage was to transfer the data on the strips of tape onto a computer disc to form a disc library. From this library the computer could compile all the weaving data necessary for a complete name and punch out a continuous strip of tape. The computer also had to perform a task which had previously been done manually, that was sorting the name orders by colour. The above were the two main functions of the computer but others such as order validation, printing factory tickets, invoicing and producing statistics were also added. Introducing the computer and writing the suite of programmes took about one year and was done by a software house. That development brought the CASHMATIC system up to the state shown in Figure 3.1 and it was used continually in that form until 1980 when an improved microcomputer based system was introduced. The events leading up to that introduction will now be described.

3.2 Introducing Microcomputers into the Nametape System

The CASHMATIC development was described earlier as a 'tremendous success' so why was it necessary to introduce microcomputers? The simple answer was that the microcomputer could perform the same task more efficiently and more reliably, but that needs further explanation.

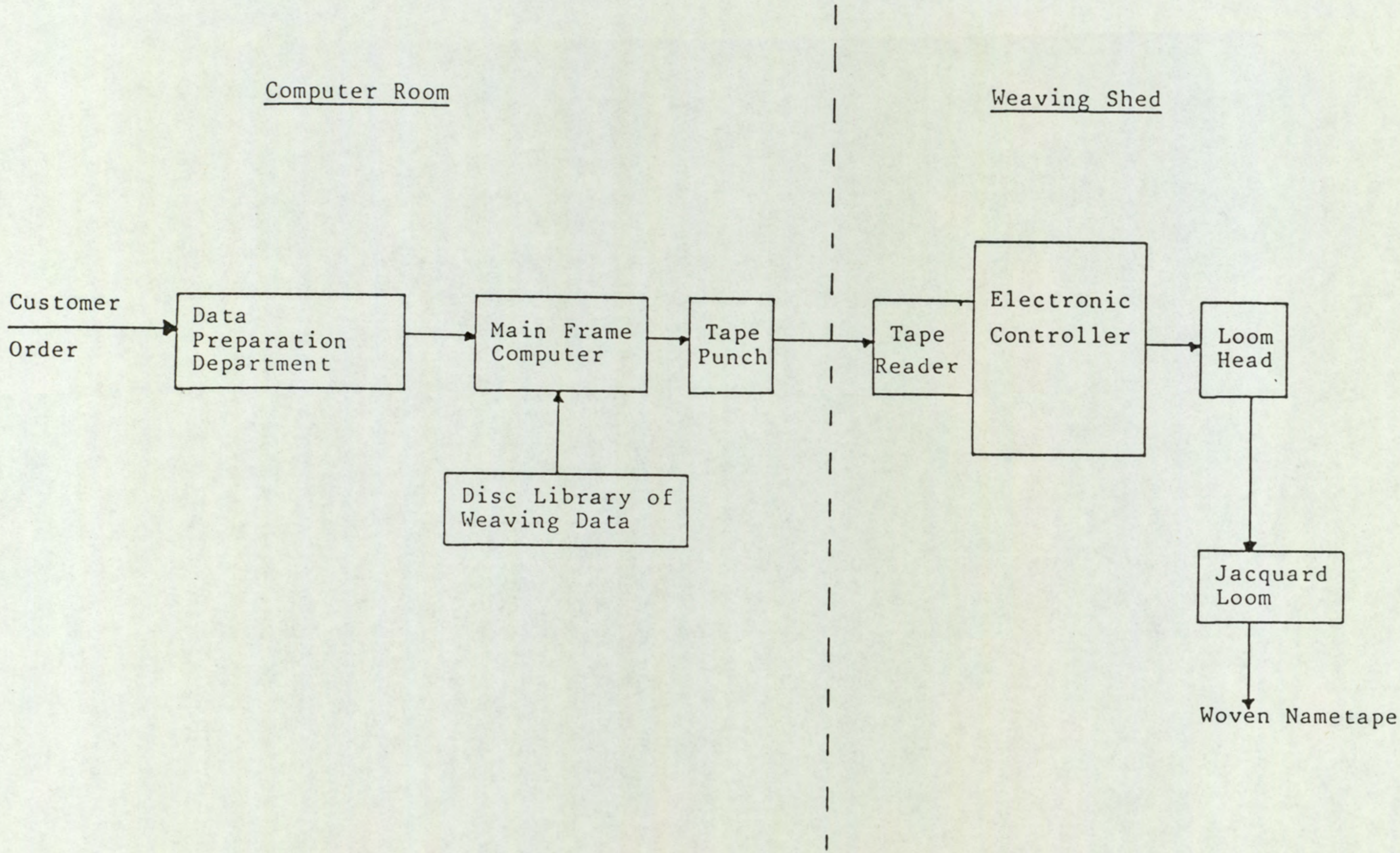


Figure 3.1 The Nametape System Block Diagram (before 1980)

3.1.2 The CASHMATIC system, good though it was, used large amounts of paper tape. For example, in 1979 the company processed over 300,000 nametape orders, and each order consumed five metres of paper tape, that gave an annual consumption of 1,500 Kilometres of paper tape. The system was in continual use for twelve years, and handling that amount of tape over that period of time had worn out the mechanical parts of both the tape punches and tape readers. The electronics was also showing signs of age and becoming less and less reliable. A decision was made in 1977 to update the system with modern components and redesign it so as to greatly reduce the paper tape consumption.

3.2.1 <u>The Technical Problem</u>

The main reason for updating the system was to reduce the amount of paper tape required. Some of the suggestions put forward simply replaced the reels of paper tape with floppy discs or magnetic tape, but these were dismissed by the company because everybody understood paper tape and wanted to retain it.

The proposal that was finally accepted was to transfer the library of weaving data from the main frame computer to the electronic controller next to the loom (refer to Figure 3.1). By doing that the paper tape forming the link between the computer and the controller contained only the characters representing the letters of the name, instead of all the weaving data for the individual warp threads.

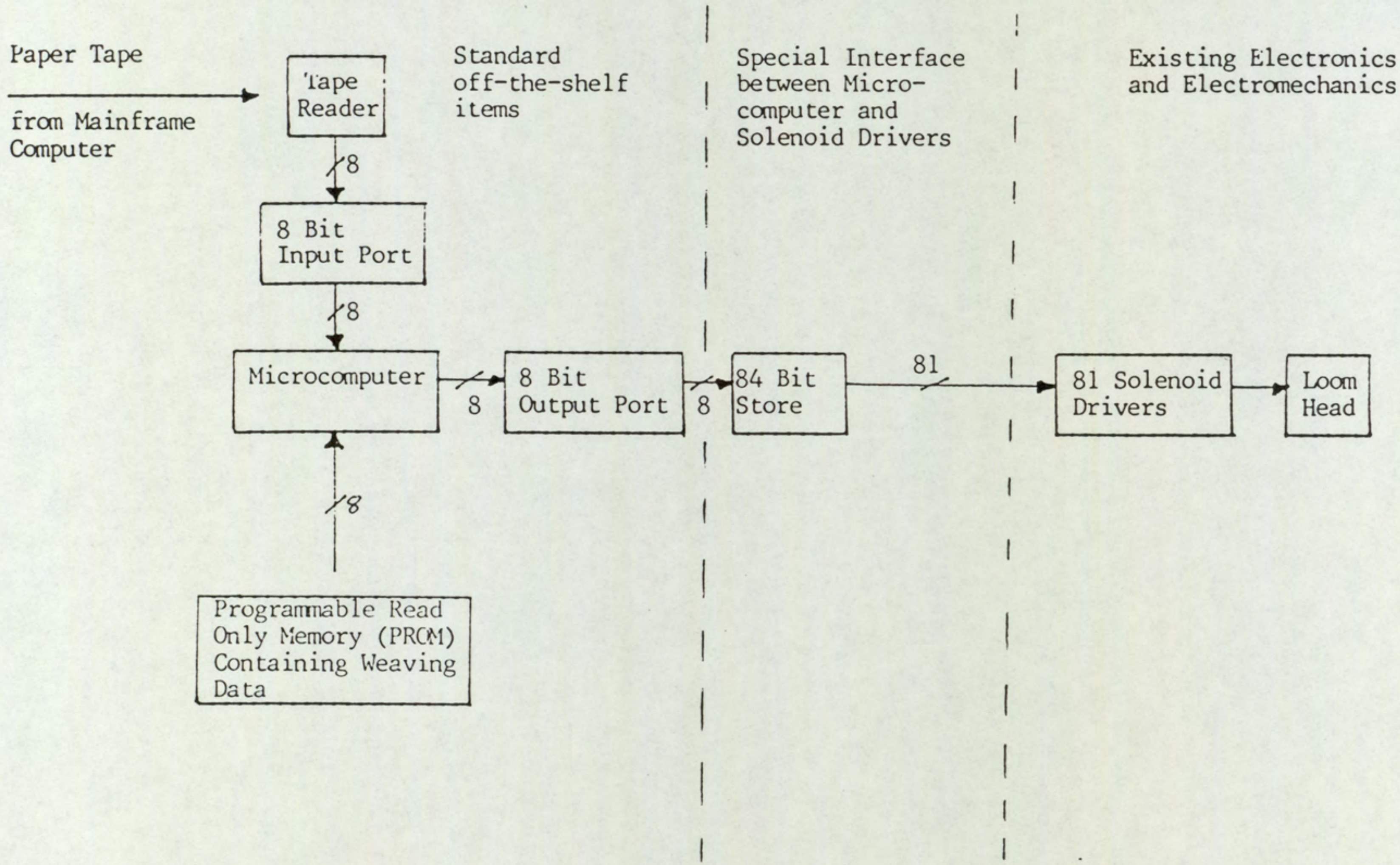


Figure 3.2 The Block Diagram of the Microcomputer Based Controller (Nametapes)

3.2.1 This proposal required an electronic controller with memory capacity and an ability to perform computations; the solution adopted was based on a microcomputer with a solid state memory. Figure 3.2 shows the block diagram of the microcomputer based controller. It also shows that the bulk of the design was either already available within the existing controller or available "off-the-shelf". The 84 bit store was the only piece of hardware that had to be designed. What the diagram does not show is the control programme that the microcomputer required to make it read the tape, select the weaving data from memory, and present it to the 84 bit store. This control programme was peculiar to this application and as such could not be based on any existing design. Before the control programme could be designed, three decisions were required. These were the format of the tape from the mainframe computer, the format of the weaving data in the memory and the technical details of the 84 bit store. What emerged from the above was that to produce the new controller four related tasks had to be completed simultaneously. Task 1 was to design, build and test the 84 bit store such that it would interface with both the microcomputer and the existing solenoid drivers. Task 2 was to transfer all the weaving data stored on the library disc on the mainframe computer into the Programmable Read Only Memory (PROM), changing the format as necessary. Task 3 was to amend the existing programme in the mainframe computer such that the tape output contained

3.2.1 only the required style number and the name to be woven in the format acceptable to the controller. Task 4 was to design, write and test the control programme for the microcomputer.

The above four tasks give an indication of the complexity of the work necessary to produce the microcomputer based controller, and taken individually none of them was very demanding. For example, the 84 bit store was constructed from about thirty components which would represent about one weeks's work for a skilled wireman. All the other tasks involve software of one form or another, but in tasks 2 and 3 only amendments were required. Task 4 was perhaps the most demanding for it involved about 800 lines of assembly code programming. This should occupy a skilled programmer for about four months, at the end of which he will have produced a programme that is both fully tested and documented.

Further work was necessary to turn the design into a production unit that could be duplicated twenty times. A method of installing additional nametape characters directly into PROM also had to be devised, but neither of these two extra tasks should have presented any serious difficulties after ten years of nametape system development.

To summarise, the technical problems that had to be solved were not great, and yet all the tasks outlined above were beyond the abilities of the staff at Cash's.

3.2.1 However, the technology was readily available and there was no shortage of experts willing to help the company introduce microcomputers into the nametape department. Exactly how the company approached the problem of introducing a technology it did not understand is described in the next section.

3.2.2 <u>The Company's Approach to the Technical Problem</u>

In the past, the company had relied on the engineering company and the software house to solve its technical problems, and this arrangement had produced good results over a ten year development period. Over the same period however, the company had made no serious attempt to improve its in-house skills, being content to maintain the equipment it had and send for the engineer in the event of a serious breakdown. This attitude was perfectly reasonable because the company had no desire to expand into the field of engineering. However, this approach does have drawbacks when the equipment concerned has to be specially designed and regularly updated as was the case with the nametape system. The reliance on external companies meant that the specialist know-how needed to solve the nametape problems was retained by the external companies rather than by Cash's. This being the case it would seem that the best way to introduce microcomputers would be to use the same engineering firm again. This approach offers several advantages; the two companies had successfully worked

3.2.2 together before, the engineering company was aware of the special techniques required for weaving nametapes, and it already knew in detail how the existing system operated. The one major disadvantage was that such a move would further increase Cash's dependence on the external company.

All technical developments are governed by economics and the introduction of microcomputers was no exception. It was the cost factor alone that made the company decide not to use the same external company again. They submitted a quotation for £80,000 to carry out all the work detailed in 3.2.1 over a period of twelve months and this was considered to be excessive. The company considered recruiting the engineers it needed but found that it could not afford to pay the level of salary necessary to attract people with the required qualifications and experience. Even if the company could find the salary, it would still be faced with high capital expenditure (or hiring charges) for the test and development equipment that the engineers would need.

An alternative approach to the problem came from the Industrial Liaison Centre (ILC) of the local Polytechnic. They claimed to have at their disposal the skills and resources necessary to produce the microcomputer based controllers and to carry out the amendments to the existing software.

3.2.2 The company had been involved with the ILC on another project and were generally satisfied with the service it provided. In November 1977 the ILC submitted detailed design proposals for the controllers and a quotation for ₤35,000; they expected to complete the project in eighteen months. The proposal was accepted by the company and the ILC was asked to proceed. When the two quotations are compared it would appear that by waiting an extra six months, the company had saved the sum of ₤45,000, this assumes of course that both delivery dates are met. However, the two quotations cannot be directly compared because of the different organisation behind each one. In the case of the engineering company all the necessary resources would be committed to the project, full time, until it was completed. This commitment is essential since the engineering company would not receive payment until the job was completed and without payment the company could not continue. It is a very different situation at the ILC. Any work done for the ILC is secondary to the Polytechnic's prime function of education, hence Polytechnic staff work for the ILC in their spare time using resources that are normally used for education. Commitment to the ILC is limited because it is not the major source of income; if the ILC fails to complete a job, the Polytechnic does not suffer and only the client is inconvenienced. It would appear that the major difference between the quotations was that one represented full-time work on the project while the other only part-time.

3.2.2 This raises an important question; if the engineering company with ten years experience behind them, decided that the extra £45,000 worth of human input was necessary to bring the project to a successful conclusion, just what will happen to the project when that input is removed? What did happen is described in the next section.

3.2.3 <u>An Account of the Nametape Project</u>

The technical requirements of the project were described in 3.2.1 and were broken down into four tasks, these were as follows:

Task 1 - To design, build and test the 84 bit store such that it will interface with both the microcomputer and the existing solenoid drivers.

Task 2 - To transfer all the weaving data on the library disc on the mainframe computer into the Programmable Read Only Memory (PROM), changing the format as necessary.

Task 3 - To amend the existing programme in the mainframe computer such that the tape output contains only the required style and the name to be woven in the format acceptable to the controller.

Task 4 - To design, write and test the control programme for the microcomputer.

Once the above four tasks were completed, a total of twenty controllers had to be produced and installed in the weaving shed.

3.2.3 The ILC offered the services of three consultants and the tasks were assigned as follows:

Consultant 1	-	Task 1
Consultant 2	-	Tasks 2 and 3
Consultant 3	-	Task 4

The ILC liaised with the Technical Director of Cash's and it was he who provided the weaving knowledge. Project planning was minimal, but it was generally agreed that the first twelve months would be spent developing a prototype controller, which would then be brought to the company for trials. Assuming the trials were successful, the remaining six months would be spent producing and installing the twenty production controllers. Project control took the form of progress meetings which were held, on average, every two months and attended by the Director, the ILC representative and one or more of the consultants. These meetings were mainly to inform the company of any progress that had been made and only rarely was technical information exchanged.

It was suggested in section 3.1.2 that the continual interchange between the two companies may have been a factor in bringing the project to a successful conclusion. In the case of the microcomputer project this factor was missing. In particular, the Works Electrician who had been so involved with the earlier project was barely kept

3.2.3 informed of project progress. One reason for this was because the Electrician himself felt that microelectronic technology was beyond him and he did not want to be embarrassed in front of the highly qualified consultants. Whatever the reasons, the lack of interchange allowed the consultants to work very much in isolation away from the company. The minutes of the progress meetings recorded the progress of the project during the first twelve months. For the first nine months, they reported only delays and lack of progress due mainly to the lack of electronic components and equipment. It was not until the eleventh month that the minutes reported "... the prototype had been completed and tests in conjunction with the software were now in progress.". The same situation was reported in the twelfth month and the trials at the company were put back two months.

After twelve months work the project had failed to meet its first target of a trial at the company. The progress that had been made is best described by examining the four tasks. Task 1 was not complete but the hardware had been constructed and was under development. There was little or no progress with either Task 2 or Task 3, and Task 4 was in the same condition as Task 1 that is, not complete, but under development.

A further six months work was to result in a trial at the company but it was a complete failure.

3.2.3 During that same six month period the researcher from the University of Aston joined the company to study innovation in the small company. His involvement with the nametape system development is described in the next section.

3.2.4 <u>The Researcher's Involvement with the Nametape Project</u>

There were several innovative projects in progress when the researcher joined the company in October 1978, but it was the nametape project with which he became most deeply involved.

Before joining the company it had been decided that the researcher should concentrate on the problems of implementing a new system in a small company environment. With this in mind it was decided that the researcher would be involved with the production and installation of the twenty microcomputer based controllers. This approach assumed that the project would keep to schedule which in the event it did not.

What actually happened was that the researcher spent the first four months working in another area of the company while at the same time keeping in touch with the nametape development by weekly meetings with the consultants. During those first four months the researcher learnt a great deal about the techniques of weaving and also became familiar with the technical problems associated

3.2.4 with the nametape development. The next two months were spent working closely with consultant 1 on producing a firm design for the production version of the micro-computer based controller; there were also some early discussions with the sub-contractor who was to build the twenty production units. It should be remembered that at that time the prototype unit had still not had its trial run at the company.

The prototype controller was brought to the company for the first time eighteen months after the development had started. A trial proved impossible because, due to poor construction and inadequate testing, the prototype was very unreliable. During the preceeding six months, the researcher had only monitored the development of the prototype, but with the unit now on site he intervened as a graduate electronics engineer to try and make it work. Before describing the effect of that intervention, the progress related to each of the four tasks is examined eighteen months into the project. The prototype trial depended on tasks 1 and 4 being completed or at least in a working condition. Eighteen months of development work had failed to complete either task, and neither was in a working condition. Tasks 2 and 3 had been delayed due to illness and neither was in a working condition.

3.2.4 It was clear to all concerned that the project was behind schedule, even so the ILC seemed unable to improve the situation.

The researcher worked on the prototype unit full time for about two weeks, assisted occasionally by consultant 1. This effort resulted in a limited trial during which three nametape characters were successfully woven. This work by the researcher confirmed that the basic design philosophy was correct, however, it also confirmed that many of the difficulties were due to the poor design of the prototype unit. Based on these findings, the researcher recommended that work on the first production unit should be started immediately.

The production unit design had none of the shortcomings found on the prototype, however, there was an element of risk involved and because of this the consultant opposed the researcher's recommendation. The consultant insisted that the prototype unit should first be made to work properly, and then put into normal use for several months to confirm its reliability; when that was confirmed, only then should work begin on the production units.

The company considered the risks on one hand and the further delays on the other; the Managing Director was consulted and recommended that the researcher's

3.2.4 recommendation should be accepted. Following the decision to go ahead the consultant wrote a letter to the company in which he stated "...I consider this move premature since the prototype is still not fully proven. I cannot, therefore, accept responsibility for any costs or difficulties incurred due to changes which may have to be made. ...".

The researcher completed the wiring schedules for the production unit and within a week of the trial, work was started on the first unit, which was a cabinet containing four identical controllers. The sub-contractors estimated that it would take twelve weeks to produce the first unit and then two weeks each for the other four units. That estimate was taken as the basis for calculating the revised completion date by which time all the tasks had to be completed. Allowing five months to build all the cabinets and one month to install them at the company, gave a completion date of 1st December 1979 assuming there were no further delays.

One factor which, in the researcher's opinion, had had a detrimental effect on the development of the prototype unit was the total lack of test procedures, test programmes and specialised test equipment. Without such aids, the commissioning of the production units was going to present serious problems, particularly to a company

3.2.4 with such limited technical resources. This problem was overcome in two ways; firstly the researcher wrote out some test procedures and a specification for the test programme and designed a special piece of test equipment. Arrangements were then made with the sub-contractors, for the major commissioning work to be done by them using their resources and following the test procedures. The additional programmes, equipment and other arrangements added about 5% to the capital cost.

Moving away from the technical aspects for a moment, very little has been said of the end users reaction to the coming of the new controllers. The first area to examine is the effect of the delays during the technical development. The end users, in particular the Works Electrician and the Nametape Supervisor, were only given limited information as to project progress and were normally only made aware of the project when a company trial was approaching. There were a total of four cancelled trials and one unsuccessful trial over a period of eight months and this fact did little to give the end users confidence in the new system or the consultants. Quite simply trial dates and delivery dates were regarded as jokes. This attitude also had an effect on the way the end users viewed the researcher, initially he was seen as 'just another academic who will let us down'. This feeling of being let down was very real for the end users were only too

3.2.4 aware of the problems that the old, unreliable system was producing. They saw the arrival of the prototype unit as a glimmer of hope and interest in the new technology was considerable. It is probably true to say that the researcher spent almost as much time answering questions as he did on technical development. The limited trials raised hopes further and also improved the researcher's reputation, but a perfect trial was needed to convince them that the end was in sight.

The development work on the prototype continued after it was rebuilt to eliminate the major design faults and bring it closer to the production unit design. The re-building work was done at the company by the Works Electrician. After some minor changes to the hardware and the elimination of a software fault, the prototype ran perfectly and news of the perfect loom trial spread rapidly. That trial was achieved within the twelve weeks it took to build the first production unit, so when the commissioning work started most people were, for the first time, optimistic.

It took a total of two weeks to commission the first unit, using the test procedures, and all the work was done at the sub-contractors; the researcher supervised all the commissioning work. The unit was then moved to the company for its first trial which was arranged

3.2.4 for a Saturday afternoon so as not to disrupt production. In preparation for the trial some progress had been made with Task 2 and the data for over one hundred nametape characters was available on PROM. The trial only lasted for two hours because it was a total success. At the first attempt, all four controllers within the production unit, controlled the looms and all the available nametape characters were woven without fault. That trial proved to be the turning point in the project because it was now clear to all that the new system was on its way; the risk that the company had taken had paid off.

Although the first production unit trial was successful, the project was still far from complete, that trial in fact only completed Task 1. Task 2 had made some progress and with one complete character style on PROM could be described as 25% complete. Task 3 was making progress but at that time, the amended programme had still not produced any tape of the correct format. Task 4 was making progress, although it tended to be rather slow because of the method of testing the programmes. It was stated in 3.2.1 that Task 4 was the most demanding of all the tasks, however, it was made more difficult because of the manner in which it was attempted. The ILC claimed to have at their disposal all the necessary resources to carry out a project of this nature.

3.2.4 However, it transpired that the facilities available for developing a microcomputer programme were in fact very limited. They were able to write the programme and assemble it, but they had no simulation or emulation facilities to test the result. Because of this shortcoming, all programmes were delivered to the company untested and containing many errors. The only way of finding the errors was to run the programme on the controller and note all the operating faults. These faults then had to be traced by stepping through the programme line by line using a 'Monitor' programme to find out where it went wrong. When the errors were located the programme was edited back at the ILC and reassembled. This process was very time consuming and made even worse by the fact that the programmes were delivered without documentation. It was found that consultant 3 simply did not have sufficient spare time to test the programmes within a reasonable time scale, so much of this work was done by the researcher in order to complete Task 4 by the December 1st deadline. The involvement of the researcher in both the hardware and the software development had one very important side effect apart from getting the work done. The researcher became familiar with all the technical details and software techniques that were used in the new nametape system, and because of this the company found that they were able to alter the system without having to send for the consultants.

3.2.4 Task 2 was also completed by the deadline; however transferring all the existing data into PROM was only part of the problem. The company wished to add further characters to the existing four styles for reasons of commonality and also to introduce a completely new upper and lower case style. A method had to be devised to accomplish this and the researcher came up with the following system. The necessary work was to be done by the Nametape Supervisor who already had experience of reading a textile draft and putting the information onto paper tape. The conversion work for the microcomputer system was slightly different in that the weaving data had to be expressed in hexadecimal numbers and then programmed into PROM. The Supervisor was taught how to convert the weaving data on the draft into hexadecimal numbers, and she wrote them down on a specially designed coding sheet. The completed coding sheet was given to a skilled punch operator who punched the numbers onto paper tape. The Supervisor then fed the tape through the PROM Programmer's tape reader and programmed the PROM. Using this method over two hundred extra characters were added to the existing four styles. An example of a textile draft and the hexadecimal conversion on the coding sheet is given in Appendix C.

By December 1st, 1979 all the controllers had been tested and delivered, all the character styles were

3.2.4 available on PROM, and the controller programme was complete, only Task 3 was still outstanding. It was early December before the amended programme in the mainframe computer produced its first piece of tape of the correct format, and a further months work was necessary before the amended suite of programmes was released for normal use. While this work was going on the new controllers were soak tested for about four days each. Plate 3.1 shows the front and rear views of a cabinet containing four loom controllers.

The new nametape system was eventually implemented on January 21st 1980 and the new controllers performed reliably from the start, the mainframe computer programme however had not been adequately tested and it was several months before all the errors were corrected. Exactly how the new system performed is described in the next section.

3.3 The Effects of Implementing the new Nametape System

These effects are examined from the points of view of system performance, the end users and the customers.

3.3.1 The Effects on System Performance

The major aim of developing a new nametape system was to reduce the consumption of paper tape, which would in turn, improve the reliability of the system.

3.3.1 This aim was achieved, for a name that would have consumed five metres of tape using the old system only required five centimetres of tape using the new. This reduction of tape consumption also significantly reduced the computer time needed to process and punch the name orders. For example, to process a batch of 2000 nametape orders using the old system used to take most of one day, with the new system this was reduced to less than one hour.

The combination of the reduced amount of paper tape and the reliability of the new controller did produce a more reliable system. This is best illustrated by comparing the percentage of remakes for the year before the new system with those after. Figure 3.3 shows the numbers of orders received for thirteen four week periods for both 1979 and 1980 and the corresponding numbers of remakes. The percentage of remakes within each four week period is also shown and an average calculated for each year. These calculations show that by implementing the new nametape system, the average percentage of remakes was reduced from 4.8% to 2.0%.

A remake was produced for one of three reasons, the order was lost in the post, the order was made in the wrong style or colour, or an error was made during manufacture.

	1979			1980		
4 Week Period	No. of Orders	No. of Remakes	% Remakes	No. of Orders	No. of Remakes	% Remakes
1	23161	411	1.7	23144	1397	6
2	17815	619	3.5	21872	753	3.4
3	19982	620	3.1	19463	578	2.9
4	21243	645	3.0	21338	452	2.1
5	26316	788	3.0	26105	670	2.5
6	22058	1160	5.2	26831	475	1.7
7	44894	2164	4.8	39851	448	1.1
8	58080	2616	4.5	64355	684	1.1
9	52375	2575	4.9	50977	817	1.6
10	34430	1635	4.8	40842	792	1.9
11	19333	2716	14.0	24735	486	2.0
12	23573	1422	6.0	22483	366	1.6
13	12707	753	5.9	16047	278	1.7
	Total 374967	Total 18124	Average 4.8	Total 398023	Total 8196	Average 2.0

Figure 3.3 Volume of Nametape Orders and Remakes for 1979 and 1980 (January to January)

3.3.1 During 1980 the first reason accounted for 50% of the remakes, the second for 30% and the third for 20%, any technical failures appearing under the third reason. From the above figures it can be seen that in 1980 technical failures accounted for only 0.4% of the remakes.

The new system also allowed remakes to be dealt with more quickly because it was no longer necessary to send them back to the mainframe computer to be processed again. Instead the Nametape Supervisor was able to manually prepare the short pieces of tape and put them on the controllers at the first available opportunity. This allowed the company to deliver nametapes to the customer within twenty-four hours of receiving a complaint.

The new system greatly improved the flexibility of the nametape operation because of the comparative ease with which the characters could be changed by reprogramming the PROM's. An important feature of this capability was that all alteration and addition could be done by the company without reference to the consultants.

During the first two months of the system's operation, the company designed, converted and installed a further three nametape styles into PROM. This enabled the company to launch two new products, and further controllers

3.3.1 were required, from the sub-contractors, to produce them. All this work was done without reference to the consultants and with a minimum of supervision from the researcher. This demonstrated that the company could exploit the new technology while remaining essentially independent of the technical experts.

3.3.2 <u>The Effects on the End Users</u>

It is clear from the above that the new system was a technical success, but how did the improved performance effect the end users and what was their reaction to it?

The person most affected by the implementation of the new system was the Nametape Supervisor. The new controllers made her job easier because they required less attention, but at the same time a new dimension was added because of her involvement with the programming of the PROMS. The combined effect of the two changes made her job more rewarding without being more demanding, with the result that she was happy to work with the new technology. She accepted the new controllers as hers and would apply pressure to the other departments to keep them all operating; she even placed vases of plastic flowers on top of each cabinet to improve their appearance and decorated them at Christmas.

The nametape weavers were indirectly affected by the new system, because the increased reliability of the controllers

3.3.2 meant that the looms ran longer and produced less bad work. The positive effect of this was to increase the amount of work each loom produced which gave the weavers a corresponding increase in bonus payments. It also had another unexpected effect. The frequent breakdowns with the old system resulted in the weavers spending a fair proportion of their day in the Supervisor's office reporting and describing the fault and keeping up with company gossip. The new system all but removed the need to visit the Supervisor's office and as a consequence, the weavers became visibly bored during the first few weeks that the new system was in operation. Fortunately, the weavers quickly adapted to the situation and it wasn't long before they had all found out how to operate the controllers for themselves. Once that happened, the weaver was able to immediately correct any faulty nametapes simply by resetting the controller to weave the name again. The overall reaction to the new system was very favourable, and much of that reaction must have been due to the fact that the system performed so well.

3.3.3 The Effect on Sales and the Customers

The new system was a technical success, and it was liked by the end users but was it better from the customer's point of view?

3.3.3 A nametape is usually a last minute purchase, so delivery time is very important. The majority of customers place their orders shortly before the beginning of the autumn school term, and this results in a glut of orders between June and September, the company refer to this as the 'busy season'. During the busy season the company is producing over fifteen thousand nametape orders per week, and to meet this demand the nametape department operates twenty-four hours a day, five and a half days a week. Delivery during this period was normally quoted as four to six weeks, but during 1979 some customers were having to wait eight to twelve weeks which, for a last minute purchase, was quite unacceptable.

By reducing the number of remakes, the new system effectively gave the nametape department an increase in production capacity and this had a corresponding effect on the company's ability to deliver during the busy season. Although the volume of orders increased by approximately 6% (see Fig. 3.3) from 1979 to 1980, the company was able to give a ten day delivery service throughout the busy season and still have capacity to spare. This service was much appreciated by the customers and for the first time, the company received letters of thanks praising the quick and efficient service. It was thought that the improved delivery brought about the increase in volume which in turn

3.3.3 meant that the nametape department exceeded its sales budget by £38,500.

3.4 Conclusions

In its first year of operation the new system exceeded most expectations and helped the company through a difficult period, for of all the departments only nametapes showed an increase in volume between 1979 and 1980. This view was supported by the Managing Director in a memo concerning holiday arrangements in which she stated that "... from June to early October the profitable nametape business is at its height and we simply cannot afford to jeopardize that business which this year (1980) has been so successful and has played a vital part in keeping the Company going."

With all the advantages of the new system it was a pity that its implementation was delayed by eight months.

PLATE 3.1

Front and rear views of the microcomputer
based Nametape Loom Controller (4 Loom Version)

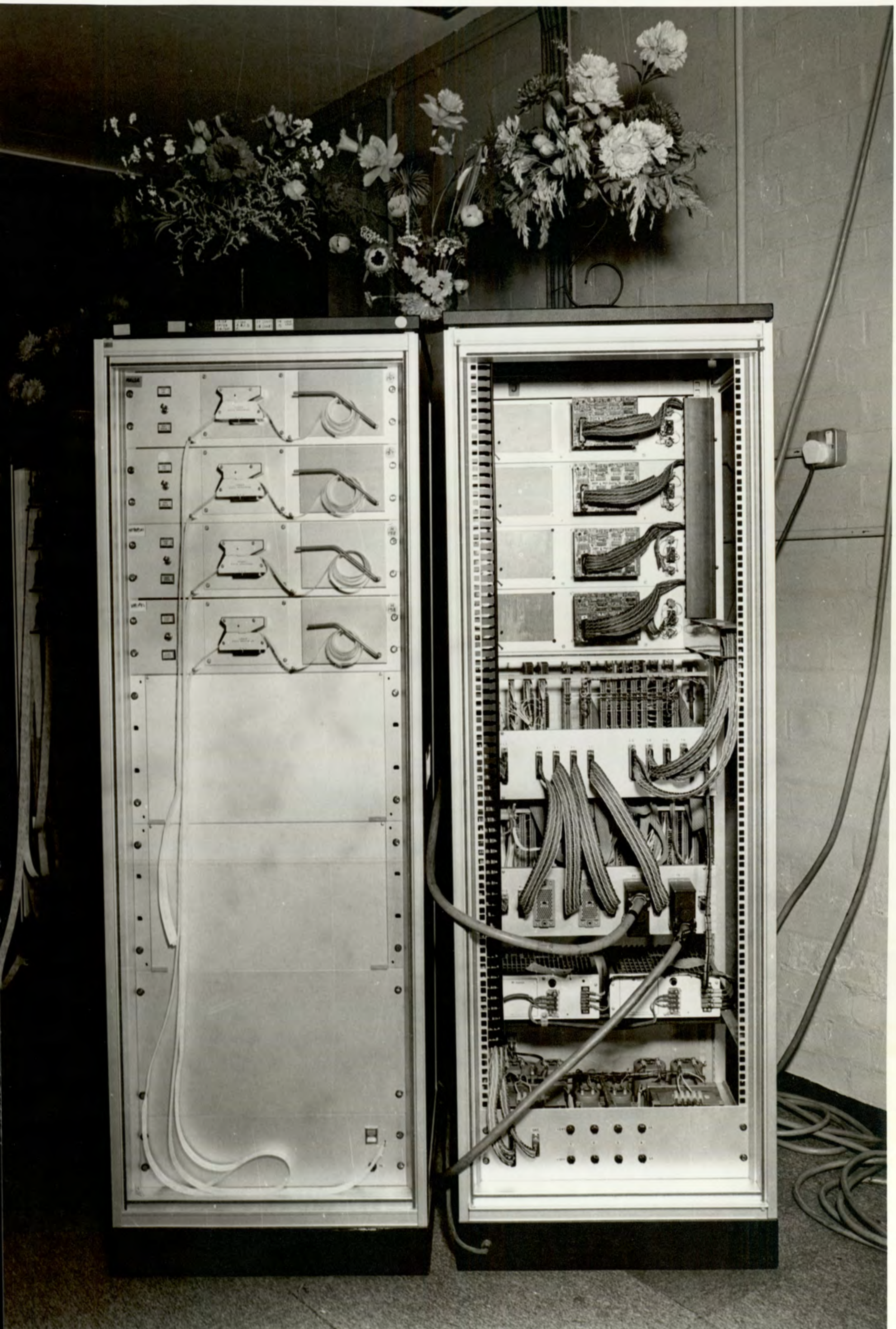
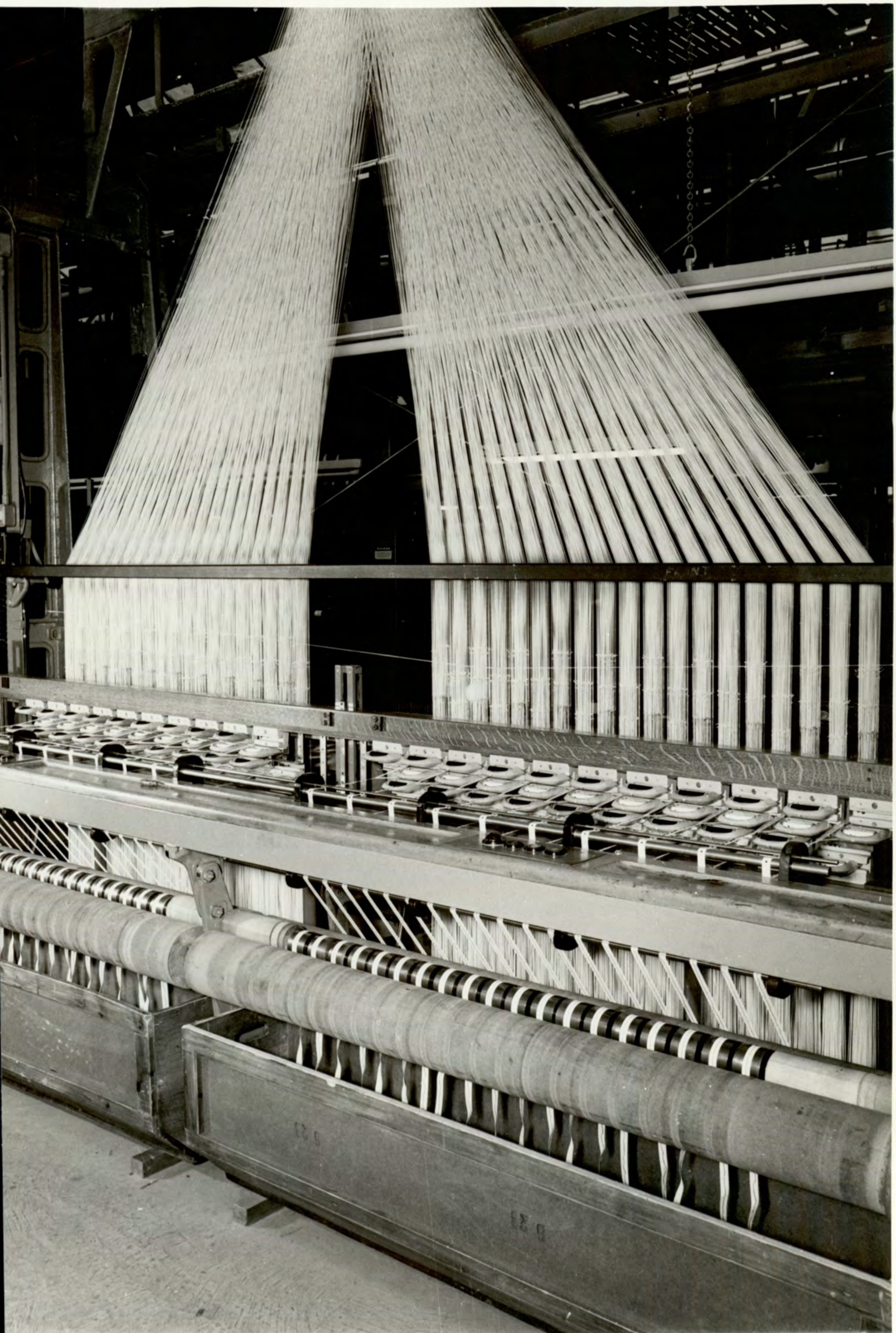


PLATE 3.2

A 38 space Jacquard shuttle loom
used for weaving nametapes



CHAPTER 4

Introducing Microcomputers into Luggage Strap Weaving

4.0 Introduction

The case study described in this chapter shows how a small company approached the problem of introducing a new technology into a production process. This case was carried out shortly after the successful implementation of the microcomputer based nametape system (see Chapter 3) and had a great deal in common with that development. The nametape development had one flaw, the system was implemented eight months late. The intention of the luggage strap project was to develop and implement a similar system, in the same small company environment, and to do so to an agreed schedule. The researcher was very fortunate in that he was involved with the project from the start and was able to plan it such that the shortcomings of the nametape project were avoided. The nametape system had taken twenty-six months to develop and implement, the researcher allowed just four months for the luggage strap project. The study is divided into three sections. The first describes the background to luggage strap weaving and the methods used before microcomputers were introduced. The second section describes the development and implementation of the microcomputer system and the involvement of the researcher.

4.0 The final section examines the performance of the system, the end users reactions to it and the market response to the new product.

4.1 Background

The luggage strap was made in the ribbon department, ribbon being the company's oldest product dating back to the mid nineteenth century when the company was founded. Changing fashions had reduced the demand for ribbon over the years and when the company replaced the ribbon looms in 1978, they purchased two looms that were able to weave webbing as well as ribbon. The new looms were capable of weaving 32mm nylon webbing and the weaving pattern was controlled by a photoelectric system which read up to twenty punched holes in a continuous paper loop.

The idea for a nylon luggage strap came from the Technical Director but he took the idea one stage further. He devised a weaving structure that, when used in conjunction with the punched holes in the paper loop, produced a strap with a design showing on one side only. This idea was developed and a luggage strap with the word 'Bagstrapper' woven into it was marketed by the company. These were offered in a choice of four colours which was possible because the company had its own dyehouse on site. This facility also allowed the company to prepare sample straps for airlines and travel companies incorporating their logos in the correct colours.

4.1 To produce a bespoke strap involved designing the lettering or logo on point paper and then reading the design and manually punching the necessary holes in the continuous paper loop. Allowing for corrections, this took about one day and to recover the cost of this effort, a minimum order quantity of one thousand straps was usually quoted. This quantity deterred a good many customers and the company began to look for ways of reducing the design effort needed for each order. The ultimate aim was to offer a quantity of one or two to each customer, each order being to the customer's requirements. From this train of thought came the idea for the personalised luggage strap, with each order having the customer's name woven into it. This was a concept that the company was familiar with for its nametape business was capable of processing half a million individual orders each year. They were confident that if an automated system could be applied to the luggage strap loom, then a large market could be generated for individual personalised luggage straps.

The company was in no position to attempt such a development as it had no in-house expertise in the field of automation. An approach was made to an external company and they produced a proposal for a very complex system for controlling the luggage strap loom; the cost of the system was £35,000.

4.1 That proposal was made early in 1979 and the discussions continued until August 1979 when it was concluded that the external company could not supply an acceptable system at a reasonable cost. The researcher had been involved with most of the discussions mentioned above and soon after they had reached the unsuccessful conclusion an alternative approach was suggested. This was for the researcher to apply his knowledge of the nametape system to the technical problem of the luggage strap system. This approach was adopted and is described in the next section.

4.2 Developing the Personalised Luggage Strap (PLS) System

The personalised luggage strap (PLS) was a new product, and because of this the PLS project involved both product development and process development. In this respect, the project was different from the nametape development where only process development was needed to produce the same product for a well known market. Because of the new product aspect, the commercial risks were greater and it was mainly the enthusiasm of the Managing Director that allowed the project to proceed. Unfortunately, he was to be removed from the position of Managing Director before the development was completed and this undoubtedly had a detrimental effect on the project which will be mentioned later.

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4.2 Serious discussions regarding the development started in April 1980 and by the end of April the researcher had produced a written proposal which outlined the technical details and a six step plan for the development with estimated times, costs and resources required for each step.

That proposal (see Appendix D) was intended as a basis for further discussions, however, it was taken before a Board meeting before the end of April and steps one and two were approved. That allowed the development to proceed to loom trials, and the estimated cost and time for the two steps was a total of £200 and six weeks. The technical problems that had to be solved are described in the next section.

4.2.1 <u>The Technical Problem</u>

The main aim of the technical development was to make it possible to produce one-off luggage straps at a reasonable cost. To achieve this aim it was intended to apply the highly automated nametape system to the manufacture of luggage straps.

The nametape system had two major components, the first being a computerised order processing system, and the second an automatic control system for the weaving process.

4.2.1 The link between the two halves was in the form of a small reel of paper tape which had punched in it details of the customers orders. It was proposed to use the same major system components for the PLS project and in this way reduce the technical problems to making changes to existing hardware and software. A block diagram of the PLS system is shown in Figure 4.1.

Taking the two major components of the nametape system, four changes had to be made to produce the PLS system. The first change was to amend the suite of programmes used in the mainframe computer so that they related to luggage straps rather than nametapes. The main function of sorting orders by colour and punching tape were still required but the colours, batch sizes and order validation tables were all different for PLS. At first it was thought that these changes would be fairly minor, but as the project progressed it was found necessary to introduce extra functions to deal with logos and strap layout.

The other three changes all related to the microcomputer based controller and a block diagram of the PLS version is shown in Figure 4.2.

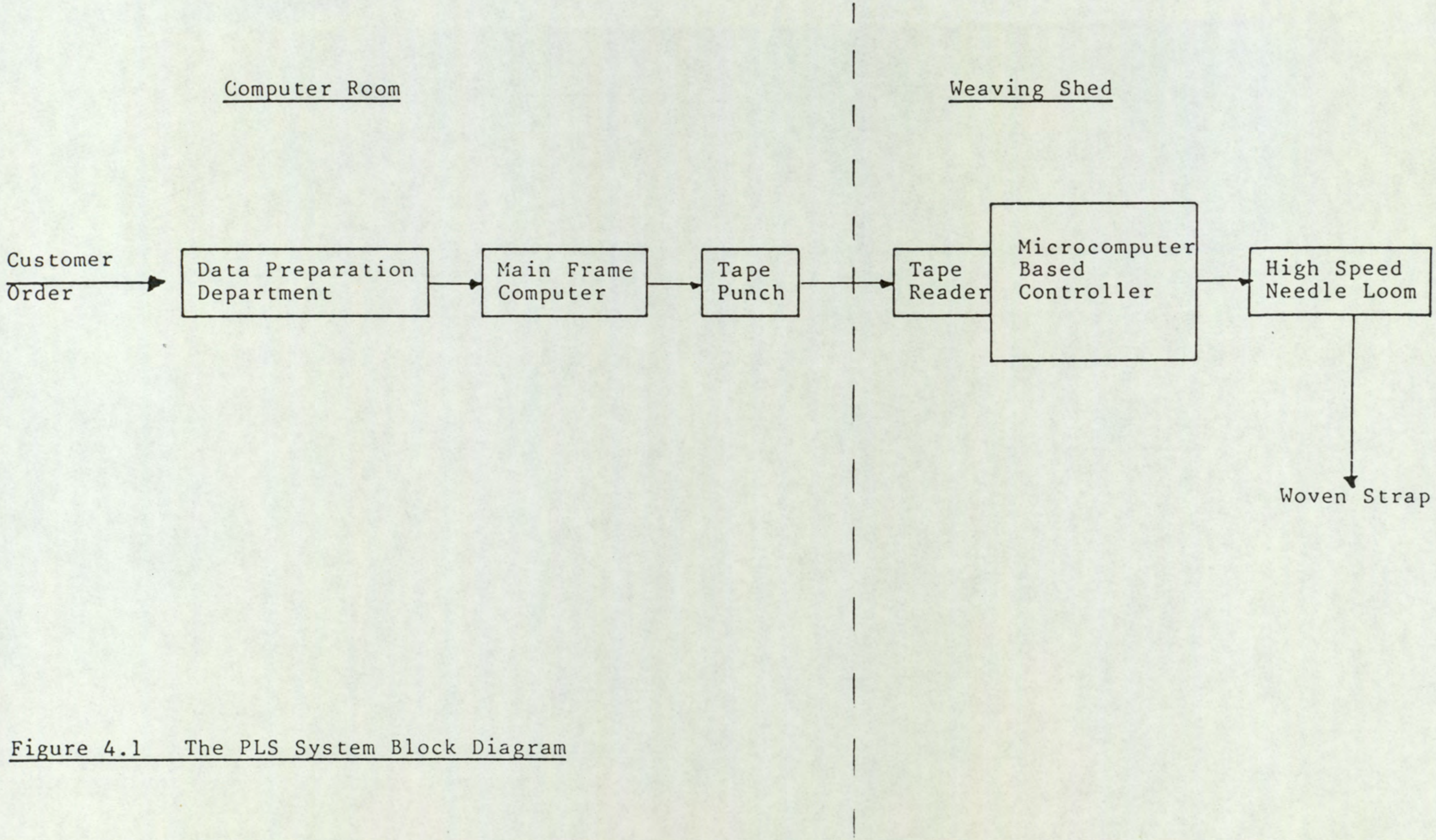


Figure 4.1 The PLS System Block Diagram

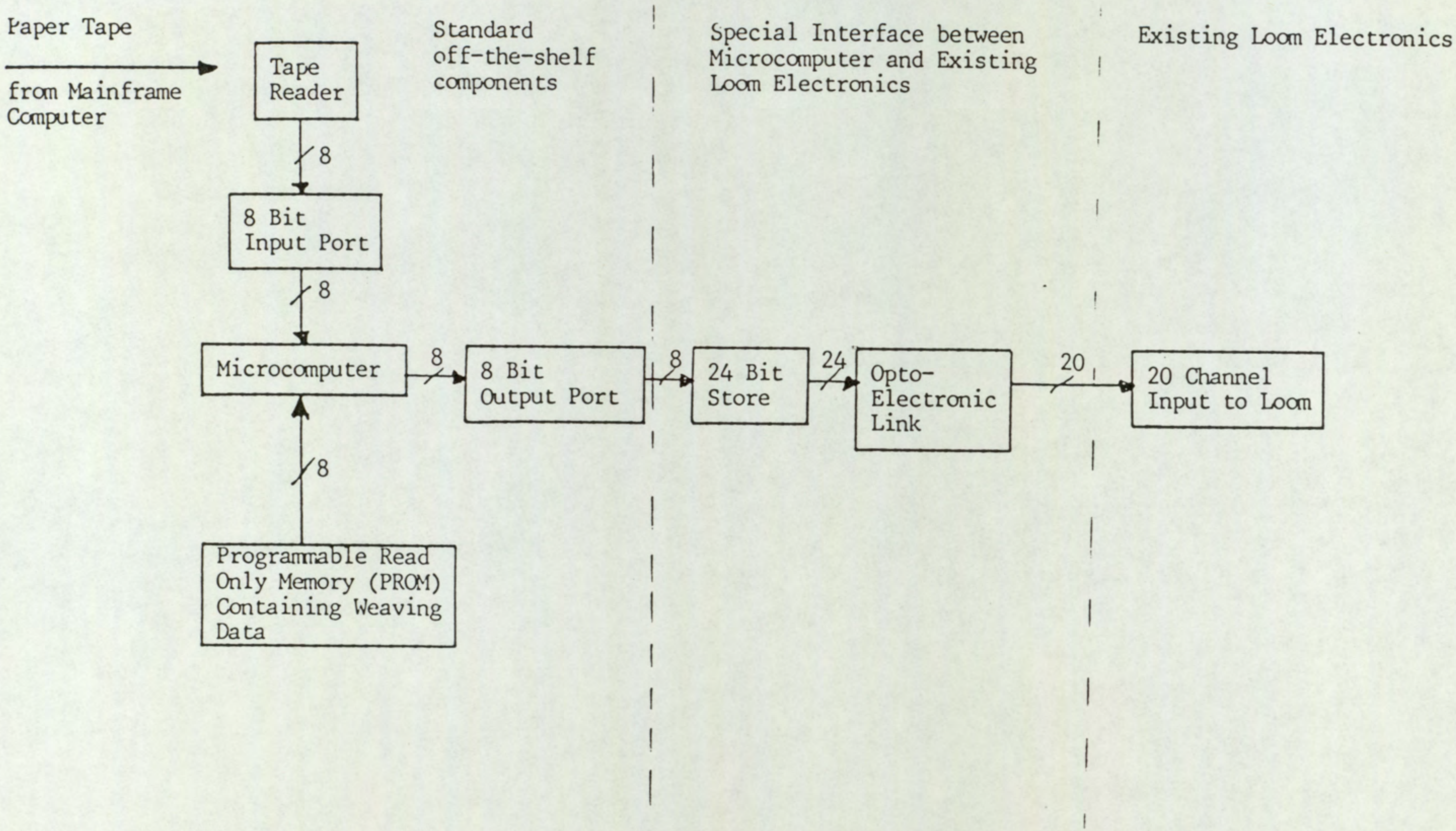


Figure 4.2 The Block Diagram of the Microcomputer based Controller (PLS)

4.2.1 Two of the changes concerned the microcomputer software; one was to amend the control programme for the different type of loom and weaving data and the other to replace the weaving data itself. The remaining change involved redesigning the interface between the microcomputer and the loom electronics to suit the circuits on the luggage strap loom. In order to connect the interface an additional plug and a mainshaft timing device also had to be fitted to the loom. Details of these changes were included in the proposal which is reproduced in Appendix D.

The above changes can be expressed in terms of four tasks which compare with the four tasks described in the nametape development in Chapter 3.

Task 1 - To design, build and test the interface between the microcomputer and the loom electronics.

Task 2 - To design and programme into PROM the weaving data for producing lettering on the luggage strap.

Task 3 - To amend the existing programme in the mainframe computer to deal with luggage strap orders.

Task 4 - To amend the control programme for the different type of loom and weaving data.

4.2.1 Task 1 involved a completely new design and was constructed from about thirty components on a single card. To make wiring changes easier, all electrical connections were wire-wrapped. All connections to the loom were via a single 37 way plug.

Task 2 involved new designs for the lettering, but the method of installing weaving data into PROM was only a variation of the method developed for the nametape system. An example of a PLS letter design and the resulting hexadecimal conversion is given in Appendix F.

Task 3 was missing from the written proposal in any detail and the PLS project was over half way before it was decided exactly what changes were necessary to successfully process, by computer, the full range of orders.

Two additional functions had to be added to make sure that the finished strap was always the same length, regardless of the length of the customer's name, and that the layout of the strap was adjusted to produce a visually pleasing product. This was an essential addition to the mainframe programme because the alternative was for each strap to be manually laid out, the calculations for which took in the region of ten minutes per strap. An example of these calculations is reproduced at the end of Appendix E.

4.2.1 Task 4 involved amending an existing microcomputer programme, and the changes were not major, however, this task was made more difficult because the company did not possess a microcomputer development system. Most of the development work was done by re-programming the programme PROM's using the change facility on the PROM programmer, this proved reasonably effective though rather slow and tedious. The final programme was produced by using a microcomputer development system at Aston University.

The above four tasks all had to be successfully completed in order to solve the technical problem, the remaining task was to build, and install at the company, a production version of the loom controller which would be equipped to control both luggage strap looms. The approach to the tasks is described in the next section.

4.2.2 <u>The Company's Approach to the Technical Problems</u>

In the past the company had relied on external companies and consultants to solve its technical problems, and in many ways the approach to the PLS project was similar. The researcher was the external expert brought in to solve the problem and behind him were the resources of the University of Aston; the important difference was that the researcher was based at the company and, as a temporary employee, was acting on the company's behalf.

4.2.2 The company's approach to the technical problem could perhaps be more accurately described as the researcher's approach because it was he who planned the project, controlled the project, and did the majority of the technical work including the system design. Reference has already been made to the project proposal that was produced by the researcher and included a six step plan to complete the project in seventeen weeks. That plan is summarised below:

Step 1 - Confirm feasibility of opto-electronic link between loom and loom controller and check loom operation and timing.

Step 2 - Build interface card, build interface card test box and test both. Modify major software routine and check against interface card. Install characters and check output on test box, convert one loom for automatic operation and repeat all tests at the loom. Weaving trials at the loom.

Step 3 - Install new software routines into main programme, install a complete character font, and continue loom trials.

Step 4 - Initiate construction of production unit, this should run in parallel with Step 3.

Step 5 - Production unit testing and commissioning and further loom trials.

4.2.2 Step 6 - System in operation.

The timing of these steps was as follows:

Step 1 - Week 1 to Week 2

Step 2 - Week 3 to Week 6

Step 3 - Week 7 to Week 10 extended to Week 13 if necessary

Step 4 - Week 7 to Week 14

Step 5 - Week 14 to Week 17

Step 6 - Week 17 onwards

The thinking behind this plan was based on the researcher's experience of the nametape development and was aimed at removing the shortcomings of that development. In the researcher's opinion, the two most serious shortcomings were the failure to meet the first target of a loom trial after twelve months work, and the failure of the loom trial due to poor construction and inadequate testing. It was felt that the major reason for both these failures was the fact that the development was done away from the company and the loom.

The aim of Steps 1 and 2 was to produce results quickly rather than waiting eighteen months only to find that the design was incorrect as happened with the nametape development. It is interesting to note that the nametape interface and the PLS interface did in fact contain the same number of components.

4.2.2 Step 1 was at the loom, checking its operation and carrying out very simple tests to confirm that it could be controlled in the manner intended. Step 1 was also the time to make initial contact with the end users of the new system, to ensure that they were aware of what was happening and were involved from the very start.

Step 2 was the most important part of the project for if the weaving trials did not take place as planned, the whole project could be reviewed and if necessary abandoned before any major investment was made. Much of Step 2 was construction and testing work, and to complete this in the time allowed required not only delegation of work, but also careful design to ensure that both construction and testing were straightforward. Step 2 included the construction of a test unit which was used to simulate the loom and make testing more efficient. Step 2 was made easier because, being based on the nametape controller, the PLS controller used a nametape controller as its basis. This removed the need to construct a prototype rack to hold the tape reader, power supplies and microcomputer. This affected the design thinking and resulted in a single design for both the prototype and the production unit. This compares with two different designs in the case of the nametape development.

4.2.2 Steps 3 and 4 were based on the nametape development, where software development and further weaving trials were run in parallel with the construction of the production unit. The software development included the installation of a font of characters which would allow sample straps to be produced for the sales department.

Step 5 allowed four weeks to install and commission the production unit and this was to include the final conversion of both looms for microcomputer control and generally tidying up the installation. Step 5 overlapped Step 6 by one week to serve as a formal handing over period.

To carry out the plan of work above required resources and those came from a variety of sources. Within the company, the people most involved were the Technical Director who provided the textile knowledge, the researcher, the Electronics Engineer, the Electrical Engineer and the Computer Manager and Operator. The woven character alphabets were produced in the company's Design Room and were processed by the Data Preparation department. The ILC of the local Polytechnic provided some electronic test equipment and the consultant responsible for the nametape mainframe computer programmes advised the researcher on several occasions.

4.2.2 The University of Aston provided access to a microcomputer development system and the sub-contractor who worked on the nametape system also constructed the PLS controller production unit.

The six step plan described above only allowed for the expected, it made no allowance for the extra effort needed to complete Task 3 for example; this being the case how did it perform in practice? The next section describes how each task was completed against the background of the six step plan.

4.2.3 <u>An Account of the PLS Project</u>

The company initially authorised the expenditure of £200 on the PLS project which covered the first six weeks of development up to the point of loom trials. To achieve a loom trial in six weeks required task 1 to be complete and task 4 to be well advanced, also at least one character from task 2 needed to be available.

The project made good progress during the first few weeks with Step 1 being completed in the first week and the major construction work of Step 2 being completed by week 3. The various components were tested during week 4 and on the last day of week 4 a loom trial was attempted. At the very first attempt the loom was successfully controlled by the microcomputer and produced perfect weaving for about ten hours before being switched off.

4.2.3 Having proved the principle of operation, the wiring schedule was prepared for the production unit controller and sent to the sub-contractors to obtain a firm quotation. This was received during week 7 and confirmed that the cost of the controller, excluding tape reader, power supplies and microcomputer was just under £2,000; this agreed with the researcher's estimate as did the delivery of six to eight weeks.

While that quotation was being prepared, further weaving trials had been carried out on the second luggage strap loom, and it was found necessary to make a slight change to the controller design to ensure that it performed reliably on both looms. The later trials produced two woven characters because further progress had been made with the software development of Task 4.

Although the project was making good progress, the company seemed reluctant to agree to either the major capital expenditure or to having a character font designed which were what Steps 3 and 4 entailed. In order to get a quick decision on the capital expenditure, the amount requested was reduced by £2,000 so that the local Board could approve the expenditure. This saving was achieved by equipping the production unit to operate one loom instead of two and by utilising costly components that were held as spares for the nametape system.

4.2.3 This was not an ideal solution but it did result in the capital expenditure for the remainder of the PLS project being approved in Week 9, this being two weeks later than planned. The sub-contractor was instructed to proceed immediately with the construction of the production unit. To compensate for the delay, the final conversion of both looms was brought forward and completed during week 9. From week 8 onwards, the sales department started asking for samples of the PLS, these could not be supplied because the Technical Director was waiting for a recommendation from Marketing as to the style of lettering to be offered. That recommendation never came so the Technical Director made his own decision and twelve letters were designed and installed in the PLS controller for trial purposes. By the end of week 10 the controller was running reliably with all functions available and producing woven samples of the PLS.

The first few samples confirmed that if the product was to be visually pleasing then the layout of the strap had to change depending on the length of the name. For example, if only two initials were required then these could be repeated eight times along the length of the strap, however, an eighteen letter name could only be repeated four times. It was decided that the mainframe computer was the best place for such calculations and that they should be added to the tape punching programme.

4.2.3 This presented two problems; first this was not included in the six step plan, and second, the tape punching programme was written in ICL PLAN which no-one at the company understood. If the consultant responsible was asked to amend the programmes, the project would almost certainly be delayed.

By chance the consultant came into the company and his advice was sought as to the best way of introducing the extra calculations into the existing programme. He was extremely helpful and suggested a method that did not disturb the majority of the programme. The researcher although not familiar with ICL PLAN spent the next one and a half weeks trying to amend the programme, with some success, but progress was slow because he could only make one amendment per day due to computer loading. This limitation was overcome by the researcher learning how to operate the computer himself and running it for sixteen hours over the weekend. The weekend's work produced three reels of paper tape that were woven out to confirm that the variable strap layout calculations were correct and producing a strap of a fixed length regardless of the length of the name.

That brought the project into week 13 when progress was reviewed at the first formal lettered strapping meeting. A short report prepared by the researcher for that meeting gives an indication of the progress achieved and is

4.2.3 reproduced in Appendix E. Several decisions came from that meeting, the most important of which, from the technical point of view, being the acceptance of the two lettering styles suggested by the Technical Director. That acceptance allowed design work on the characters to begin, but even so that work was started six weeks later than planned. The other important decision was to allow the Sales Manager to offer the PLS to a mail order catalogue in time for the Christmas issue. Although that decision was made in July it would be February of the next year before any orders were received.

In terms of tasks completed, the first thirteen weeks work had produced mainly success with only one major task outstanding. Every possible aspect of task 1 was completed by week 10, and the interface had been running reliably from week 7. Task 4 was completed by week 13 although the programme was only available in a 'patched' form. Work to obtain a clean copy of the programme started during week 15 at the University of Aston. Task 3 was also completed by week 13 except for the character validation tables which were not available because of the delay in starting task 4. Task 4 was the only major task outstanding and that situation occurred simply because the decision to start Task 4 was delayed by six weeks. This delay was not for technical reasons, but because marketing

4.2.3 were unable to suggest styles of lettering that would be acceptable to the customers; the lettering styles were eventually specified by the Technical Director. The work on task 4 and the remaining part of task 3 began in week 14 and were completed by the middle of week 17. The method used to complete task 4 was the same as that used for installing nametape weaving data into PROM but with a new design of coding sheet (see Appendix F). To reduce the time spent on task 4 to a minimum, the researcher did all the hexadecimal conversion work, installed the data into PROM and made the corrections.

The sub-contractors completed the production unit controller six weeks after receiving the order and it worked perfectly; it was delivered to the company during week 16.

By week 17, the suite of programmes was available on the mainframe computer and the production unit controller was fully equipped with two complete fonts of characters.

A full system test was done to confirm that all characters could be processed through the computer and woven on the loom, and this was successfully completed during week 17.

The test confirmed that task 1 to 4 were complete and that steps 1 to 5 were complete.

4.2.3 The planned completion date for step 5 was week 17, and despite the various delays, step 5 was in fact completed during week 17, in other words the project was completed on schedule.

Plate 4.1 shows the PLS loom and the loom controller.

Although the system was available on time, it was to lie idle for nearly six months while the company decided how to market the new product. An enquiry from Germany for 10,000 straps prompted the company to equip the loom controller cabinet for two looms instead of only one. The basic design allowed for two looms but only one interface card was fitted originally in order to save money. The conversion to two loom operation took two weeks and cost £200. The German enquiry was not translated into a firm order, however, about twelve months after the system was completed, sufficient orders had been received to keep one loom running to capacity. The events leading up to that are described in the next section.

4.3 Operating the PLS System

This section examines the performance of the system, the end users reaction to it, and the market response to the PLS during the first twelve months of operation.

4.3.1 System Performance

The system proved to be very reliable and sufficiently flexible to deal with a wide variety of customer requests without being modified. During the first six months the system was idle for much of the time, only being used to produce complimentary PLS's for the PLS project team and the occasional sample for a potential customer. That situation remained until February 1981 when orders began to arrive from the mail order catalogue. However, these only amounted to about fifty per week which was less than one tenth of the capacity of the system with one loom operating on two shifts. The estimated capacity of the system was 400 orders/shift/loom/week. The system came under pressure towards the end of 1981 when the order intake increased to around 800 per week. This necessitated processing orders through the mainframe computer every day, and running the loom controller and one loom continuously for sixteen hours per day. The controller was normally left running twenty four hours a day, seven days a week. The system continued to prove to be reliable with only the mechanical parts of the loom showing any signs of strain. In conclusion, the system performed as it was intended and did not need any modifications during the first twelve months of operation.

4.3.2 The End-Users Response to the System

The PLS system represented the first attempt at introducing automation into the ribbon department. However, the response was favourable and it is believed that this was due, at least in part, to the fact that the development work was done on the shop floor with the involvement of the end users. There was never any difficulty in persuading the end users to operate the system, in fact it proved impossible to stop the weavers from operating it themselves.

There was one notable difference between the nametape system users and the PLS system users. The nametape system was normally operated by one person and as such it became very much 'her system'. This situation did not occur with the PLS system simply because the ribbon department operated on a two shift basis and two groups of people operated the system rather than one individual. The end users reaction can best be summed up by saying that they were interested and pleased to see a new product being made in the ribbon department, the fact that this involved a new technology was not seen as a threat but as a sign that the company was looking to the future.

4.3.3 The Market Response to the PLS

The PLS was initially sold through a mail order catalogue, 4.3.3 but the response was limited with only fifty orders per week being received by the company. A 2000 letter mailshot to travel agents, luggage shops and sports shops produced over a hundred new accounts but very few orders. The product was then offered to the company's nametape retailers but that also produced only a limited response. A far more successful approach was Direct Response Advertising in the Sunday newspapers which produced over a thousand orders from each advertisement. This was backed up by putting the product into further mail order catalogues and the company is now reasonably confident that it can maintain a reasonable level of sales. The sales growth was slow and was linked to the promotional effort that the company devoted to the product. It is possible that this effort might have been very different if the Managing Director, who was a major proponent of the PLS, had not been removed from his position half way through the PLS project.

4.4 Conclusions

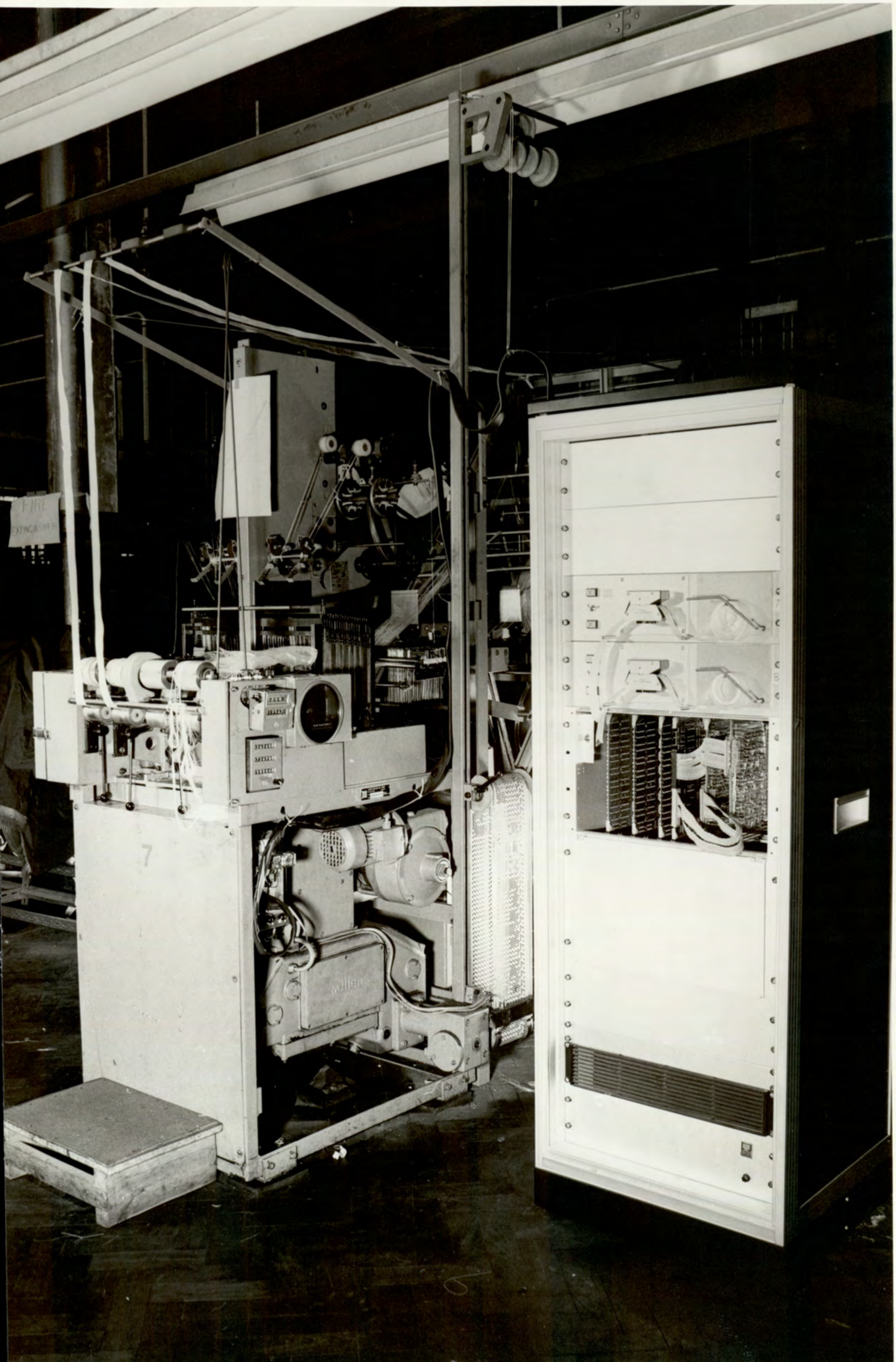
The PLS project demonstrated that microcomputers could be introduced into luggage strap weaving relatively easily if the technical approach was correct. It also indicated some of the problems of getting a new product into the market place. If the order levels can be maintained then the PLS system will make a significant contribution to the ribbon department's income.

PLATE 4.1

The P.L.S. needle loom and the

microcomputer based P.L.S. Loom Controller

(2 loom version)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CHAPTER 5

Analysis of the Case Studies

5.0 Introduction

This analysis is not concerned with the technical performance of the two systems described in Chapters 3 and 4, it deals solely with the manner in which the technical problems were approached and solved and as such is mainly concerned with the innovation management. This is not to say that the technical aspects can be ignored, in fact, it will be shown that effective project management depends to a great extent on the level of the manager's technical knowledge.

The analysis is presented in three parts. The first part examines the various stages of the nametape system development and from them compiles a list of factors that appeared to have an advantageous effect on the project outcome.

The second part examines the factors from the first part and develops what would seem to be a preferred, and at the same time, practical approach to the problem of introducing a new technology into a small company. This approach is generalised and forms the hypothesis upon which this thesis is based.

5.0 The third part examines just how effective that approach was when it was applied to the Personalised Luggage Strap (PLS) system development project and suggests some minor improvements to increase the effectiveness.

5.1 Analysis of the Nametape Project

During its life the nametape development had three different organisational approaches applied to it. The first was a joint development with a small engineering company, the second was again a joint development but with the Industrial Liaison Centre (ILC) of a Polytechnic, and the third was a continuation of the development with the ILC but with the researcher also involved. In very simple terms the first and last approaches were successful while the second was not, the reasons for this will now be examined.

The first approach was a joint development with a small engineering company and although this was not examined in great detail in the case study, several factors do emerge. The first was that the engineering company assumed full responsibility for producing a technical solution, which was essential because it was they who understood the electronic technology.

5.1 So from the point of view of technical development, the project management came from the engineering company and it was their management who planned the project, controlled the project, set the targets and applied pressure to their engineers and technicians to meet them. Another important function of the same management was to keep the weaving company informed of project progress, and the way this was done depended on further factors.

The engineering company assigned an engineer to work on the project full-time, and it was this engineer who was responsible for the majority of the liaison between the two companies. An essential part of this liaison was that the engineer worked very closely with the Electrician and Development Manager from the weaving company. It also appeared that the engineer spent a high proportion of his time at the weaving company, particularly during the development phase of the project. Another factor that should not be ignored was included in the last sentence, that is that much of the development work was done not at the engineering company but at the textile company with the engineer and the Electrician both contributing to the development.
The last factor is concerned with the efficiency of the development work, which is often poor if the test and development facilities are limited.

5.1 This did not appear to be the case with the engineering company, particularly as special test equipment was available for development and retained by the weaving company for maintenance purposes.

The above factors can be summarised as follows:

1. The project was managed by engineers familiar with the technology.
2. An engineer was assigned to work on the project full-time.
3. There was close liaison between the two companies, particularly between engineers.
4. Much of the development work was done at the weaving company.
5. Special test equipment was available to aid development.

The above factors are not listed in order of priority, in fact, at this stage there is no evidence to show that they are relevant, except that the project with those factors present was very successful.

Taking the five factors as a starting point, the second approach to the nametape development can be examined. This approach involved the ILC of a Polytechnic and three academic consultants were assigned to the project.

5.1 The first factor concerns the project manager and on this point, it was far from clear as to exactly who was responsible for planning and controlling the project. The three consultants were only concerned with their own technical problems which suggests that the project was managed by either the ILC or the Development Manager at the weaving company. Of these two it was the Manager who had financial control over the project, but he was not an engineer and as such could not assess the work of the consultants. The main function of the ILC was not project management but keeping the company informed of progress, so it must be concluded that the project was managed by the Development Manager at the weaving company and as he was not an engineer familiar with the electronic technology, the first factor was not present.

The second factor suggests that an engineer should be assigned to work full-time on the project, this factor was also missing simply because academic consultants only worked for the ILC in their spare time. It is also a fact that the ILC and the Development Manager had other work to do so in effect the whole project depended on part-time effort.

The third factor of close liaison between engineering and weaving was also missing because the two sides only met at formal progress meetings which took place on

5.1 average once every two months. These meetings were mainly to inform the company of project progress and there was very little interchange of technical information.

The consultants worked for the entire project period of eighteen months away from the company, so factor four was also absent. The eighteen month development did not produce a machine that operated correctly, in fact, it hardly worked at all. This suggests that the development work was not being done efficiently which implies limited test and development facilities. This was confirmed because no special test equipment was constructed and the development facilities (especially software development) were limited; so factor five was also absent.

With all five factors missing it is perhaps not surprising that the eighteen months of development produced a prototype machine that was six months late and did not work properly. There was one very important lesson to be learnt from the above example. The project manager only had control over the financial arrangements for he was apparently unable to ensure that the project either kept up to schedule or provided an acceptable technical solution.

5.1 This does not mean that the manager was incompetent but it does suggest that his lack of engineering knowledge put him in a very weak position. It would appear that the Development Manager assumed that he would get the same level of service from the ILC as he had had from the engineering company, even though the cost was much reduced.

The third approach to the nametape development was the same as the second approach but the researcher was also involved, as a temporary employee of the weaving company. The effect that the researcher had on the five factors was not instantaneous as it may appear here but gradual, over a period of about six months.

When the researcher joined the company, the Development Manager had become the Technical Director, and as such was still responsible for nametape development and retained his position as project manager of the name-tape project. However, the researcher reported to the Technical Director and over the months became more and more involved with the nametape project, particularly from a technical point of view.

When the researcher intervened as a development engineer just after the abortive trial of the prototype unit, a situation quickly developed where the researcher became

5.1 technically responsible for the project, although he had no formal authority. From that point it was the researcher, backed by the Technical Director, who decided the direction of the project, and as the project was then being managed by an engineer familiar with the technology, the first factor was present. After the researcher's intervention, he worked on the project full-time until the system was implemented, so clearly the second factor was also present.

The prototype unit was kept at the company and the researcher continued to work on it using equipment loaned from the ILC, so the fourth factor was present. This on-site development also greatly increased the liaison between engineering and weaving, and the researcher visited the ILC several times a week to improve liaison between the ILC and the company. It is interesting to note that the third factor was now present although the formal progress meetings were suspended.

Having experienced some difficulty with the testing of the prototype unit, the researcher produced a test procedure, and a design for a special piece of test equipment. He also made arrangements for the production units to be tested at the sub-contractors in order to

5.1 gain access to their test facilities. These actions overcame serious problems as far as the hardware development was concerned, but they did little to improve the software development. The situation was improved by the researcher testing much of the software at the company using the limited resources available, but that did not overcome the fact that the ILC did not have the facilities (e.g. simulator and emulator) to efficiently produce error free programmes. However, the test procedures and test equipment proved their worth during the commissioning phase so to a great extent the fifth factor was also present.

What the above appears to show is that by introducing one individual, the situation changed from no factors present to all five factors present without a major escalation of project costs. It is also important to note that with all five factors present the project went on to be very successful. The above shows that the factors can be affected by a small change in project manning, but what is far from clear is why they changed. For example, were they all dependent on one another so that changing one affected all five, or were they all dependent on another factor or factors not mentioned, that were also affected by the manning change?
There is one further possibility and that is that the factors changed with time and the arrival of the

5.1 researcher was purely coincidental. Whatever the reason, it may become clearer if the changes that occurred after the researcher intervened are examined in more detail.

It was stated during the description of the second approach that it was unclear as to who was responsible for planning and controlling the project. The company had ultimate financial control but the planning and project monitoring seemed to come from the ILC. It is perhaps an exaggeration to say that the project was planned, because there was only one target to be met before the completion date and in the event that target was not met until longer after the completion date. Could it be that the project planning and control was lacking in some way and if so did the researcher change the situation?

It cannot be claimed that the researcher formally planned the project, but there was some evidence of planning ahead in that the test procedures were produced two months before they were required. As far as targets were concerned, those were determined by the delivery dates quoted for the production units. However, there was one major difference in that the targets were only twelve and twenty-four weeks into the future, compared with twelve and eighteen months on the ILC plan. There was also more pressure to meet the targets after the company took the risk of placing orders for the major

5.1 components and the production units, before the prototype had been fully proven. It is quite possible that the combination of planning ahead, the short term targets, and the pressure that resulted from introducing risk did have an effect on project control, for it is known that in the areas where the researcher was involved the targets were met.

The researcher was a graduate engineer and as soon as he started to work full-time on the nametape project factor two was present, but in terms of engineers working on the project, the numbers increased by more than one due to considerable delegation by the researcher. Before the researcher intervened the hardware consultant had tried to do all the jobs himself, after the intervention as many jobs as possible were delegated both within and outside the company. This delegation also had an effect on factor three (liaison) for it was found that with only one day's training, technical jobs could be delegated to nametape staff and that served to bring the technical and weaving specialists closer together. That move was to eventually make the company independent of both the consultants and the researcher.

The changes that occurred following the researcher's intervention are listed below:

5.1 a. The project was managed by an engineer familiar with the new technology.

b. Short term targets were set.

c. An element of risk was introduced.

d. Pressure was applied to ensure that the targets were met.

e. Full-time staff were present in the project team.

f. Work was delegated both within and outside the company.

g. Liaison was informal and constant.

h. Company staff, particularly the end users, were involved.

i. The majority of the development work was done at the company.

j. Special equipment and procedures were developed to aid testing.

Changes a to d relate to factor one, e and f to factor two, g and h to factor three and i and j to factors four and five respectively.

The above changes did bring the nametape project to a successful conclusion, however, it was felt that further changes were necessary to remove certain limitations, particularly those related to spare time working and limited facilities, in order to produce what might be termed, a preferred approach to introducing a new

5.1 technology into a small company with limited resources. This approach, including a practical example, is developed in the next section.

5.2 The Preferred Organisational Approach and Research Hypothesis

The weaving company did not possess any technical facilities of its own, so however it approached the project, it was always dependent on external facilities. This need not be a serious limitation provided those facilities are available when the company needs them, at a reasonable cost. This was not the case with the ILC facilities for a number of reasons. The facilities were only available when they were not required for their primary function of education, and during that time they could only be used by the consultant who was also only available when not engaged on his primary task of education. This combination resulted in the company having only indirect access to the facilities for no more than a few hours a week. Without doubt the worst aspect of this arrangement was that the consultant, who did not answer to the company, was in a position to set the pace of the project. The implementation of the new nametape system was ultimately delayed because the software consultant failed to complete the programming work in time. From the above it is suggested that the company should gain direct

5.2 access to the necessary facilities and that consultants who can only offer their services on a part-time basis should be used in an advisory capacity only.

These two extra factors can be added to the list of changes at the end of 5.1 to produce a list of factors to describe the preferred organisational approach as follows:

a. The project should be managed by a company based engineer familiar with the new technology.
b. Short term targets should be set.
c. An element of risk may improve project progress.
d. Pressure should be applied to ensure that targets are met.
e. Full-time staff should be used where possible.
f. Part-time consultants should only be used in an advisory capacity.
g. Work should be delegated both within and outside the company.
h. Liaison between the two technologies should be informal and constant.
i. The end users at the company should be involved as much as possible.
j. The majority of the development work should be done at the company.

5.2 k. The company should gain direct access to the necessary external technical facilities.

l. Special test equipment should be developed to aid testing and maintenance.

From the above twelve factors, a practical project approach was developed and used to carry out the PLS project. The planned approach was described in the PLS system proposal which is reproduced in Appendix D. Before examining how effective the approach was in practice, the practical aspects of each factor will be described.

The first factor was put into practice by the researcher himself for he was fortunate in being able to plan and control the project according to the preferred approach. The researcher also designed and developed most of the PLS system, but as with the nametape project, ultimate financial control was retained by the Technical Director.

The basis of the project organisation was a six step plan to complete the project in seventeen weeks, and there were short term deadlines (factor b.) in the form of five targets with time periods of between two and eight weeks to achieve them. The plan called for a demonstration after six weeks which put pressure on the project team from the very start (Factor d.), and

5.2 if that was achieved the production unit was to be ordered (factor c.) and the development allowed to continue.

The full-time staff (factor e.) was the researcher, all other staff being borrowed from various departments within the company to complete specific tasks before returning to their normal duties. This arrangement and the use of a sub-contractor to build the production unit covered factor g. It was necessary to call in a consultant for advice on amending a programme that he had written, however, the consultant advised only (factor f.) and the researcher did the actual programme amendments.

With the researcher (an engineer) being based at the company (weaving), liaison between the two technologies was both informal and constant (factor h.) and this included considerable liaison between the researcher and the end users during loom trials (factor i.).

With the exception of the production unit, all construction work and development was done at the company (factor j.), with about 70% of the development work being done at the loom. The construction work during the first four weeks included a special test box to simulate the loom (factor l.).

5.2 It took two attempts to satisfy factor k, because requests to have direct access to the ILC's facilities and pay for hourly use were refused. Direct access was gained, however, to a superior facility at the University of Aston.

The practical aspects of the preferred approach are quite straightforward and could easily be described as simple common-sense, however, the aim of the PLS project, from a research viewpoint, was to test the effectiveness of the approach on a real project.

The preferred approach is best summarised in terms of a research hypothesis as follows:-

> An effective way of introducing a new technology into a small company with limited resources is to use an internally based consultant and a combination of internal and external resources.

The next section examines the effectiveness of the approach to determine whether or not the hypothesis is supported.

5.3 Analysis of the PLS Project

The project organisation was based on a six step plan over a seventeen week period which was part of the written project proposal. The six steps took the project from feasibility check through to normal production use and each step detailed the technical tasks that had to be completed within a specified time. This fairly simple plan allowed the researcher to monitor and control the project because, with each task having a typical time period of only four weeks, any deviations from the plan were soon noticed.

For the first six weeks the project made good progress and the first two targets were met ahead of schedule. From the first week, ten of the twelve factors were present in the project, the missing two being the part-time consultant and risk. The first six weeks were concerned with technical uncertainty, and because of this the plan reduced the financial risk to the company to a minimum, only if the second target was met would investment and financial risk be requested. The fact that the second target (successful loom trial) was met after six weeks gives an indication of the effect of those ten factors. This is made particularly clear when this achievement is compared with the nametape project where it took eighteen months to reach an abortive loom trial; it goes without saying that in the case of the nametape project, all ten factors were absent.

5.3 From week six, it became clear that the project was planned to proceed and was capable of proceeding at a rate that the company could not accept. The company's recent experience of technical projects had convinced them that they were always behind schedule and they were clearly expecting the same from the PLS project. In a memorandum written during the first week of the project the Managing Director spoke of a completion date two months after that predicted (and achieved) by the researcher, he commented "...this is conservative, but one learns that circumspection and software completion dates are close bed-fellows.".

This mistrust of schedules had a detrimental effect on the PLS project because the company was not in a position to authorise further expenditure and design room effort in week seven as required by the six stage plan. The necessary authority was given eventually but Step 4 was delayed by two weeks, and Step 3 by six weeks. The delayed decisions had a good deal to do with the fact that the PLS project involved a new product with an unknown market. The financial department was unhappy with the market predictions and therefore held back on the capital expenditure, the sales department was uncertain about the details of the product and therefore the design room effort was held up. This suggests that the project plan should have been more comprehensive to include product detail and market

5.3 predictions rather than just the technical details of the process to produce the new product.

A third setback was encountered in week 10, again to do with product detail, and it was clear that further technical effort was required to produce the desired result. Fortunately it had no effect on the work completed by week 10 or on the work that followed. The technical problem was solved by the researcher over two weekends, and as such had no effect on project progress.

It is believed that the three setbacks all had a common reason and that was assumption. This was mentioned before when the second unsuccessful approach to the nametape development was examined, and in that case it concerned the project manager's assumption that he would get a similar level of service from the ILC as he had had from the engineering company. In a similar way, the researcher assumed that the other departments would put as much effort into the PLS project as he had planned for and would therefore be in a position to make the decisions when necessary. He also assumed that the product was better defined than it was and that an existing computer programme would process the orders. The latter problem was in fact the easiest to overcome.

5.3 A better project plan might have had a holding period after Step 2 so that the prototype system could be used to produce some samples for test marketing and product definition.

The project plan included a three week slack period which occurred while the production unit was being built, and by a combination of using the slack period and rescheduling other tasks, the six week delay associated with Step 3 was absorbed. In fact, during that delay samples were produced, and the product was defined in detail exactly as suggested above.

The project went on to be completed on schedule and the performance was as expected. This would suggest that, apart from the two extra factors relating to product definition and market predictions, the preferred organisational approach with its twelve factors does appear to be an effective way of introducing a new technology into a small company with limited resources.

5.4 <u>Conclusions</u>

In the ideal world, the project should not have had to absorb delays, but the fact that they were absorbed supports the idea of a simple step by step plan with short term targets. It is suggested that the project success was due to a combination of the preferred approach and the manner in which it was implemented and it can also be claimed that the research hypothesis was supported.

CHAPTER 6

Discussion on the Research Project

6.0 Introduction

This chapter first restates the aims and achievements of the research project, and then discusses the research findings against the background of literature. This discussion leads to the concept of the internal consultant, and the roles of this individual are examined using a simple model.

6.1 Project Aims

The major aim of the research project was the achievement of successful innovation, the innovation being the introduction of a new technology into the manufacturing process of a small company. To achieve this practical aim, action research methods were used which involved the researcher in the technical and managerial aspects of the innovative project. As a result of using action research methods, it was hoped to introduce the new technology successfully, and to learn more about the innovation process.

6.2 Practical Achievements

The major aim of the research project was achieved with the new technology being successfully introduced.

6.2 The events and actions leading up to the successful introduction were recorded and later analysed; the results of the analysis were expressed in the form of factors which were then compared with those found in the existing innovation literature. The factors described an alternative approach to innovation in the small company and this approach was developed and further investigated using a second innovative project. This was achieved by translating the approach into a project plan, which was then used to introduce the new technology into another division of the same small company. The introduction was not only successful but achieved more quickly and efficiently.

6.3 Research Findings

The research findings can best be summarised by stating the research hypothesis developed in Chapter 5.

> An effective way of introducing a new technology into a small company with limited resources is to use an internally based consultant and a combination of internal and external resources.

This hypothesis was developed from a list of twelve factors, also developed in Chapter 4, and shown below divided into four groups.

6.3 1. Project Control

a. The project should be managed by a company based engineer familiar with the new technology.

b. Short term targets should be set.

c. An element of risk may improve project progress.

d. Pressure should be applied to ensure that targets are met.

2. Human Resources

e. Full-time staff should be used where possible.

f. Part-time consultants should only be used in an advisory capacity.

g. Work should be delegated both within and outside the company.

3. Communication

h. Liaison between the two technologies should be informal and constant.

i. The end users at the company should be involved as much as possible.

j. The majority of the development work should be done at the company.

4. Technical Resources

k. The company should gain direct access to the necessary external technical facilities.

6.3 4. l. Special test equipment should be developed to aid testing and maintenance.

The factors listed above are very specific to the problem of introducing microcomputers into the manufacturing process of a small company, however, similar factors can be found in the innovation literature.

Factor a. suggests that the project should be managed by an engineer and this is supported in several studies that refer to the presence of a graduate engineer or scientist in a position of authority (Freeman 1972, Rothwell 1976).

Factors b., c. and d. are all concerned with project control and there is general agreement that targets (factor b.) or 'milestone events' as Twiss (1976) calls them, should be used as a means of gauging project progress. Both Twiss and Reader (1977) favour the use of project control charts to indicate adherence to or deviation from the project plan.

The use of a full-time or part-time staff (Factors e. and f.) is not specifically referred to, however, the need for a high level of commitment does appear as a

6.3 factor (Twiss 1976) and this is unlikely to be present if only part-time staff are used.

It was found that the delegation of work (factor g.) to people who were able to concentrate on the matter in hand tended to increase the level of commitment within the project.

Good communication both within the innovating company and between the innovating company and its external experts is a factor that is usually associated with successful innovation. In a summary of nine examples of innovation research, Rothwell (1977) noted that good communication was an important factor in all the studies. His own work in the textile industry (Rothwell 1978), stressed the importance of communication and in particular the need for planned communication between separated units. He also recognised the need for informal contact (factor h.) and claimed that "... if regular informal contact between the units can be established, so much the better.".

The involvement of end users (factor i.) with the introduction of computer systems is well documented by authors such as Mumford and Pettigrew (1975) and Jackson (1980).

6.3 Both authors consider involvement to be essential for the successful operation of the computer system. In the more general innovation literature, the same factor appears as either attention to market needs or collaboration with customers. This is because much of the literature is concerned with product innovation rather than process innovation. In the case of process innovation (the subject of this thesis) the end users within the innovating company are the 'customers', and it is collaboration with them that results in their needs being taken into account.

The work by Freeman (1972) concluded that attention to market needs was one of, if not the most significant factor in innovation success. This was confirmed by Rothwell (1977) when the factor of 'attention to market needs' appeared in all nine of the research studies he was summarising.

The need to carry out development work at the company (factor j.) has a good deal to do with the previous factor, in that on site development is more likely to take into account market needs, that is the needs of the end users at the company. Several cases of development work being done in isolation from the market, all of which resulted in failure, were reported by Rothwell (1978).

6.3 Factors k. and l. are concerned with facilities and equipment and appear in the literature as availability of resources (Langrish 1972). However, the availability of resources is also likely to influence the efficiency of the development work and this factor also appears in the literature (Freeman 1972).

In general the factors from this research agree with those from existing innovation literature, however, as stated before, the literature is lacking in describing methods for achieving the factors associated with success.

The particular problem to be addressed is how to make effective use of external consultants when introducing a new technology.

Consultants are generally considered to be expensive, therefore, if they are to be used, they must be effective. The cost of using consultants is likely to be a significant factor when considering the introduction of new technology, and this is particularly true in the case of process innovation using microcomputers in a small company. A study by Bessant (1980) on the adoption of new technology, confirmed that the capital cost (i.e. cost of equipment and expertise) was a significant obstacle to adoption.

6.3 In the case where the capital cost of the new equipment is very high (i.e. millions of pounds) then the cost of the consultant is much less significant, however, that situation is not the subject of this research.

The nametape case study described an attempt to use academic consultants as a source of technical expertise, academics being generally less expensive than full-time consultants. However, because of problems with liaison, the early results were disappointing. On the subject of using consultants, the literature presents arguments both for and against. For example, Howlett (1980) claims that although consultants are expensive, they are also cost effective because the innovating company will have the benefit of the new technology more quickly than if they attempt to 'go it alone'. This was not the case with the nametape development and other less than successful examples appear in the literature. Allen (1977), for example, found that the use of consultantants was often associated with below average solutions to technical problems, and Rothwell (1978) describes the failure of eight projects all involving the use of external consultants. Rothwell claims that the major reason for the difficulties was poor liaison between the consultants and the company, and this factor was also noted during the nametape development.

6.3 The particular problems associated with liaison between academics and industrialists have been examined in the past. For example, Curran and Busby (1972) claimed that the problems were due to the members of the university staff having no substantial period of experience in industry. This is perhaps not so true in the 1980's but the problems still remain. A later study by Pelc (1978) concluded that problems arise because of the different expectations of people within a university and a manufacturing company. Pelc suggested that universities and industry are likely to interact most efficiently in the areas of applied research and development, leaving basic research to the universities and implementation to industry. The research reported in this thesis supports this suggestion.

The above presents a depressing picture of introducing new technology using consultants, however, there is one method of transferring a technology with a better record of success; transfer the technologist. This observation was made by Burns (1969) when he described the mechanism of technological transfer as "... one of agents, not agencies...". This may represent the ideal but it may be impractical in the case of one-off development projects involving new technology. An alternative approach is offered by Lien (1979) who

6.3 suggests the use of a middleman to facilitate the technology transfer process. The combination of the last two mechanisms plus the researcher's observations led him towards the concept of the Internal Consultant, and the way that such an individual could aid the introduction of new technology using external consultants.

6.4 The Internal Consultant

The internal consultant is familiar with the new technology being introduced and is based at the company receiving the new technology. He advises the company on their use of external consultants and monitors the relevance and quality of the consultants work. He also ensures that sufficient information regarding the new technology is transferred to the company, so that it may be operated, maintained and further developed.

It would appear that the researcher took on the role of internal consultant for the duration of the research project, however, this was not immediately recognised. As the nametape project moved towards a successful conclusion, following the researcher's intervention, it was thought that this was because the researcher had become the Project Champion. The champion figure was identified by Schon (1967a) and is described as an individual "...capable of using any and every means

6.4 of informal sales and pressure in order to succeed.". Twiss (1976) describes the champion as "...a highly committed individual who places the success of the project above all other considerations...". A typical champion is described by Roberts (1969) as about thirty years of age, with an M.Sc. degree and a development oriented background. The champion figure appears in much of the innovation literature and is normally linked with successful innovation, although it is recognised that a misguided champion can cause failure. The researcher possessed the necessary qualifications, and was committed to bringing the project to a successful conclusion; to achieve the success he acted like a champion, but the methods employed should be explained further.

As a temporary employee, the researcher had no formal authority within the company and as such could not directly influence the direction of the nametape project. However because of this technical knowledge, he possessed what might be termed 'sapient authority', and with the backing of the Technical Director, became responsible for the technical aspects of the project. This put the researcher in a position where he was responsible for the communication of technical information. This position brought with it the role of co-ordinator for as Koehler (1976) noted, communication has a co-ordinating role.

6.4 As the project gained momentum, an informal organisation emerged that was concerned only with the nametape project. It was the existence of the informal organisation that allowed the nametape project to proceed without the need to change the formal organisation, which was still required to carry out the main manufacturing function of the company. The presence of informal organisations is reported in the innovation literature with Kingsbury (1967) noting their considerable influence and Ellis (1979) suggesting their use to stimulate innovation.

It is believed that the informal organisation emerged because of the management style adopted by the researcher. As stated above, the researcher lacked formal authority and because of this a participative approach was adopted, with the emphasis on the involvement of the people concerned. Smith (1978) noted that innovation is a people-oriented process and this fact should not be overlooked when attempting to control the innovation process. In the case of the nametape project it is believed that the involvement of the end users had a good deal to do with the ultimate success of the project, and it is suggested that where new skills have to be learnt as a result of the innovation, the involvement of the end users is paramount. This suggestion is supported in the literature by authors such as Jackson (1980), Mumford and Pettigrew

64 (1975), and Mumford (1980), all of whom report examples of successfully introducing computer systems with the involvement and participation of the end users.

What the above appears to show is that by gaining control of the flow of technical information, and by making use of the informal organisation, the researcher, in his role as Internal Consultant, was able to co-ordinate the nametape project and bring it to a successful conclusion. The same approach was used with the PLS project with only minor changes.

The need for an individual to co-ordinate the various aspects of a project was noted by Bessant (1978). Bessant's research examined innovative projects within the R & D department of a large chemical company rather than innovation in the small company, however, the roles of Bessant's Integration Specialist and that of the Internal Consultant, described here, are very similar. Both are concerned with the bringing together or integration of the various technologies and skills that go to make up an innovative project. Without these individuals there is differentiation and a breakdown of communications leading to unsuccessful innovation. The effects of differentiation and integration within organisations were examined by Lawrence and Lorsch (1967) but they concentrate on resolving interdepartmental

6.4 conflict in large companies rather than liaison between a small company and its consultants. But once again, the roles of the individual responsible for integration are very similar to those of the Internal Consultant.

To try to more clearly describe the information control role of the internal consultant, a four stage model has been developed (Figure 6.1) that shows the paths and levels of information flow both within the company and between the company and its consultants and contractors. The four stages cover the major phases of an innovative project and are Project Evaluation, Technical Design, Development and Implementation, and Operation. The model shows an example of a small company using external contractors and part-time academic consultants and is based on observations from the case studies reported in this thesis.

Stage 1 is the evaluation phase during which the internal consultant advises the Director on the nature and scale of external assistance required. A brief outline of the work required is produced and a formal approach is made to the external contrators and consultants. They in turn consult with their own engineers and submit proposals which are then examined by the Director and internal consultant.

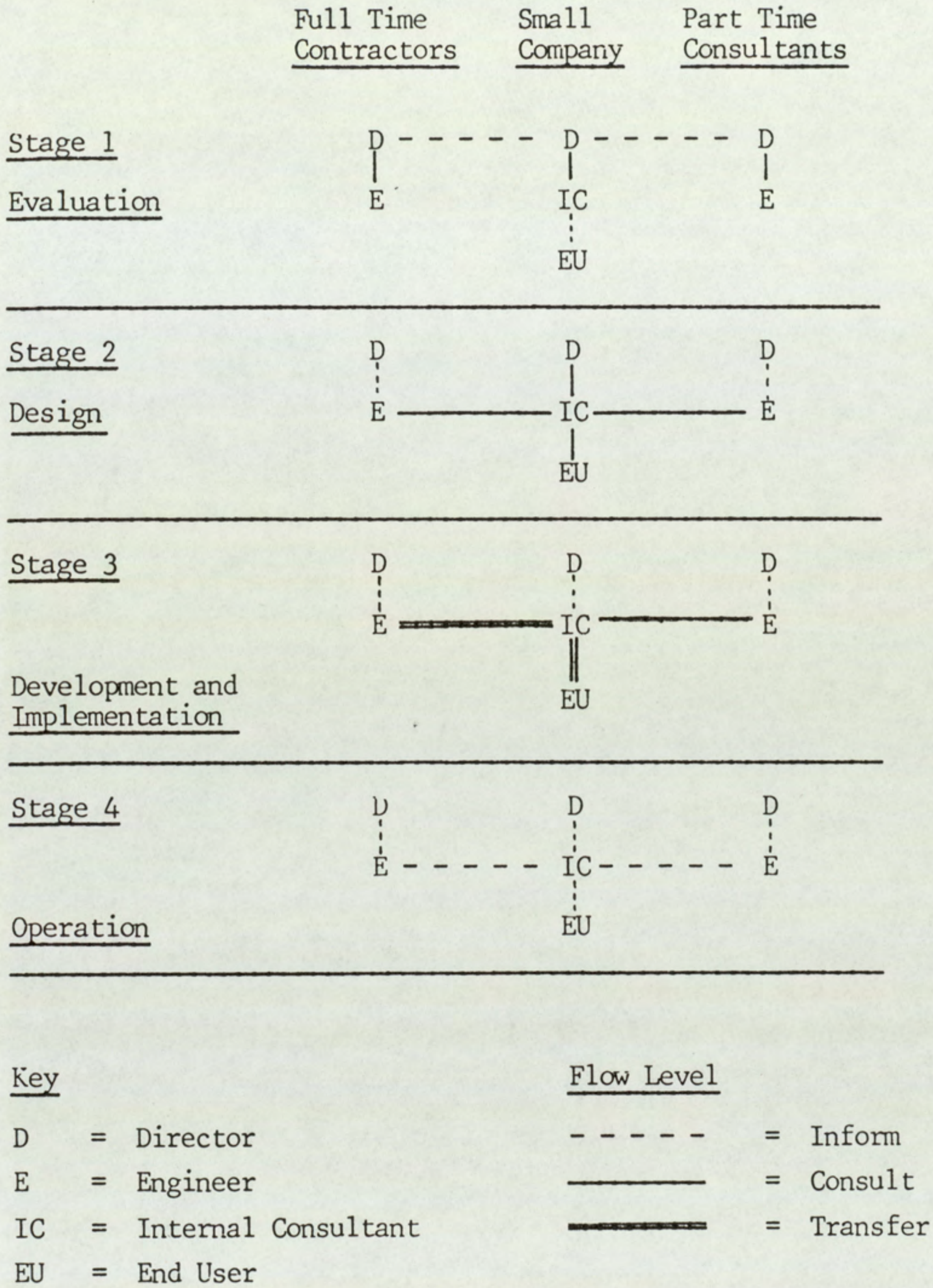

Figure 6.1 Four Stage Information Flow Model

6.4 The end users are kept informed.

Stage 2 is the technical design phase, and the model shows that the information flow changes from inform to consult, but more important, the interchange between the companies moves from the level of Director down to that of the engineers.

The internal consultant forms the major link between the small company and the technical experts, and because the internal consultant and the experts are familiar with the new technology, information flow is uninhibited. Another important role of the internal consultant is to act as an interpreter between the technical experts and the non-expert Director and end users; this allows non-technical people to contribute to the technical design.

Stage 3 is the development and implementation phase and is the most demanding. During this phase it is not advisable to rely on part-time assistance and therefore the input from the consultants is limited to consulting only. The full-time staff, that is the contractor's engineer, the internal consultant, and the end users are fully committed to transferring and implementing the new technology, and it is during

6.4 this phase that the majority of the information is transferred. It is important to note that the information is ultimately transferred to the end users; it should not be retained by the internal consultant.

Stage 4 is the operation phase when the new technology has been introduced and is in normal use. All the information necessary to operate, maintain and further develop the technology should have been transferred to the end users. If this is achieved, the internal consultant is no longer required, and the level of information flow reduces to that of keeping interested parties informed of system performance.

The four stage model gives a simplistic view of an extremely complex process; however, it is suggested that it does help to clarify the position and role of the internal consultant. There is one question that the model does not answer and that is where does the internal consultant come from? For the work described in this thesis the position of internal consultant was filled by a postgraduate research student. This may have been a very cost effective solution, but it cannot be suggested as a general solution.

6.4 In order to identify sources of potential internal consultants it is first necessary to describe the individual required. To qualify for the position of internal consultant an individual must a. be familiar with the new technology and b. be able to base himself full-time at the innovating company.

The first requirement is necessary because the internal consultant will be the main link between the innovating company and its external experts, and because he must assess both the technical problems, and the solution provided by the external experts. The ability to do this calls for a high level of technical competence and considerable industrial experience.

The second requirement is necessary because the internal consultant must not only act on behalf of the innovating company, he must also become conversant with the technology of the innovating company in order that he can offer sound advice when attempting to bring the old and new technologies together. This requires that he is not only based at the innovating company, but also given time to become familiar with the existing technology.

6.4 The combination of the need for high technical competence, and the extended periods spent at the innovating company make it unlikely that a small company could afford to fill the position of internal consultant with a professional technical consultant. For example, if a full-time consultant had been used for the nametape development, then the capital cost would have been increased by about 250% and made the whole project uneconomic.

The use of academic consultants can reduce the cost, but because of their inability to work full-time, the time scales will inevitably be extended; this may be unacceptable to a small company looking to new technology as a way of reducing costs. The observations from the nametape case study suggest that academic consultants can only be used successfully if an internal consultant is present.

There may be a case for the secondment of academics into industry so that they can simultaneously study innovation at first hand, and provide industry with affordable internal consultants. This research has shown that a postgraduate research student can function as an internal consultant, so there is no reason why a research associate or research fellow should not be able to fill the position, provided

6.4 the individual has sufficient industrial experience. An arrangement such as this could make academics more aware of industry's needs and small companies in particular, could be encouraged to participate with the offer of a cash incentive provided by the Department of Industry or the Science and Engineering Research Council.

A final suggestion that can be made is to appoint an internal consultant to the full-time staff of the innovating company. This can prove cost effective if there are several projects that require his attention or if a production process needs regular updating. There can be difficulty in attracting and retaining an individual with the relevant experience but even so, while he is employed he will cost far less than a consultant.

The difficulty with finding a suitable internal consultant is one of the drawbacks of the approach recommended by this research. When using an internal consultant there is another problem that has to be handled carefully and that is overdependence on the internal consultant. The internal consultant is required to help the innovating company introduce the new technology, but if he is too willing to help, the company may adopt a passive, dependent role and

6.4 not learn how to properly operate and maintain the new technology in the absence of the internal consultant. Exactly the same problems are described when using action methods to bring about organisational change. As a solution, Warr (1977) offers the following advice "The problem is not how to avoid this dependence completely, it is one of building on it where appropriate but not otherwise and of encouraging a gradual reduction in dependence as the project develops towards its conclusion.".

It must be concluded that the combination of one full-time internal consultant and several part-time consultants, offers the most cost effective method of introducing a new technology into the small company.

The results of this research also demonstrate that the use of an internal consultant increases the chances of achieving successful innovation and as such is an important factor in bringing about the transfer of technology into the small company.

CHAPTER 7

Conclusions and Further Work

7.1 General Conclusions

The research project achieved the following:

1. A new technology was successfully introduced into the manufacturing process of a small company; this was achieved using action research methods.

2. The events and actions leading to the successful introduction were recorded, and later analysed to produce a list of twelve relevant factors and a preferred method of achieving them.

3. The preferred method was used to introduce the new technology into another division of the same small company. Again action research methods were used and the introduction was successful and completed to schedule.

4. Further analysis of the factors, the preferred method and the literature produced the concept of the internal consultant. This concept was refined and the major roles of the internal consultant were defined.

7.1 The conclusions from the research were as follows:-

1. The majority of innovation literature has concentrated on examining examples of innovation several years after they were completed. This has resulted in factors associated with success or failure but little or no detail of the methods employed to bring about successful innovation.

2. This research has demonstrated that action research methods can be applied to innovation research and can record the innovation process as it happens.

3. The action research approach allows the researcher to influence the innovation process and immediately apply the findings of the research. This would appear to increase the probability of achieving successful innovation.

4. The action research approach produces not only factors associated with successful innovation but also methods for achieving the factors. From a practical viewpoint, the methods by which the factors are achieved are more important than the factors themselves.

7.1 5. During the research, the action researcher took on the role of internal consultant and this figure has much in common with the champion figure described in the innovation literature.

6. The presence of an internal consultant is particularly important when introducing a new technology into a small company using external assistance.

7. The major function of the internal consultant is controlling the flow of technical information.

8. Commercial consultancy services are unable to provide an individual capable of functioning as an internal consultant at a cost that would be acceptable to a small company.

9. The high cost of a technical consultant is only significant when the hardware costs associated with the new technology are low (i.e. less than £50,000).

10. There may be further opportunities for university/industry collaboration if universities can provide researchers to fill the position of Internal Consultant at a reasonable cost.

7.2 Further Work

This research has shown that innovation in the small company can be successfully achieved by the use of an internal consultant. However, the discussion suggests that the individuals required to fill the position of internal consultant, for periods of six to twelve months, are generally not available at a cost that a small company can afford. The cost of the consultant is particularly significant in the case of projects where the hardware costs are well below £50,000.

This suggests that the current consultancy services offered by both full-time and academic consultants should be examined in the light of the lower cost hardware and the need for smaller companies to invest in new technology. There would appear to be scope for more effective collaboration between universities and industry and it is suggested that both could benefit from working more closely together over an extended period. The possibility of universities providing industry with internal consultants should be examined in more detail, not forgetting the financial incentives that might be available for such schemes from the Department of Industry. In fact, a scheme for seconding researchers and academics into industry may be a more cost effective way of encouraging

7.2 the adoption of new technology than the incentives on offer at present.

The use of an internal consultant does not guarantee success over the whole range of innovative activity. It has been shown here that the use of such an individual can produce success in the case of transferring a known technology into a small company environment. But it does not follow that a method that is successful when applied to incremental innovation will also be successful when applied to radical innovation. However, the ability to describe the use of an internal consultant as a method associated with successful innovation came about by the use of an action research approach to innovation research. Whereas the results of this type of research may be specific to the type of innovation studied, there is no reason why a similar research method should not be applied to the study of more complex and radical examples of technological innovation, with the emphasis on identifying methods for achieving successful innovation. Innovation research has produced plenty of factors associated with successful innovation, what are needed now are methods for achieving them; it is suggested that these will only be found by innovation researchers being involved with innovation and experiencing the process for themselves.

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APPENDIX B : GLOSSARY

CASHMATIC	the name given to the Cash's automated system for producing woven nametapes (CASH + AUTOMATIC).
I.H.D.	Interdisciplinary Higher Degrees.
I.L.C.	Industrial Liaison Centre.
Jacquard	Louis Marie Jacquard (born 1752) was the inventor of the loom mounting still used today to lift and control individual warp threads.
Pick	one pick is the insertion of one weft thread.
PLS	Personalised Luggage Strap.
PROM	Programmable Read Only Memory.
Shuttle	a device for holding a spool of weft thread.
Warp Thread	in the case of a nametape the warp threads run lengthways.
Weft Thread	the weft threads are inserted at 90 degrees to the warp.

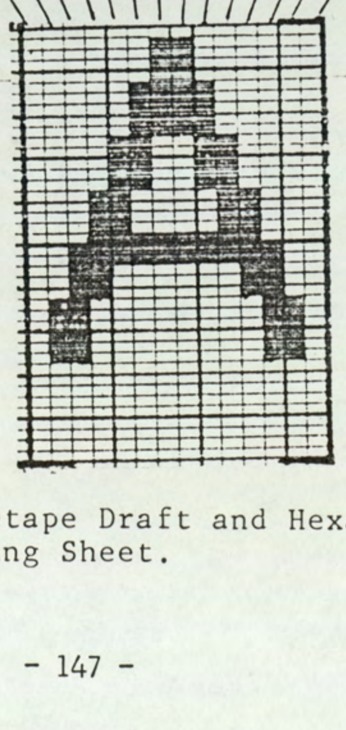
NUMBER OF PRE-CEEDING GROUND: 00

NUMBER OF FIGURE PICKS: 0E

Pick Number 1	FF	FF	FF	FF	FF
Pick Number 2	FF	81	FF	FF	FF
Pick Number 3	FF	80	0F	FF	FF
Pick Number 4	FF	FE	00	7F	FF
Pick Number 5	FF	FF	C0	03	FF
Pick Number 6	FF	FF	C7	80	1F
Pick Number 7	FF	FF	C7	FC	01
Pick Number 8	FF	FF	C7	FC	01
Pick Number 9	FF	FF	C7	80	1F
Pick Number 10	FF	FF	C0	03	FF
Pick Number 11	FF	FE	00	7F	FF
Pick Number 12	FF	80	0F	FF	FF
Pick Number 13	FF	81	FF	FF	FF
Pick Number 14	FF	FF	FF	FF	FF

NUMBER OF FOLL-OWING GROUND: 00

Sheet of



APPENDIX C: Nametape Draft and Hexadecimal Coding Sheet.

APPENDIX D

P.L.S. Project Proposal

23rd April 1980

Cash's UK

A Division of J.&J.Cash Limited

Kingfield Road Coventry CV1 4DU Tel 0203 555222 Telex 31397 Cash CVG

By Appointment
To Her Majesty The Queen
Manufacturers of Woven Name Tapes

THIS REPORT NOT TO BE ISSUED

PROPOSAL FOR MICROPROCESSOR CONTROL OF THE MULLER MUTRONIC LOOM

JCL/SP
23rd April 1980

Woven and printed labels, badges, pictures, premiums, ribbons, trimmings and nametapes

Registered Offices: Kingfield, Coventry/Registered in London No. 43765

CASH'S U.K.

JCL/SP
22/4/80

Proposal for Microprocessor Control of the Muller Mutronic Loom

1. Introduction

The Mutronic is a high speed (1,000 picks/minute) 4 space needle loom. It has 20 shafts which are controlled from 20 photo-cells which read a continuous loop of paper. Patterning is achieved by a combination of punched holes in the paper loop and warp attachments to the 20 shafts. It is proposed to connect an additional 20 photo-cells in parallel with the existing set and control the light sources for the new set from the microprocessor.

The proposal is to be able to weave characters in the same way as Cashmatic II. There would, therefore, be a FONT of characters available and the loom controller would read 8 hole paper tape via a tape reader to determine the sequence of characters to be woven.

The major parts of the hardware and software would be identical to those used in Cashmatic II. The paper tape format would be identical thus the existing I.C.L. computer could sort orders and produce the tapes as required.

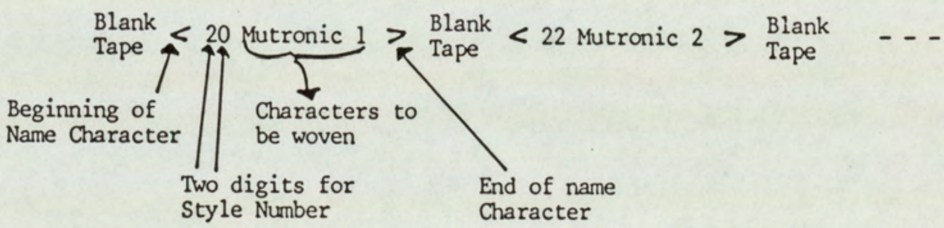
The Cashmatic II system has an additional facility for producing SPECIALS, this would not be provided on the Mutronic system but there would be an AUTO/NORMAL option. When switched to AUTO the loom would ignore any holes punched in the paper loop and, instead, take its information from the microprocessor controller, this would limit it's capability to the characters stored in the FONT.

1. When switched to NORMAL (also if the controller were either disconnected or switched off) the loom reverts to its normal mode of operation taking its patterning information from the paper loop.

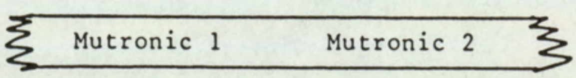
2. The FONT Characters

2.1 General

As with Cashmatic II it is proposed to be able to select one of several fonts by specifying a style number when preparing the 8 hole paper tape. The tape format would be identical to Cashmatic II.



The above would produce from the loom:

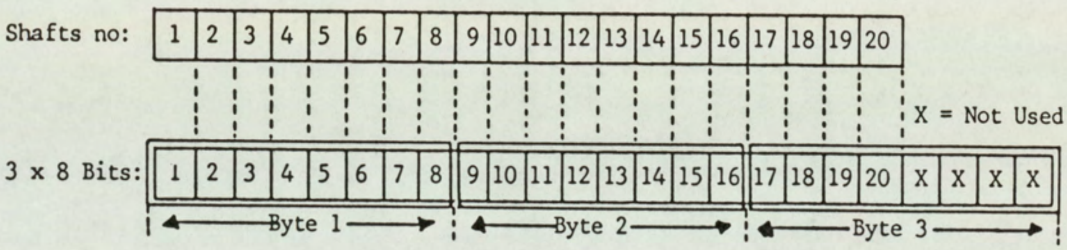


← Towards take down roller

As with Cashmatic II reel header and order colour information could be added to the input paper tape as required.

2. 2.2 Data Format

The microprocessor works in blocks of eight bits (eight bits = 1 byte) and, therefore, a minimum of three bytes is required for each pick. An additional byte of information is required to tell the processor how many picks go to make up one character.



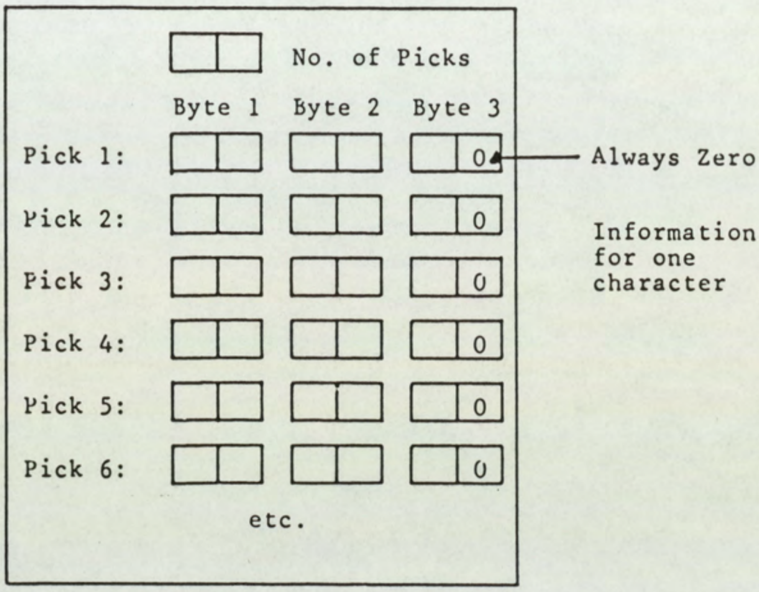
The processor works with 0 (nought) and 1 (one) only, therefore, a single pick of data may be represented as follows:

0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0
			4				8			11			14			17		19					

As '1' is defined as representing a hole in the paper roll and therefore lifting the shaft. The above pick will lift shafts 4, 8, 11, 14, 17 and 19.

A standard sheet will be prepared as shown on the next page for converting a drafted character into code acceptable to the processor. Hexidecimal numbers must be used when completing the sheet.

2. 2.2



These characters would be installed in memory using the procedure developed for Cashmatic II.

3. The Loom Controller

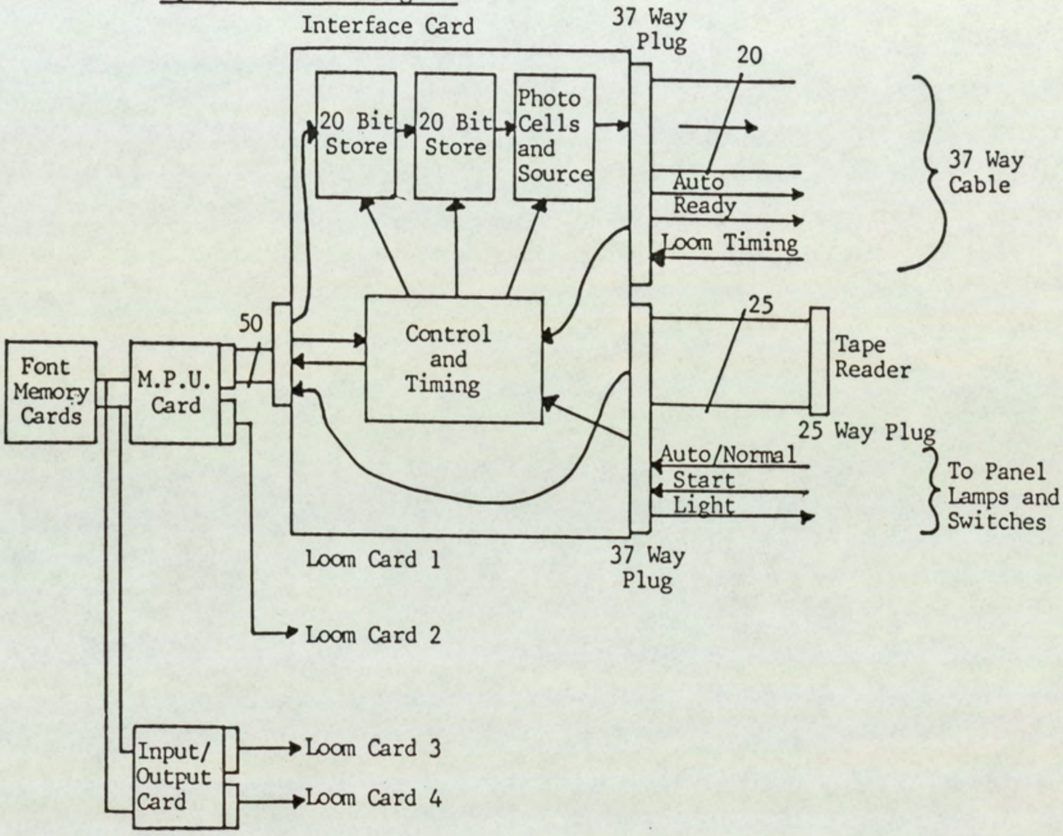
3.1 Hardware

The Mutronic controller will use the same microprocessor and memory cards as Cashmatic II. Other common components will be the Tape Reader and Panel, Power Supplies, Rack Components and Edge Connectors.

It is proposed to design one card to interface between the loom, the tape reader and the microprocessor.

This card will control one loom only but a single microprocessor card has the ability to feed two such cards and the system could be extended to feed four if necessary.

3. 3.1 System Block Diagram



See Appendix 1 for further details.

3.2 Software

The software would be a modified version of that used for Cashmatic II Master Font. This should result in tremendous time savings as the existing program is known to operate the tape reader and successfully find and output any character in any style.

3. 3.2 It is thought that only four routines would need to be re-written. These would be FNTPRG (Main Program), FIGWEV (Weave Figure Pick), FIGPAD (Prepare data for output) and INTNAM (Pattern between names). Other routines such as OUTPUT (Output data to interface) and PISET (Set up interface) would need one or two numbers changing because there would now be only 20 ends compared with 80 for Cashmatic II, however, these changes would be of a minor nature and would not require the routine to be re-written. See Appendix 2 for further details.

3.3 Loom Modifications

3.3.1 Addition of hardware to give Loom Trigger signal

Because of the speed of the loom it is proposed that this signal be derived from an optical sensor detecting a hole in a disc connected to the mainshaft.

3.3.2 Addition of a 37 way socket

This socket and cable would be the only connection between the loom and the Loom Controller. This socket would be wired to the existing photo-cell amplifiers, to the Loom Trigger sensor and to the relays mentioned in 3.3.3.

3. 3.3 3.3.3 Addition of Two Relays and Two Indicator Lamps

The first relay would control the changeover from normal operation to automatic operation. With this relay de-energised the loom would operate as a standard Muller Mutronic taking its patterning information from the paper loop. When the relay is energised an indicator loop (AUTO) illuminates to show that the loom is in AUTO mode. In this mode the photo-cells for the paper loop are disconnected and the patterning information will come from the loom controller. When in AUTO mode the loom cannot be started unless the loom controller is ready.

The second relay controls the stopping and starting of the loom and is only energised when the loom controller is ready to supply data to the loom. This means that a tape has been loaded and that the START FONT button has been pressed and released. In this condition the relay is energised and an indicator lamp (READY) is illuminated at the loom, it is then left for the operator to start the loom. At the end of the tape the loom will be stopped automatically and the READY light extinguished. (See Appendix 3 for further details).

4. Project Approach

4.1 Introduction

All that has gone before is a result of a study of the circuits, drawings and programs of both Cashmatic II and the Muller Mutronic loom, it is, therefore, a design which exists on paper only. The information available for Cashmatic II is very detailed compared to that available for the Muller, it will, therefore, be necessary to carry out tests and trials on the Muller loom to prove that the design suggested is feasible.

4.2 Opto-electronic Link Feasibility - Step 1

The link between the loom and the loom controller is purely optical and it must be shown that this will work and that the changeover from AUTO to NORMAL will take place without difficulty. At the same time it is hoped to gain a more intimate knowledge of the loom operation and fit the Loom Trigger sensor.

4.3 Build Interface Card and Test - Step 2

It is proposed to build the interface card on a Motorola Wire Wrap card. Wire wrap is a means of making an electrical connection without soldering. The card has about 30 components and will be wired by Cash's U.K. personnel. For efficient testing away from the loom a special test box comprising very simply of twenty lights and a loom trigger will also be built at this time.

4. 4.3 For early testing the Cashmatic II SPECIAL program will be used with FIGPAD, FIGWEV, and OUTPUT modified to suit the new interface. This program is much simpler but will enable the full testing of the major new routines. At this stage one or two characters would be drafted and converted into hexidecimal code and, having confirmed that the data output was correct using the test box, woven out on the loom. Having reached this stage a prolonged trial (one week) will be necessary to confirm that the system is reliable. Note: Cashmatic II Prototype unit used as basis for system.

4.4 Modify and Test Master FONT Program - Step 3

This work would run in parallel with the drafting, coding and installation of a character font and test the system in its entirety.

4.5 Initiate Construction of Production Unit - Step 4

The decision to initiate the construction of the production unit shall be taken as early as possible. It should certainly be taken at the same time as Step 3 and preferably during the latter part of Step 2. A policy decision will be required regarding the interface card. All development will be done on a Wire Wrap version but if it is envisaged to buy several Mutronic controllers then the interface card circuit will need to be converted into a printed circuit to reduce the card construction cost to reasonable levels. (See Section 5 for details).

4. 4.6 Production Unit Testing and Commissioning - Step 5

The first production unit will require thorough testing to eliminate all wiring/scheduling errors, and a prolonged trial to confirm its reliability under production conditions. The documentation would now be finalized.

4.7 Operation and Maintenance - Step 6

The operators would be involved as much as possible during all stages of development so that they would become familiar with the system well before it was released for production use. This approach was successful with Cashmatic II and would be used again for the Mutronic development.

Because of commonality with the major Cashmatic II components maintenance should not be a serious problem. Also because the interface has been reduced to one card only, fault correction should be a simple matter of changing the one card.

4.8 Access to Facilities to carry out the above

It is intended to maintain the existing links with the Lanchester Polytechnic and use their facilities wherever possible. However, it is not intended to use the Polytechnic as a source of consultancy, this has proved very time consuming in the past and a different arrangement will be sought for this project.

4. 4.8 Cash's U.K. now employs a full time Electronics Engineer who should be able to design and develop the system detailed above but he will need to use special test equipment and have access to a computer for developing the programs. It is suggested that Cash's U.K. negotiate with the Polytechnic for the hire of equipment and computer time and the use of expert help should it be required.

What must be avoided is the situation where the Polytechnic consultant, who is part time, is setting the pace of the project.

It is intended to use Tekdata Limited for the construction of the production unit, mainly because their standard of workmanship is very high, but also because they have prepared their own drawings/documentation for most of the Cashmatic II metalwork and these drawings could be used again for the Mutronic development thereby saving drawing costs.

5. <u>Costs and Time</u>

The proposed design and this report were prepared by Cash's U.K. personnel, therefore, no capital cost is shown for this study.

5. Step 1

Hardware	£100.00
Electronic Engineer's Time - 2 Weeks @ £ per week	£
Electrical Engineer's Time - 3 days @ £ per day	£
Fitter's Time - 2 days @ £ per day ...	£
Equipment Hire - Scope @ £ per week ...	£
Lost Production - 1 week @ £ per week ...	£

Step 2

Hardware	£100.00
Electronic Engineer's Time - 4 Weeks @ £ per week	£
Electrical Engineer's Time - 2 days @ £ per day	£
Design Room Time - ½ day @ £ per day...	£
Equipment Hire - Scope @ £ per week ...	£
Lost Production - 1 week @ £ per week ...	£

5. Step 3

Electronic Engineer's Time - 4 Weeks @ £ per week	£
Electrical Engineer's Time - 4 days @ £ per day	£
Design Room Time - 1 week @ £ per week	£
Equipment Hire - Scope, RAM, Teletype @ £ per week	£
Computer Hire - 20 Hours @ £ per hour..	£
Draft to Code Conversion - 1 week @ £ per week	£
Lost Production - 1 week @ £ per week..	£

Step 4

Hardware - Cabinet, Rack, P/S, 2 Readers, IMPU, 2 MEM, 32K PROM	£2,200.00
Construction 1 off 2 Loom Cabinet - 6 - 8 weeks	£2,000.00
Electronic Engineer's Time 1 week @ £ per week	£
*Printed Circuit Design - once only cost ...	£1,000.00
*Interface Card - Wire Wrap	£400.00 each
*Interface Card - Printed Circuit... ...	£100.00 each

* See 4.5

Proposals for Microprocessor Control of the Muller Mutronic Loom
Continued...

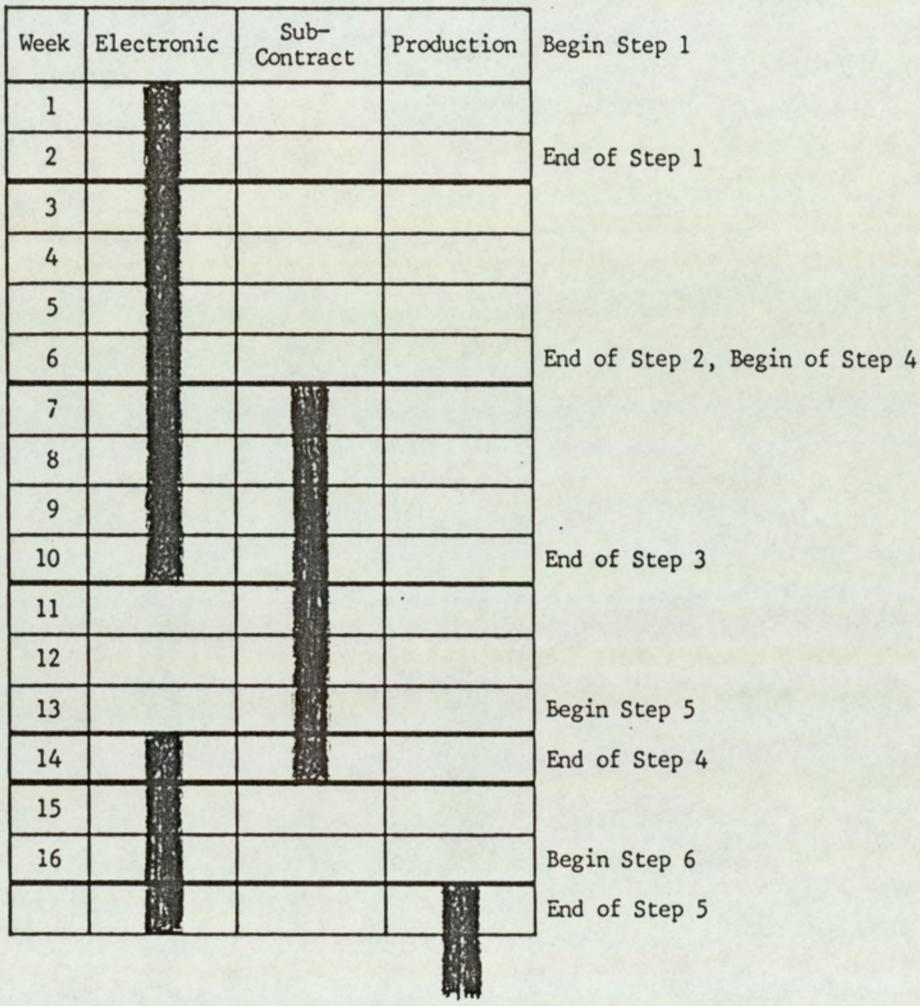
5. Step 5

Electronic Engineer's Time - 4 weeks @ £ per week	£
Equipment Hire - Scope, RAM, Teletype - 1 week @ £ per week	£
Computer Time - 5 hours @ £ per hour ...	£
Electrical Engineer's Time - 2 days @ £ per day	£
Lost Production - 1 week @ £ per week	£

Step 6

Hardware - either 1 card - Wire Wrap ...	£400.00 each
or 1 card - Printed Circuit..	£100.00 each

5. <u>Major Time Factors</u>



The above assumes, essentially, full time working by the Electronics Engineer which cannot be guaranteed.

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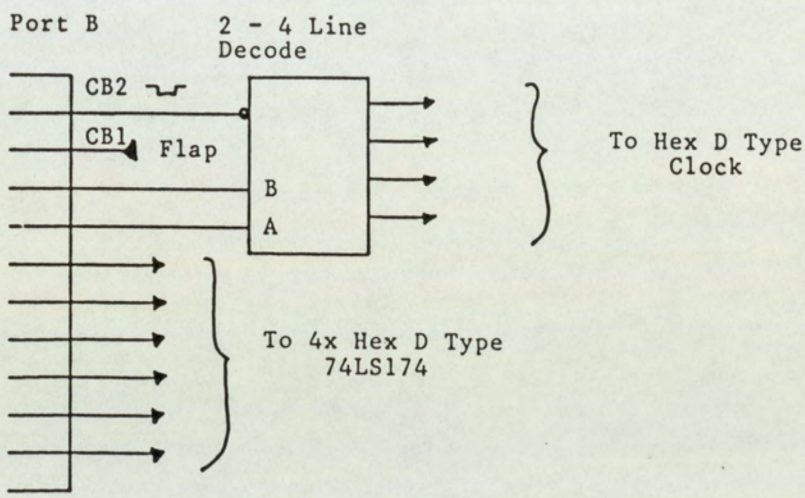
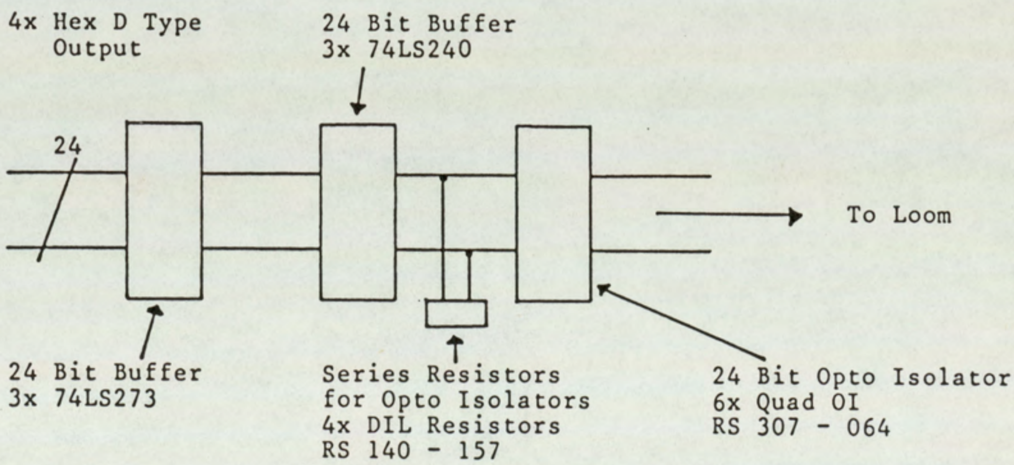
Proposal for Microprocessor Control of the Muller Mutronic Loom - Appendix 1

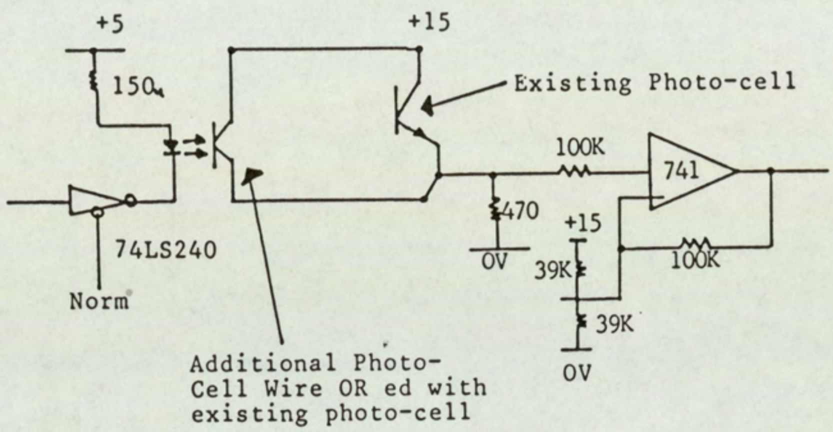




Note: Port A wire as 6820 card on Cashmatic II.

Proposal for Microprocessor Control of the Muller Mutronic Loom - Appendix 1. Continued...

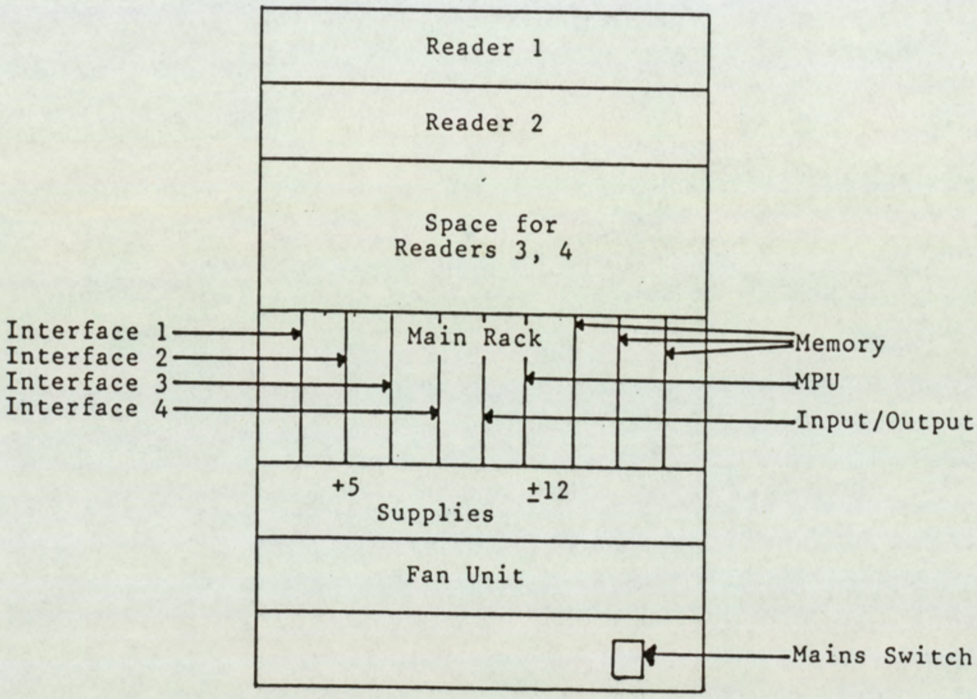
Loom Circuit



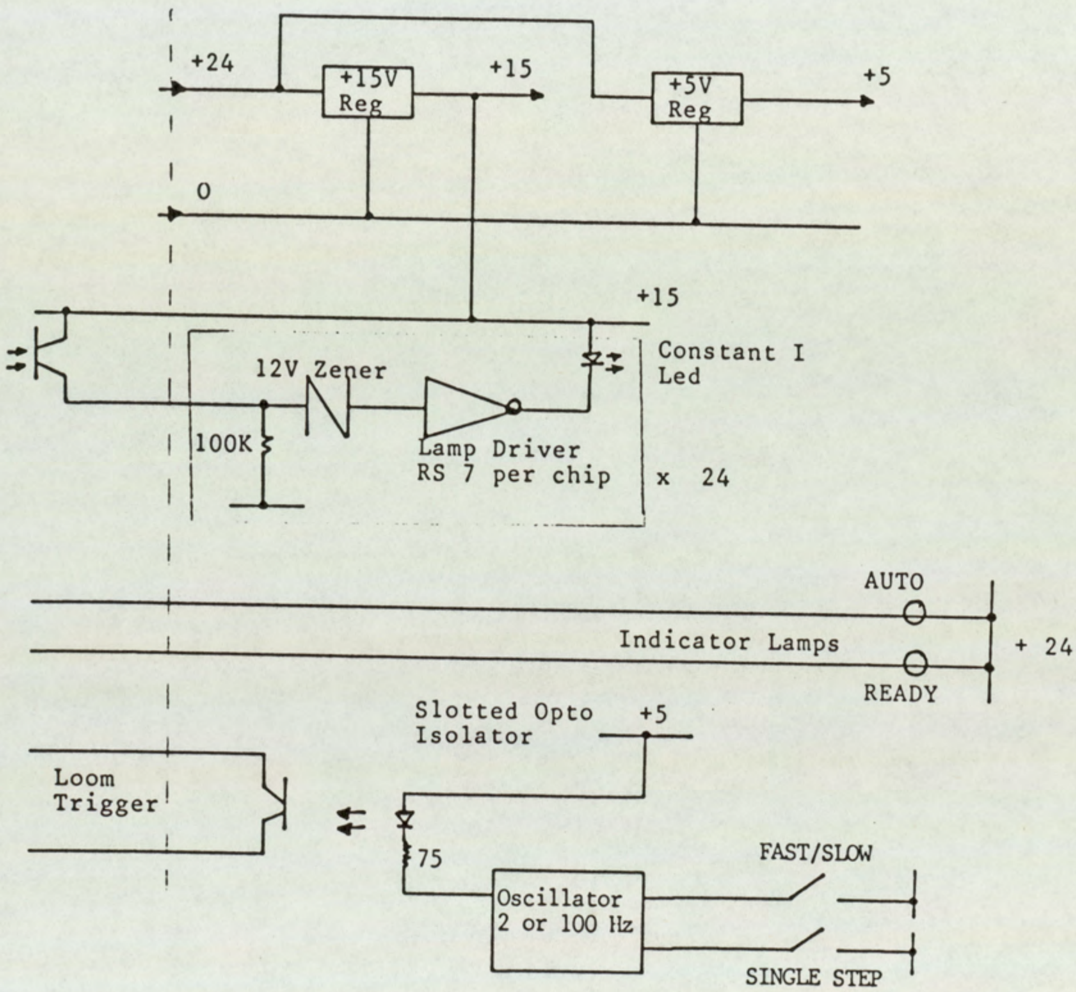
Parts List

1	x	74LS138	£1.00	each
4	x	74LS174	£1.00	"
3	x	74LS273	£1.76	"
3	x	74LS240	£1.83	"
4	x	150 DIL Resistors (7)	£0.57	"
6	x	QUAD O/I	£2.48	"
2	x	75452	£1.00	"
1	x	74LS132	£0.50	"
1	x	74LS279	£1.70	"
1	x	74L10	£1.50	"
1	x	74LS74	£0.40	"
1	x	74LS123	£0.74	"
1	x	1K DIL Resistors (13)	£0.57	"
1	x	16 Pin DIL Plug	£1.50	"
1	x	50 Way Wire Wrap Plug	£5.00	"
13	x	16 Pin Wire Wrap Sockets	£0.40	"
6	x	20 Pin Wire Wrap Sockets	£0.60	"
8	x	14 Pin Wire Wrap Sockets	£0.40	"
1	x	Motorola Wire Wrap Board	£47.00	"

General Layout



Test Box



Sheet 4 of 4

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Proposal for Microprocessor Control of
the Muller Mutronic Loom - Appendix 2

FNTPRG

Header Start to be re-defined and all references to GRDWEV deleted.

FIGWEV

Delete all references to grounds and PUL only 3 bytes instead of 5 or 8.

FIGPAD

Required to assemble 3 bytes of data into 4 as shown below.

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	X	X	X	X

X = Don't Care
Font Data
3 Bytes

Steering		Data					
0	0	1	2	3	4	5	6
0	1	7	8	9	10	11	12
1	0	13	14	15	16	17	18
1	1	19	20	X	X	X	X

Output Buffer
Data 4 Bytes

Sheet 1 of 3

INTNAM

To be defined.

OUTPUT

Output 4 bytes instead of 12.

PISET

Change address from 14XX to 84XX. This also applies to OUTSET and INSET.

FIGPAD Amended Program

```
FIGPAD  JSR     LOMVAR
        STX     SC11
        LDA  A  SC1
        LSR  A
        LSR  A
        STA  A  OB, X       First Byte
        INX
        LDA  A  SC2
        LSR  A
        LSR  A
        LSR  A
        LSR  A
        STA  A  OB, X
        LDA  A  SC1
```

```
FIGPAD  ASL  A
        ASL  A
        ASL  A
        ASL  A
        AND  A   #$30
        ORA  A   #$40      Add Steering
        ORA  A   OB, X
        STA  A   OB, X     2nd Byte
        INX
        LDA  A   SC2
        ASL  A
        ASL  A
        AND  A   #$3C
        STA  A   OB, X
        LDA  A   SC3
        LRS  A
        LRS  A
        LRS  A
        LRS  A
        LRS  A
        LRS  A
        ORA  A   #$80      Add Steering
        ORA  A   OB, X
        STA  A   OB, X     Third Byte
        INX
        LDA  A   SC3
        AND  A   #$30
        ORA  A   #$C0      Add Steering
        STA  A   OB, X     Fourth Byte
        LDX  SC11          Restore X
        LDA  A   #$01
        STA  A   OBF, X    Set Butter Full Flag
        RTS                Return
```

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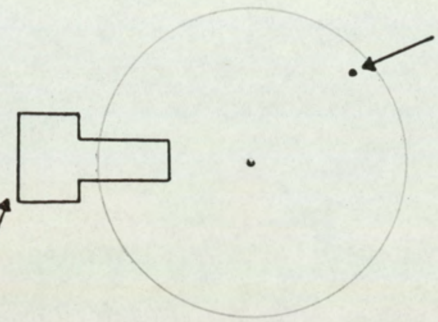
Proposal for Microprocessor Control of the Muller Mutronic Loom - Appendix 3

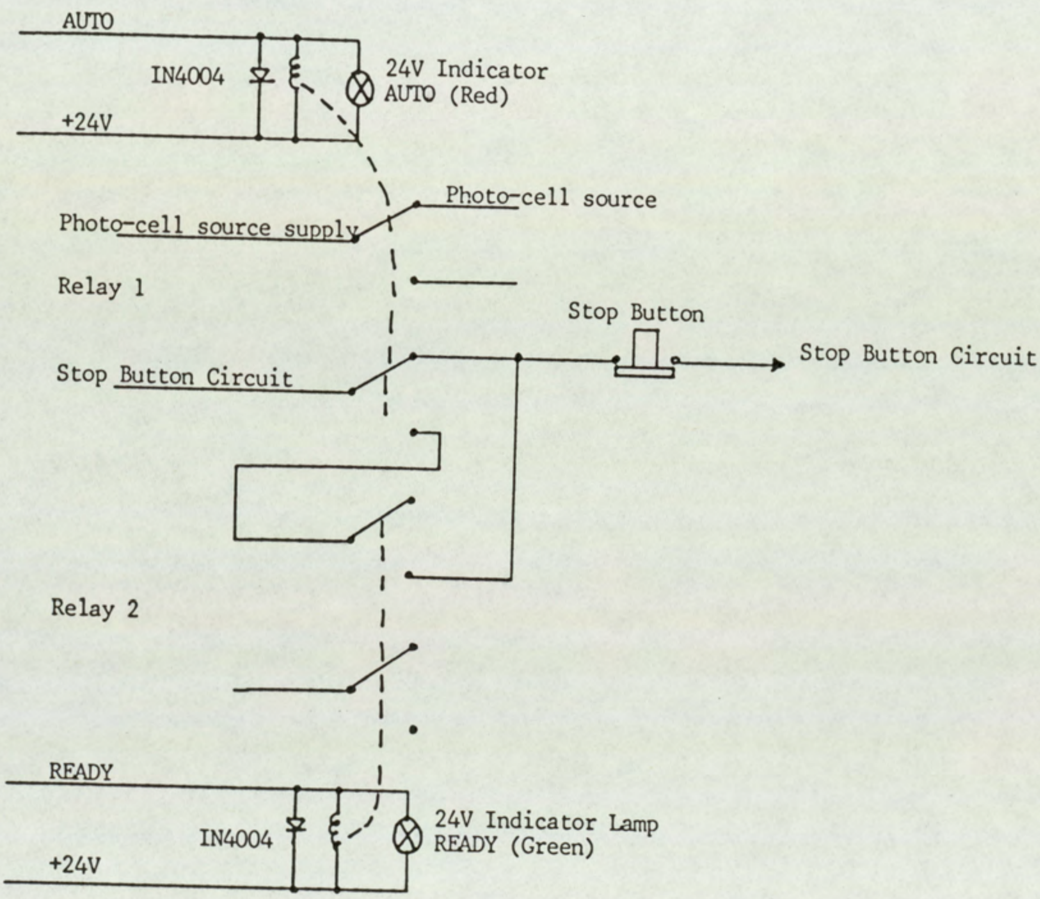
Loom Trigger



Sheet 1 of 2

Lamps and Relays

Relay 1 - Auto - Double Pole Changeover.



APPENDIX E

P.L.S. Project Report

30th July 1980

CASH'S U.K.

JCL

Lettered Strapping Meeting
to be held on
Wednesday 30th July 1980 at 2.00p.m.

A G E N D A

1. PRODUCTION

   a. Brief description of the system. CSS/JCL
   b. Loom capacity.
   c. Number of styles.
   d. Constraints on certain types of letters.
   e. Bulk orders requiring company logo's, e.g. Frames followed by Names/Initials.
   f. Number of colours and computer sort.
   g. Make-up.

2. MARKETING

   a. Method/methods to be used. Prepaid / Cash with Order / Normal Order
   b. Effect of (a) on computer invoicing system.
   c. Bulk orders requiring company logo's, e.g. Frames followed by Names/Initials.
   d. Colour requirements. Red/Brn
   e. Number of straps to be offered. 2.
   f. Packaging.

FROM:- CSS
REF:- CSS/SP
DATE:- 29/7/80

DISTRIBUTION:- AES MJK
ACA PRD
JCL ANL

CASH'S U.K.

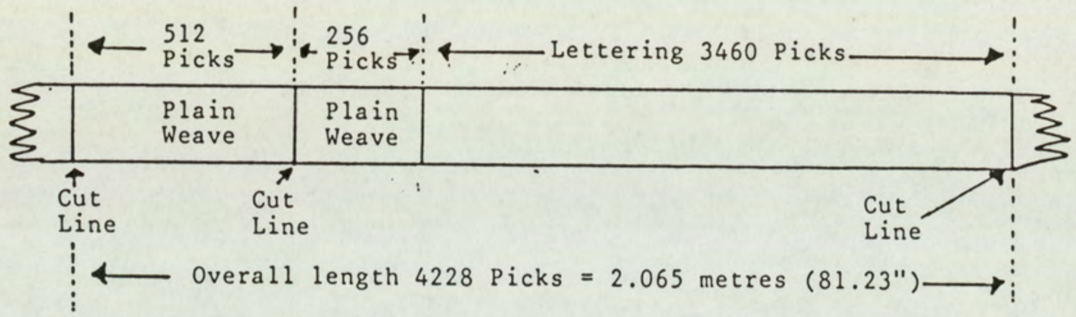
JCL/SP
30/7/80

PERSONALISED LETTERED STRAPPING

A system has been developed for weaving personalised lettered strapping on the Muller Mutronic needle loom. These straps would be made up as 'Bagstrapper'.

1. Definitions

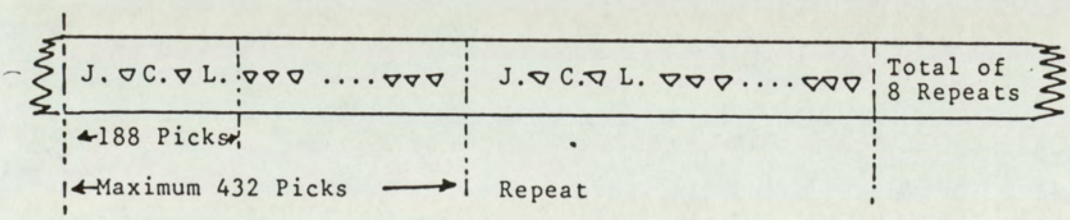
A strap of a fixed length will be produced regardless of length of name or initial as shown below.



Within the 3460 picks of lettering there are four options for repeating the Name/Initial.

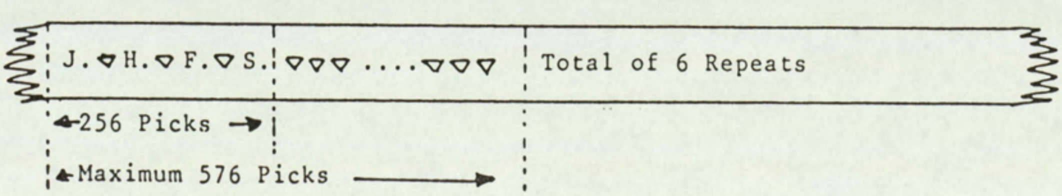
Option 1

A name/initial of not more than 188 picks, (3.6"), made up to 432 picks, (8.3"), by plain weave and dots, all repeated 8 times.



Option 2

A name/initial of not more than 256 picks, (4.9") made up to 576 picks (11"), by plain weave and dots, all repeated 6 times.



Option 3

A name/initial of not more than 336 picks, (6.5") made up to 692 picks, (13.3") by plain weave and dots, all repeated 5 times.

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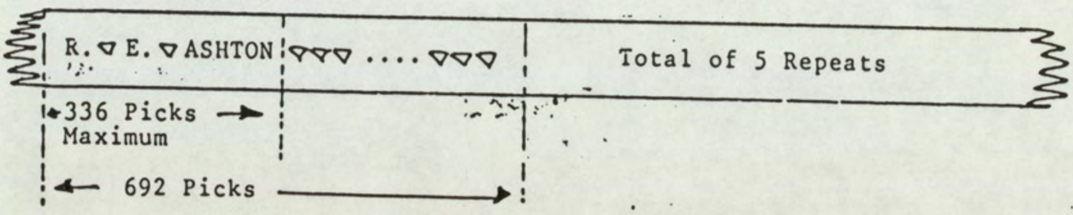
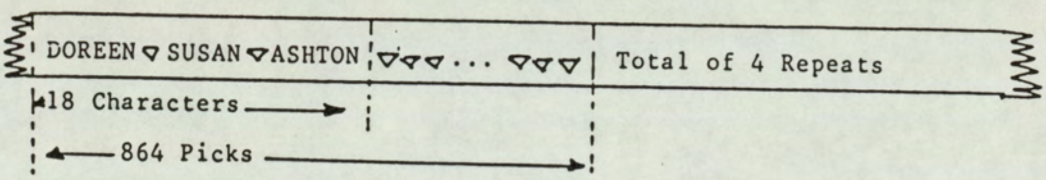
Personalised Lettered Strapping. Continued...

1. Option 3 Continued...



Option 4

A name with not more than 18 characters made up to 864 picks (16.6"), with plain weave and dots, all repeated 4 times.



A fifth option giving a three times repeat may be considered.

The decision on which option to use is made by the computer, (ICL 2903), when the order is processed and all calculations to achieve a strap of a fixed length are made by the computer. (See Appendix 'A').

2. Loom Capacity

Given a strap of a fixed length, the loom capacity in terms of orders/loom / week may be calculated as follows:

$$\frac{\text{Loom Speed (Picks/Min)} \times 60 \times \text{Shift Length}}{\text{Strap Length (Picks)}} = \text{Orders/loom/shift}$$

Loom Speed = 900 Picks/Min.
Shift Length = 7.5 hours
Strap Length = 4228 Picks

$$\frac{900 \times 60 \times 7.5}{4228} = 96 \text{ orders/loom/shift}$$

(4228 struck through, handwritten: 4180)

Assuming 80% utilisation gives approx. 76 orders/loom/shift.

With one shift working 380 orders/loom/week.

Note: One order in this case can be either two or four identical straps.

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Personalised Lettered Strapping. Continued...

3. Number of Styles

Two styles of lettering could be offered, one with both upper and lower case characters and the other with upper case only. Because the lettering height is restricted it will not be possible to put accents on the upper case vowels (e.g. Capital Ö), it will, however, be possible with the lower case vowels.

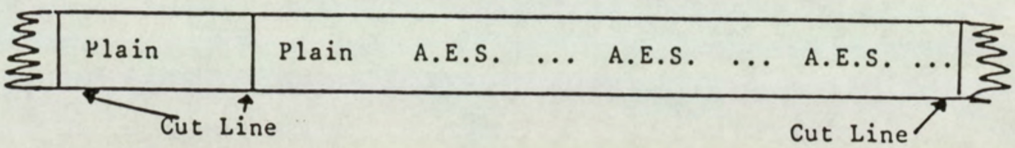
4. Special Characters and Logos

It will be possible to install a special character or logo to customer requirements providing the order quantity justifies the work necessary (i.e. design, drafting and coding). The logo once installed will be available in all styles.

5. Colours

The main strap may be dyed any colour but in order to use the existing computer sort program the number of colours will be limited to four. It will not be possible to offer a range of lettering colours.

6. Make-up



The diagram above shows that every strap has three cut line marks, these will be used by the finishing department for cutting and fusing thereby removing any need for a template. The plain weave at the beginning of each strap is of a fixed length and is used to make-up the address label section. After cutting, the make-up procedure will be identical to Bagstrapper.

J.C. Lowe.

Distribution:- AES MJK
ACA PRD
CSS ANL
PH

Personalised Lettered Strapping. Continued...

Computer Calculations

Initials: WRE

The above initials will be input to the computer as:-

W.▽R.▽E. where ▽ = one space

The number of picks is calculated as follows:-

Picks (W) + Picks (.) + Picks (▽) + Picks (R) + Picks (.) + Picks (▽) + Picks (E)
32 + 12 + 16 + 24 + 12 + 16 + 24

+ Picks (.) = Total Picks
+ 12 = 148

148 Picks is less than 188, therefore, Option 1 is adopted. i.e. Pre-defined length 432 picks repeated 8 times.

Pre-defined Length - Total Picks = Fill Picks

432 - 148 = 284

Fill picks is defined as (6 x ▽) + (N x DOT) where N is the number of dots required to fill the space available.

N is calculated by dividing the space available by 24 (one DOT has 24 picks).

Space available = Fill Picks - (6 x ▽)   ▽ = 16 Picks
= 284 - (6 x 16)
= 188

$$\therefore N = \frac{188}{24} = 7.83$$

Any remainder is disregarded ∴ N = 7

This can be expressed as:

$$N = \frac{\text{Predefined Length} - \text{Total Picks} - 96}{24}$$

and may be re-written to give Actual Pre-defined Length.

Actual Pre-defined length = (N x 24) + 96 + Total Picks
= 168 + 96 + ~~164~~ 148
= 412 Picks

The Actual Pre-defined length is now mutiplied by the Repeat Times to give Actual Strap Length.

412 x 8 = 3296

As the length required is 3460 picks there is an error of

3460 - 3296 = 164 picks

This is reduced by adding E x ▽ where E is the error divided by 16 (▽ = 16 picks).

Personalised Lettered Strapping. Continued...

$$\therefore E = \frac{164}{16} = 10.25$$

Again the remainder is disregarded ∴ E = 10

This can be expressed as:

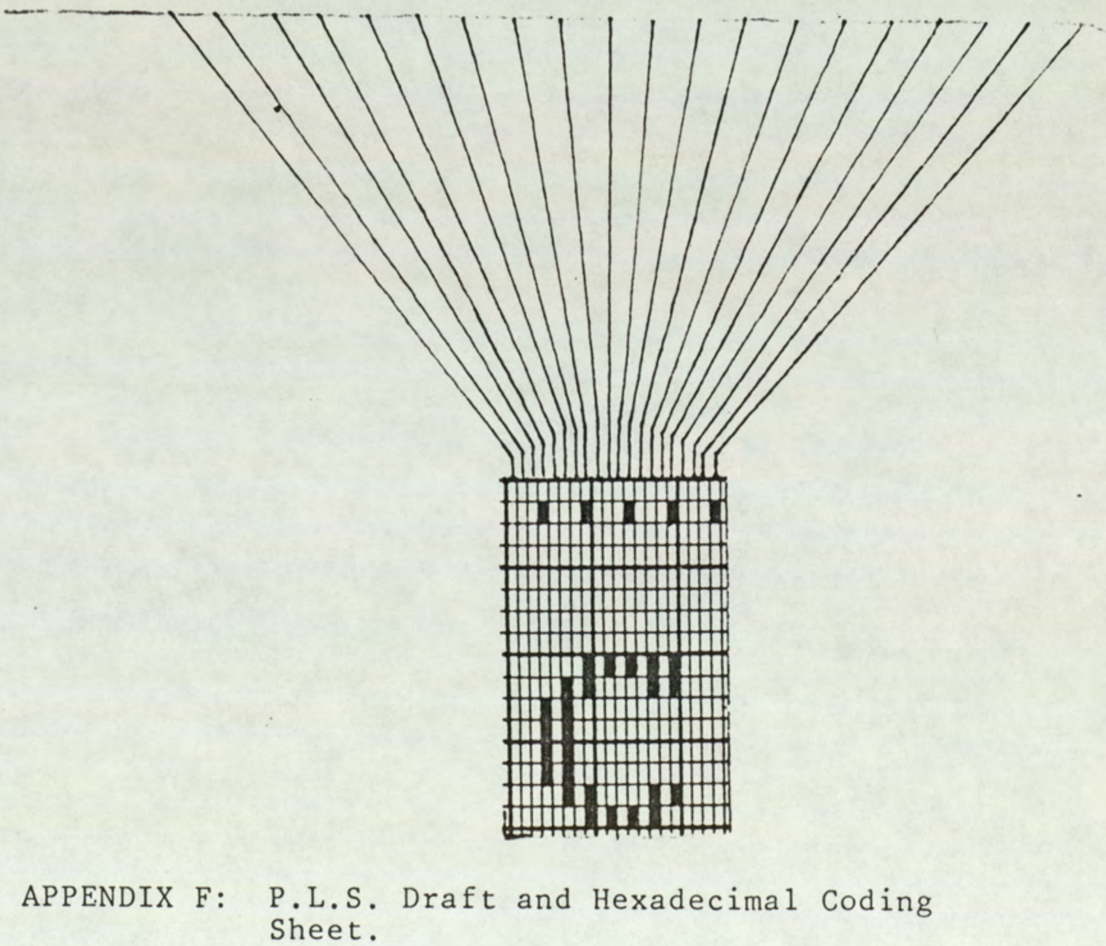
$$E = \frac{3460 - \left(\left((N \times 24) + 96 + \text{Total Picks} \right) \times \text{Repeat Times}\right)}{16}$$

This error correction procedure will produce a strap of 3456 picks instead of 3460 that is 4 picks short (.08"). The error will never be greater than 12 picks (.24") and will always produce a short strap: the error limits may be expressed as +0/-12 Picks.

All the above calculations form part of the CM44 Tape Punching program on the ICL 2903.

NUMBER OF FIGURE PICKS: 14

Pick Number 1:	3 7	F F	F 0
Pick Number 2:	5 0	0 0	0 0
Pick Number 3:	1 F	F F	F 0
Pick Number 4:	4 4	0 3	C 0
Pick Number 5:	3 7	F F	F 0
Pick Number 6:	5 0	0 7	E 0
Pick Number 7:	1 F	F F	F 0
Pick Number 8:	4 4	0 C	3 0
Pick Number 9:	3 7	F F	F 0
Pick Number 10:	5 0	0 8	1 0
Pick Number 11:	1 F	F F	F 0
Pick Number 12:	4 4	0 8	1 0
Pick Number 13:	3 7	F F	F 0
Pick Number 14:	5 0	0 C	3 0
Pick Number 15:	1 F	F F	F 0
Pick Number 16:	4 4	0 C	2 0
Pick Number 17:	3 7	F F	F 0
Pick Number 18:	5 0	0 0	0 0
Pick Number 19:	1 F	F F	F 0
Pick Number 20:	4 4	0 0	0 0



APPENDIX F: P.L.S. Draft and Hexadecimal Coding Sheet.

APPENDIX G

Cash's Product Information

[Removed for copyright reasons]