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COLLEGE OF AERONAUTICS

(Proposed Cranfield Institute of Technology)

DEPARTMENT OF PRODUCTION ENGINEERING

DESIGN PROJECT 1968/9

MANAGEMENT REPORT

THE DESIGN OF A VERSATILE AUTOMATIC ASSEMBLY MACHINE

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1. INTRODUCTION

The design of an automatic assembly machine with versatility in application was undertaken as a group project by post-graduate students attending a course in production technology. This report summarises the work done and conclusions reached during the project. In addition there are available five other reports which describe the designing of different areas of the machine in full detail (refs. 1 to 6). There is also the report of a technical survey which was carried out to investigate industrial requirements for automatic assembly. In order that this report may serve as a guide, a summary of the content of each of the other reports is included.

2. THE PRODUCTION TECHNOLOGY COURSE AND GROUP PROJECT

The aim of the production technology course at Cranfield is to provide a comprehensive education in modern production engineering, and at the same time to encourage specialisation in one of the related fields of machine tools and automation, fluid and fluidic systems, and precision engineering.

The course is made up of a number of lecture courses in various subjects, a group design project, and an individual research thesis.

The lectures attended by any one student are chosen from the range offered by different departments at Cranfield according to the student's background, past industrial experience, and his chosen specialisation.

The individual thesis, which is normally chosen in consultation with the company sponsoring the student, provides the main basis for specialisation.

The aims of the group project are, firstly to act as a unifying link for the lectures by providing opportunities for the practical application of theories developed, secondly to give experience in the varied problems of working in a group on an industrial design problem, and thirdly to provide a platform for the integration of teaching and research in the development of new automatic production systems.

During the course of the project, a board comprising staff and students meets weekly with each student taking his turn to act as secretary and chairman to the board. In the process of design specialist committees are set up by the board, and each committee is responsible for arranging its own meetings and for reporting back to the board with findings and recommendations within its field of work.

This then is the background to the machine design outlined in this report. For the group project 1968/9 the board was presented with a heavy duty switch (fig. M/01) which is manufactured in ten varieties, with the task of undertaking a design study for a versatile automatic assembly machine capable of assembling all the varieties of switch.

3. INITIAL ANALYSIS

The process of automatic assembly can be described in the following general terms.

Components to be assembled are supplied in bulk, and they must first be separated from this bulk into individual entities. Each separate component must be transported to the place of assembly and must be correctly oriented for placing. At actual assembly it must be accurately placed in the correct position. The complete process should be capable of supplying and placing the individual components in the numbers needed for the required production rate.

With this process in mind, the approach to the design problem had to satisfy two requirements. The first was to design a machine which could carry out the above assembly process for all varieties of the heavy duty switch provided, such that each variety could be assembled in batches with a minimum of changeover effort from one type to another. The second requirement was to design a machine which was versatile, so that it would be capable of being re-tooled to carry out the above assembly process for other components, perhaps also to produce assemblies in different varieties, in the same size range as the switch.

Before starting on the design of a machine of this complexity it would be normal practice to ascertain in some way the capability it should have to satisfy a major part of the market, and also to obtain some indication of the probable size and range of this market. Unfortunately the duration of the present project was such that preliminary market investigations before designing were impractical. Therefore the only guide to the capability and capacity that the machine should have was that obtained from the problems presented by the automatic assembly of the varieties and quantities of heavy duty switch.

From this it was clear that before any detailed design could start, an analysis of all the switch assemblies was required, with a breakdown into assembly stages, so that the exact tasks of the machine could be laid down. During this analysis it was necessary to remember that the switches were originally designed for manual and not automatic assembly, and it may be impractical or uneconomical to automatically assemble the components in their original form. Therefore as each component is considered for the assembly process outlined above it should also be analysed from the point of view of re-design to facilitate automatic handling.

To construct a machine capable of assembling components other than those in the switches, it follows that as little as possible of the machine should be dependent on the geometry of those components, so that changeover from one assembly to another could be made as simple and cheap as possible.

Different assemblies may also have different numbers of components and may require different assembly and fixing operations, so the size and capability of the machine need to be variable. It was considered that in theory the more likely way of achieving these needs would be to construct a machine on a modular basis, so that each machine module has a minimum dependence on any other. This should also minimise the machine dependency on any components it handles.

Even with this approach there are many possible solutions which would need investigating in detail.

After deciding the principles of design and operation of a machine it is necessary to provide means of activating and controlling it. A control system should be capable of providing motivation of any moving parts on the machine, and also synchronising and controlling these movements. It may also be desirable to provide some form of checking system in the control which could trace the process of assembly through the machine and check the progress at different stages, and perhaps provide a full automatic functional check for completed assemblies. The control system should provide for simple, central control of the machine. There are many media which could provide control systems of the type required, and these would need investigating thoroughly.

4. COMMITTEE FORMATION

After the initial analysis, it was necessary to set up committees in order that the relevant problems could be fully investigated. Firstly it was decided that although impractical to base the machine design on a survey of industrial requirements, such a survey would be very useful in assessing the final machine with regard to the demand for automatic assembly systems. It would also be interesting to compare our analysis of the problems of automatic assembly with those of other areas of industry, and to make some comparison between the assembly of the heavy duty switch and other possible components.

For these reasons a committee was formed to compile, conduct and analyse a technical survey throughout British industry.

The initial analysis showed that the project work could be broken down into four sections.

Areas of work from which the results would be dependent on the switch components were those dealing with firstly the separation, orientation and supply of the components, and secondly the analysis and provision of the actual assembly operations. It was necessary to ensure that for parts of the machine emerging from these areas a minimum part of the construction was dependent on the component geometry.

Areas of work which could be considered as being completely independent of the switch components were firstly the investigation into the basic machine principle with assembly transfer and motivation, and secondly the specification and design of a control system for the machine.

With this in mind four committees were set up to prepare the design of the versatile automatic assembly machine:

1. The Assembly Analysis and Co-ordination Committee was formed to consider the ten varieties of switch. The assemblies were to be broken down into assembly stages and re-designed if thought necessary for automatic assembly. The committee were also responsible for the specification and co-ordination of the required assembly operations, and for the design of the mechanisms needed to carry out the assembly operations that they specified.

2. The Component Supply and Separation Committee was set up to investigate the problems of supplying and separating the components for the switches. At the same time they were to consider the need for re-design of components to simplify supply and orientation. The committee was also responsible for the design of supply equipment, feeding tracks and positional escapements at the assembly head.

3. The Assembly Process Committee was formed to investigate the overall principles of machine operation which would be best for the requirements of the project. It was also the work of this committee to design the main machine structure, according to their decided principle of operation, and to provide equipment for any standard fixing operations that may be required for the switch assemblies.

4. The Control and Motivation Committee was instructed to survey ways of providing control for the designed machine, and to ascertain the best medium for control. They were also responsible for providing and controlling any movements and power that were required by the designs from other committees.

It was considered that these four committees would be able to cover all areas of the machine design. However, as their work proceeded it became evident that several mathematical and economic problems needed to be solved. It was required that cycle times be calculated for different conditions of efficiency; that breakdown probabilities be known for different qualities of components, and later on that different approaches to design be analysed and detailed costing be done. It was therefore decided that there was a need for one further committee to carry out these tasks and others of a similar nature that appeared during the project.

This committee was designated the Economic Planning Committee, and most other committees were able to receive assistance on mathematical and economic problems during the project.

A list of committee members, chairmen and staff advisors is shown in fig. M/02.

5. GENERAL ORGANISATION

In order that the complete project could be organised to finish in the time available, the work to be done by each committee was analysed in some detail, and a provisional progress chart was prepared by the management committee. A meeting of all committees enabled good estimates of the time required for each stage of the work to be made, and a final progress chart and list of events was prepared to which committees were able to work (fig. M/03 and M/04).

Weekly meetings of the management committee were held to confirm that the work of all committees was progressing satisfactorily. In some cases action was required to ensure that the work kept up to date, but the majority of the project ran slightly ahead of schedule. Discussions were held to determine the most satisfactory layout for final reports, and arrangements were made for the tracing of drawings and typing of reports.

Summaries of the work of each committee are included in the following sections. Full reports of their work are available on request (refs. 1 to 6).

6. TECHNICAL SURVEY

The technical survey committee set out to determine from industry the technical requirements for an automatic assembly machine. The 38% response to the survey showed the immense industrial interest there is in the relatively new field of automatic assembly.

Initial study of market survey techniques showed that a pilot survey was necessary to obtain the best possible results from industry. A pilot survey questionnaire was sent to 40 people, and the results obtained were used to prepare the final questionnaire. Accompanied by a letter explaining the project this was sent to the Production Director of 700 companies in the United Kingdom. Data was asked for upon one product that each company manufactured, and which they thought most suitable for automatic assembly. A letter was sent six weeks after dispatch to remind all those companies that had not already replied.

The reminder letter proved effective, giving a 30% increase in replies. The answers to each question were analysed and histograms were plotted to show the results, which are summarised below.

Of the products considered for automatic assembly, approximately 75% were of a size less than a 6 in (150 mm) cube. The most common number of components per assembly was between 17 and 20.

Two thirds of the companies who replied at present use batch assembly and the same number expected an increase in output of the product they considered for automatic assembly. The products had an average market life of 3.5 years.

For assembly, the vertical plane is by far the most commonly used, and over 80% of the components are assembled from 4 or less of the 6 sides of a cube. The most common assembly operations include locating, functional check, push or force fitting, threaded fastening, riveting and snap fitting. The machine should be capable of positioning to an accuracy of 0.001 in (0.02 mm).

If there is no space for assembly from beneath the product, when required the machine should have the ability of turning the product over. For a large majority of assemblies the placing head required movement in only two axes. When automatic assembly machines are to be used component quality should be rigorously controlled prior to assembly, and if possible improved. All assembly stations should be of modular construction such that they can be easily interchanged.

7. ASSEMBLY ANALYSIS

For an automatic assembly machine workstation layout to be successfully proposed, a detailed analysis of a chosen product to be assembled must be undertaken. This analysis must involve an investigation into the present method of assembly, the parts that make up the assembled product, and the possible and necessary areas of re-design for automatic assembly.

The assembly analysis and co-ordination committee was therefore involved in breaking down the five varieties of a contact block for an oiltight pushbutton, and making detailed comparative records of all the components required. A scheme was produced laying out the operations that the machine had to be capable of performing. This diagram is shown in M/05.

It was realised that the design of all the components of the contact block must be carefully analysed and modifications suggested to make the product suitable for automatic assembly. In consultation with the respective committees, all possible areas of design were investigated and re-designs were implemented. A reduction of four in the number of components ensued, as well as the initial object of simplification of the problems of automatic handling.

The existing manual assembly process was investigated, and detailed, and the automatic assembly sequence followed from this with the elimination of any operations obviated by the re-design of components. Sub-assemblies were investigated in detail with the reasons for the choice of manual, automatic or coupled manufacture being expounded.

In the present field of automatic assembly the tooling is mostly special purpose, costly, and often complex. It was a function of this committee to design a versatile unit to transport components from one point to another, keeping in mind that cost and re-tooling time of the machine were also of prime importance. A pick and place unit was chosen as the basis of the design because it was felt that the available motions were in themselves relatively versatile. Linear motion was chosen in preference to rotational, the unit being subdivided into three sections for easy explanation. These were the base, the head, and the claw. The requirements of each part of the unit were specified, and the design was founded on these specifications. The complete head with claws for one of the components is shown in fig. M/06.

Unfortunately the full potential of this pick-and-place unit could not be realised in its application to the assembly of the contact block.

A functional check mechanism was designed to test that the contact blocks were operating correctly.

8. COMPONENTS SUPPLY AND SEPARATION

The component supply and separation committee investigated the techniques available for automatically feeding components, and designed a feeding system for each component of the electrical contact blocks.

Before deciding upon the type of feeder required for each component it was necessary to examine each component carefully to see when characteristics would effect automatic feeding. From this investigation it was concluded that it would be extremely difficult to feed the coil spring efficiently. Also the design of the housing was such that a complicated method of orientating this part is required. There arose problems in orientating the N/O plunger and the terminal clamp, but as with the coil spring, these problems were not encountered as the parts were subsequently assembled manually. The committee decided to investigate the feasibility of re-designing the housing in order to simplify its feeding equipment. The re-design was to centralise the cut-outs (which locate contact plates) in their respective halves of the housing. Due to this housing re-design, a corresponding re-design of the contacts was necessary which increased difficulties in the feeding of these components.

All feeders which are readily available on the market were investigated for versatility and suitability for the contact block components. It was found that the vibratory bowl offered the highest degree of versatility, and therefore was used wherever possible.

The N/O and N/C plunger assemblies and the spring and cover assembly are unsuitable for automatic unscrambling, due to the fact that components of these sub-assemblies are loosely connected. Therefore it was decided to design a system where the parts are stored in a fixed orientation after assembly, and are fed to the workhead. A spiral elevator in process storage system was designed to satisfy the requirements. The system is essentially a long powered track, taking the form of a coil which can be situated between sub-assembly and main assembly positions.

The tracks used are gravity tracks, that is gravity motivates the part along the track. This results in all feeders being fixed above the assembly plane. All tracks are designed for a particular component and are such that a buffer stock of parts is provided in them to balance out any fluctuations of feedrate.

The escapements that were designed to be used on the contact block components are very much more complicated than is usually necessary. This is because the machine design required that all components be presented to the pick and place unit in the same relative positions as they are in the contact block. To do this it was necessary, in some cases, to position two or four parts at once in a fixed position relative to each other. All escapements that were designed can be used to feed one or two parts and three or four parts, depending on the components and the type of contact block.

Due to the orientation difficulties, and the shape and weight of the insulation plates, it was decided to design a head which manufactures and places the plates into the assembly. The head is placed directly over the conveyor and cuts the plates from a strip.

9. ASSEMBLY PROCESS

The committee first investigated the types of automatic assembly machines available. The advantages and disadvantages of these were evaluated when considered for the versatile assembly machine that was adopted.

The machine was based on a free transfer conveyor with a buffer stock in between each work head. The buffer stock was introduced to reduce the effective transfer time between work heads. A work holding platen was designed which had the assembly mounted upon it by means of a fixture screwed to its upper surface. At a work head it was arranged for the platen to be raised 0.125 in (3.12 mm) above the conveyor to isolate the platen from it. Therefore the above system could be subdivided into three elements:

a) The conveyor
b) The platen and fixture
c) The lifting and motivation mechanism.

These are briefly described below.

The conveyor

This is based on a slat and link mechanism (fig. M/07) which is propelled through gears which are driven by a 0.50 h.p. (375 watts) motor. The slats are shaped in a manner which allows the conveyor to be turned through angles of up to 360 degrees laterally around a minimum radius of 5.5 in (140 mm). This enables the conveyor to be continuous in the lateral plane which in turn allows the platens to be returned to the first work head after completing the circuit. The advantage is that a secondary conveyor is not required to return the platens, which reduces capital outlay.

The conveyor is made up of a number of modules (fig. M/08) of 72 in (1.83 m) long. Also corner sections have been designed to facilitate turning. The design of the modules is such that sections of the conveyor can be added or removed as workheads are changed. This makes the system more versatile as workheads are positioned adjacent to the conveyor and are not connected to it. A guard is mounted on each side of the conveyor to enable the platen to be guided when travelling between workheads.

The platen and fixture

The platen was required to be versatile in that different assemblies could be mounted upon it. This was achieved by making a platen which would be common to the system (see fig. M/09). A matrix of holes is drilled in the platen which enables either special purpose fixtures or clamps to be screwed to it. In the underside of the platen three "vee" slots are machined which locate on three hemispheres which are kinematically arranged on the lifting mechanism. This is arranged to finally position the platen under the workhead.

Mounted on the side of the platen is an accept/reject arm which is used to indicate whether the assembly mounted on the platen has had the assembly operations performed successfully or not. This mechanism is arranged to be moved into the reject position at any workhead when the assembly operation has not been completed satisfactorily. Once the arm is in the reject position the subsequent heads do not operate on that assembly.

The fixture has been designed as a special purpose unit, and therefore was required to be simple and cheap to produce. The fixture locates the body of the contact block by two holes positioned at the opposing ends, through which two pins protrude. Two holes are machined in the top of the fixture which allow the plungers of the contact block to enter, thus facilitating the assembly.

The lifting and motivation mechanism.

The lifting mechanism is designed to raise the platen above the conveyor while assembly is performed. This is shown in fig. M/10.

Incorporated with the lifting mechanism is a "buffer stop" which prevents platens moving from the buffer stock until required in the workhead (M/11). A further refinement to the system is the inclusion of the motivation system. This is used when the slowest operating cycle significantly reduces the output of assemblies. The design allows for the platen to be rapidly motivated from the buffer stock to the work head in a time considerably shorter than would be attainable under the direct motion of the conveyor. These two mechanisms are designed to be easily bolted to the conveyor where required by drilling holes in the top of the conveyor guide rails. The struts are designed to be positioned at any point of the conveyor where the workload dictates. In addition the guide rails have to be moved to allow for this, but this is easily achieved.

Fixing heads

Fixing heads were investigated and quotations obtained where possible, which were directly concerned with the assembly of the contact block. The fixing heads required were:

a) Foil blocking machine
b) Double-headed rivet machine
c) Double-headed screw running machine (2 off)
d) Screw positioning machine.

A detailed description of the operation of these workheads is included in the main report, together with information on parts feeding equipment. Fig. M/12 shows the general layout.

10. CONTROL AND MOTIVATION

To design the complete control system for the versatile automatic assembly machine it was first necessary to investigate all available practical systems of control and to select the most appropriate for the different applications on the machine.

Analysis of the problems of control for automatic assembly machines showed that the requirements could be broken down into three main functions, namely "sensing", "decision" and "action". Elements for carrying out these three functions are available in the fields of electrics, hydraulics, pneumatics and mechanics.

All the elements in these fields which merited practical consideration were investigated and compared in detail. From this investigation several practical systems for control became evident, and when considered from the particular requirements of the versatile automatic assembly machine they were narrowed down to three probable systems which could be investigated in more detail. These were:

1) micro switch and photocell electric sensors, electric relay decision logic, pneumatic cylinder action.

2) micro switch and photocell electric sensors, integrated circuit decision logic, pneumatic cylinder action.

3) fluidic sensors, turbulence amplifier decision logic, pneumatic cylinder action.

The control requirements for the machine were specified firstly to provide safe effective control, and secondly to satisfy the machine design.

Analysis showed that for safe effective control it was necessary to have a central control panel which monitored machine operations; a system to enable, as fully as possible, automatic changeover from one assembled product to another within the range for which the machine is tooled; and finally some means by which machine malfunctions could be detected and allowed for.

Areas of the designed machine which required control were, the conveyor, the platen jacking mechanism, the pick and place head, special heads, and all feeders and escapements.

An electric control console was designed, which carried indicators to show the start and finish of each assembly operation and also to give warning of empty feeder tracks or of high numbers of rejects on any assembly station. Switches to control various machine functions were also included on the panel.

As there were several varieties of switch to be assembled, each type requiring a different combination of assembly heads, a switch was provided which could be programmed through a plug board to enable automatic selection of the required combinations. A further facility was provided so that any combination of assembly stations could be selected without the need for full re-programming of the selection switch.

After full investigation related to the supplied contact block assemblies, it was found necessary to include sensors to check when assembly motions had been completed. If this completion was not detected, it could be assumed that there was some malfunction and the assembly should be rejected. A system was devised whereby platens could be marked as carrying rejects so that no further work was done on them. Statistical analysis showed that for the quality of components expected, more than three consecutive rejects could be attributed to assembly head breakdown. Therefore a counter was included to give warning on the central control panel when this occurred.

Consideration of the complete machine showed that the major areas of control would be those dealing with the control of the platen at work stations, and the control of the standard pick and place head. It was therefore decided that these two areas of control would be designed in detail in the three probable systems, so that the final system could be based on the most viable from both practical and economic considerations.

The systems were first compared from a costs point of view and the results immediately illustrated the fundamental difference between the two applications of control to the platen and to the pick and place head. In the case of the platen, where the control was largely a matter of decision logic, the electric types worked out considerably cheaper than the pneumatic type, with relays being marginally cheaper than electronics. / With the pick and place head, where the control was mainly sequential, the pneumatic type was cheaper than those based on electrics.

Taking these costs, the practical application of the various systems, and the problems of space and maintenance into account it was finally decided that for this application the best system would be to have the platen controlled using electronics with micro switch sensing and pneumatic cylinder action, while the pick and place head should use fluidic sensing and logic, controlling the pneumatic cylinder actuation.

Additional control is also included for five special heads, the conveyor, and feeders and escapements which are specified by the other design commmittees.

The complete control system is summarised on the block diagram fig. M/13 illustrating the overall modular concept.

11. ECONOMIC PLANNING

The purpose of the Economic Planning Committee was to add to the design project the facility for advisory and directive services. To expand fully the terms of reference; the work of Operations Research, Production Planning, and Finance Services were covered on a broad basis. The bias was always towards the assembly of the contact block, but the versatility of the machine was taken into account in every category of the workload. Evidence which emerged at an early stage of the project showed the likely unsuitability of the contact block for automatic assembly. For this reason the work was oriented strongly towards the aspects of the general approach to automatic assembly, and to veraatility as a main characteristic.

Major problems are inherent in automatic assembly devices and allowances in design of the machine must be made to minimise the effects of undesirable characteristics. The effects of parts quality and difficulties of assembly of some components create the majority of problems resulting in lost production time. A thorough value analysis of any assembly considered for automatic assembly is warranted, considering the above facts, to reduce the assembly materials cost. This is emphasised later.

The most effective method of minimising the effect of defective parts is to provide independent operation of assembly stations, with a free float of part assemblies between them. The system is termed 'free transfer' and the float of assemblies is termed 'buffer stock'. A computer program made available by Salford University gave the facility for plotting a graph of increase of efficiency against increase of buffer stock size. With some additional calculations it became possible to show the optimum size of the buffer stock under various conditions. The summary of this work was a buffer stock of:

1) 3 units for minimum floor space cost.
2) 5 units for the minimum practical size.
3) 7 units to give the highest effective efficiency per buffer increment.
4) 10 units to allow access for standby operators.
5) 13 units to provide the highest possible efficiency for the machine configuration as designed.

Optimisation of the cycle time was provided to meet the annual output target. The results were a cycle time of:

4 seconds when working 8 hours per day.
4 to 5.8 seconds when working 12 hours per day.
5.3 to 7.8 seconds when working 16 hours per day.

From these figures the practical cycle time achieved will clearly define the conditions of working.

Methods of calculating reliability and acceptance test data were stated. Reliability cannot be assessed quantitively without specific design information on equipment life or test data from the machine in operation. General principles to maintain high reliability include simplification of equipment and reduction of interdependent parts.

The number of standby operators which are necessary to produce the highest cost savings is two. These may be machine attendants or manual assembly operators since they should be required for a short time at infrequent intervals.

Planned maintenance is another vital factor in maintaining high machine output and a scheme is provided at an estimated cost of £3,500 per year.

With the introduction of these new staff classifications the problems involved in labour relations would require a labour agreement in the initial stages of machine operation to avoid industrial dispute.

These factors mentioned summarise the areas of investigation into the technical aspects of the machine designed in particular, and automatic assembly systems in general.

A technical problem which tends to encroach upon the financial aspect is the production of unacceptable part or whole assemblies. Since the machine will only assemble parts of a certain nature more rejects will be produced than in manual assembly, where operators can overcome some deficiencies. The cost of breaking down part, or whole assemblies is a necessary expense where assembly parts costs are high. Ideally the parts should be cheap compared with assembly cost in which case unacceptable assemblies can be discarded.

The automatic machine system is shown to be much better than the existing system of assembly on a cost basis by £41,900 extra profit per year. When considering the idealised mechanised manual method of assembly it was found that this profit would be £6,150 p.a. less, but this is offset by a cost of £11,500 p.a. in machine maintenance and efficiency loss in the automatic system. The nett effect is that the mechanised manual assembly provides greater profit. This is due to the unsuitability of the contact block based on cost savings alone. It was concluded that the contact block was best suited to mechanised manual assembly due to its high materials to labour ratio. By the use of manual assembly the high cost of servicing, 23% loss of efficiency, and the cost of maintenance is reduced. Large cost savings are to be found where suitable assembly operations are to be produced. This is generally the case when labour costs are high compared with material costs. Other points to be noted are that labour costs are constantly rising when machine costs are not, and labour brings personnel problems that are difficult to cost.

The cost of the machine was estimated as £29,000 which was within the figure of £35,000 estimated, from a mail survey carried out, as the price that industry would pay. This capital expenditure was acceptable under D.C.F. methods and acceptable depreciation schemes were laid down.

An investigation into marketing of the machine as a modular system showed purchase by instalments to be an advantage and generally suggested that this proposition would be profitable for both lessee and lessor.

12. CONCLUSIONS

This project has dealt with the complete design of an automatic assembly machine, and although most of the board members had little or no experience in the field at the start they were in consequence able to approach the problems that appeared from an unbiased and fundamental point of view. With this approach the main problems of automatic assembly became very clear, and the added task of developing a system for versatile application accentuated these problems.

The first and probably the major problem that was encountered applies to any form of automatic assembly and it can be summarised in the word "components".

Components come in different shapes, sizes, weights, qualities, different orders of cleanliness, and have to be handled in different quantities. Variation in each of these parameters presents a problem for automatic assembly. Because of the variation of shape and size it is completely impractical to try and standardize on a method for supplying components, especially as for each application the rate of supply and the required orientation of the particular component would probably be completely different. It may be possible to standardise on basic parts of a feeding device for a range of components of similar size, such as a bowl feeder, but in general the separation and orientation of components is completely component dependent and cannot be satisfactorily standardised for the purposes of versatility.

Quality of components is important especially when applying automatic assembly to a product already in production by other means. In manual assembly a bad component is rejected by the assembler, or else adapted to fit. Automatic machines can sort to a certain extent but bad components will still get through. To safe-guard the machine it is necessary to provide a high standard of components guaranteed by the manufacturer. Provision of this guarantee will cost money and is another parameter to be taken into account during any discussion on the economics of provision of automatic assembly for a product.

Similar arguments apply when the cleanliness of components is considered. Components can be manually assembled in a state of cleanliness which would cause automatic feeders and handling devices to jam with oil and swarf. It is essential that any components for automatic assembly be supplied in a clean state so that breakdown for these reasons can be minimised.

For actual assembly the simpler the geometry of the component, and the wider the assembly tolerance, then the more straightforward is the assembly problem. The more complex the shape, and the tighter the assembly fit, then the more likely is there to be some problem in practically applying a solution that in theory seems perfect.

With a large number of components to be assembled into one assembly, the problems of each individual component and assembly operation are summated so that the probability of difficulty is increased considerably. This probability increases beyond the bounds of practicability when the supplied quantities of components are other than perfect.

Thus summarising the problems of components to be handled it is ideal to have a small number of simple components which require to be placed with a low order of accuracy, and which are supplied in a clean state with a 100% guarantee of quality.

Unfortunately the practical state is never the same as the ideal, and the assembly presented for consideration in this project was no exception. There were over thirty components in some of the switch varieties, many of which were complex shapes which required accurate placing. Although in this case the components were supplied in a relatively clean state their guaranteed quality was not as high as is desirable.

It was evident from the results of the technical survey that this is a common problem. One of the reasons therefore why a free transfer system was adopted for the proposed machine was so that larger numbers of components could be handled with the effects of breakdown through faulty components being kept at a minimum.

In addition the free flow transfer system was selected because it presented the best overall solution for the problems presented by a demand for versatility. It must however be noted that for special purpose automatic assembly machines an indexing principle may well be more desirable, with or without in-process float, and that the ideal system for a particular application would depend both on the size of the assembly and components, and the order of accuracy of assembly required.

The machine design incorporates a standard head which is designed to pick parts from a supply line and to place them accurately into position in the assembly. It was required for the purposes of versatility that the control of this pick and place motion be very flexible, able to be stopped in different positions according to signals from the control system, and also to be easily variable in position and speed of operation for resetting for different assembly operations. Because of these requirements it became necessary to control the head using pneumatic cylinders controlled sequentially by fluidics. It must be pointed out that the main reasons for the use of fluidics were the advantages of fluidic sensing for sequence operation to give the required sophisticated degree of control. In the investigation into control systems it became clear that if an assembly machine were devised where a lesser degree of control was required then greater reliability, precision, and speed of operation could be obtained using a system in which the sequential control was provided by mechanical means, probably in the form of cams on a central camshaft.

Another point that became evident during the control system investigation was that for a particular machine there is no straightforward ideal means of control, and any control system and the control media used is completely dependent on the function of that particular area of the machine.

Considerable problems have been encountered in trying to tailor a general system to handle the particular components in question. Although some re-design of individual components has been suggested to facilitate certain areas of automatic handling, it has become clear that in principle it is wrong to design an automatic assembly machine to assemble an existing product. In the ideal case a product should be designed from the outset so that the components are suitable for automatic feeding and automatic assembly. In other words before embarking on a design for an automatic assembly machine it is necessary to carry out a complete value analysis so that the suitability of the product and its components for automatic assembly may be determined and the practicability and economics of re-design for this purpose may be fully investigated. This should include consideration of component materials, tolerances, and all alternative methods of manufacture and assembly. Only then should the detailed problems of assembly be considered. In the case of the proposed versatile system the advantages of versatility could only be fully utilised if products are designed with the system in view. In this way the problems of adapting the system to suit the unique complexities of existing components would be avoided.

When the principle of designing for an assembly system is accepted the possibilities of development in this area become more apparent. Products could be designed with common components so that by assembling in various ways the same elements make up different resulting assemblies. Taken even further there is the possibility that with components designed for automatic assembly, the assembly system could be formulated to enable details of the components to be dialed in so that re-tooling and setting of assembly cycles is automatic, thus providing a true "assembly centre".

One of the major points resulting from investigations into the economics of automatic assembly has hi-lighted the rather obvious fact that machines that assemble components present savings in the cost of assembling, and cannot reduce the cost of materials contained in the assembly. Indeed as has been pointed out, there may even be a necessity for increasing the materials cost in order to guarantee the required quality. From this it is plain that one of the first considerations when looking at the feasibility of automatic assembly for a particular product is whether the proportion of labour costs in assembly is a significantly large enough portion of the total cost to justify automation. Included in this consideration must be an appreciation of the effect of rising labour costs with particular reference to the significance of equal pay for female operators.

A good example of this is the heavy duty switch selected for this project. Although it has been shown that to a certain degree automatic assembly is possible, the labour to parts cost ratio at the present time is such that automatic assembly of any kind cannot be justified. Together with the high numbers of parts and their complexity, this last factor determines that the contact block is unsuited to automatic assembly from an economic point of view, and to some extent also from the practical aspect.

Summarising, it must be emphasised that the suitability and economic viability of automatic assembly applied to a product must be fully justified before it is attempted. Although the contact block turned out unsuited to the application, this in no way detracts from the suitability of the system designed or from the possibilities for versatile automatic assembly systems in the future. Analysis of the technical survey returns illustrated that the machine designed would satisfy a large proportion of present industrial requirements. It is predicted that with the growing emphasis on variety of products this type of system will find a steadily increasing application in the future. However, progress is likely to be slow until automatic assembly is a major consideration in product design.

REFERENCES

1. - Technical Survey Committee Report. CoA Memo No. 186

2. - Assembly Analysis Committee Report. CoA Memo No. 189

3. - Component Supply and Separation Committee Report. CoA Memo No. 193

4. - Assembly Process Committee Report. CoA Memo No. 194

5. - Control and Motivation Committee Report. CoA Memo No. 195

6. - Economic Planning Committee Report. CoA Memo No. 196.

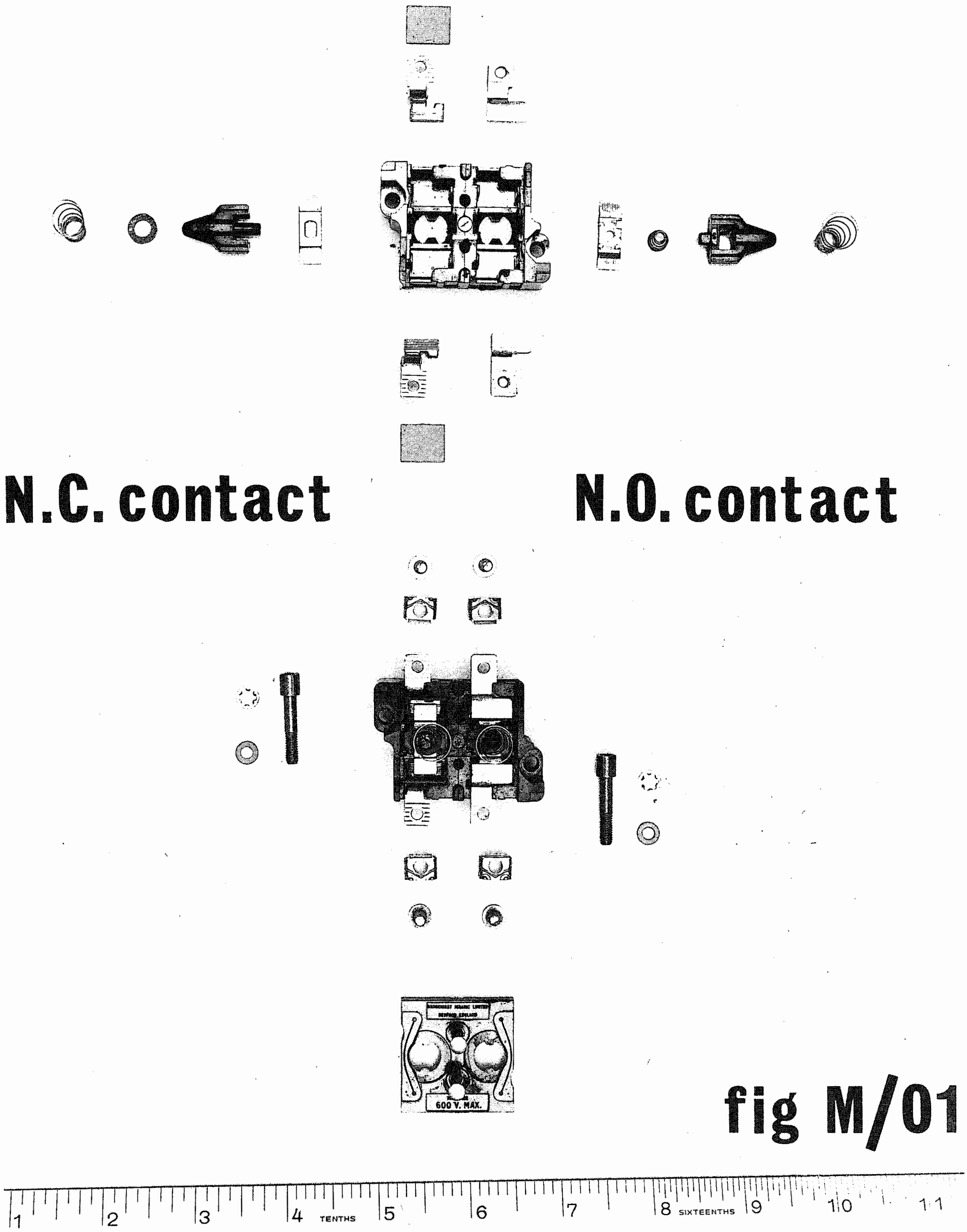


fig M/01

CHART OF COMMITTEE MEMBERS

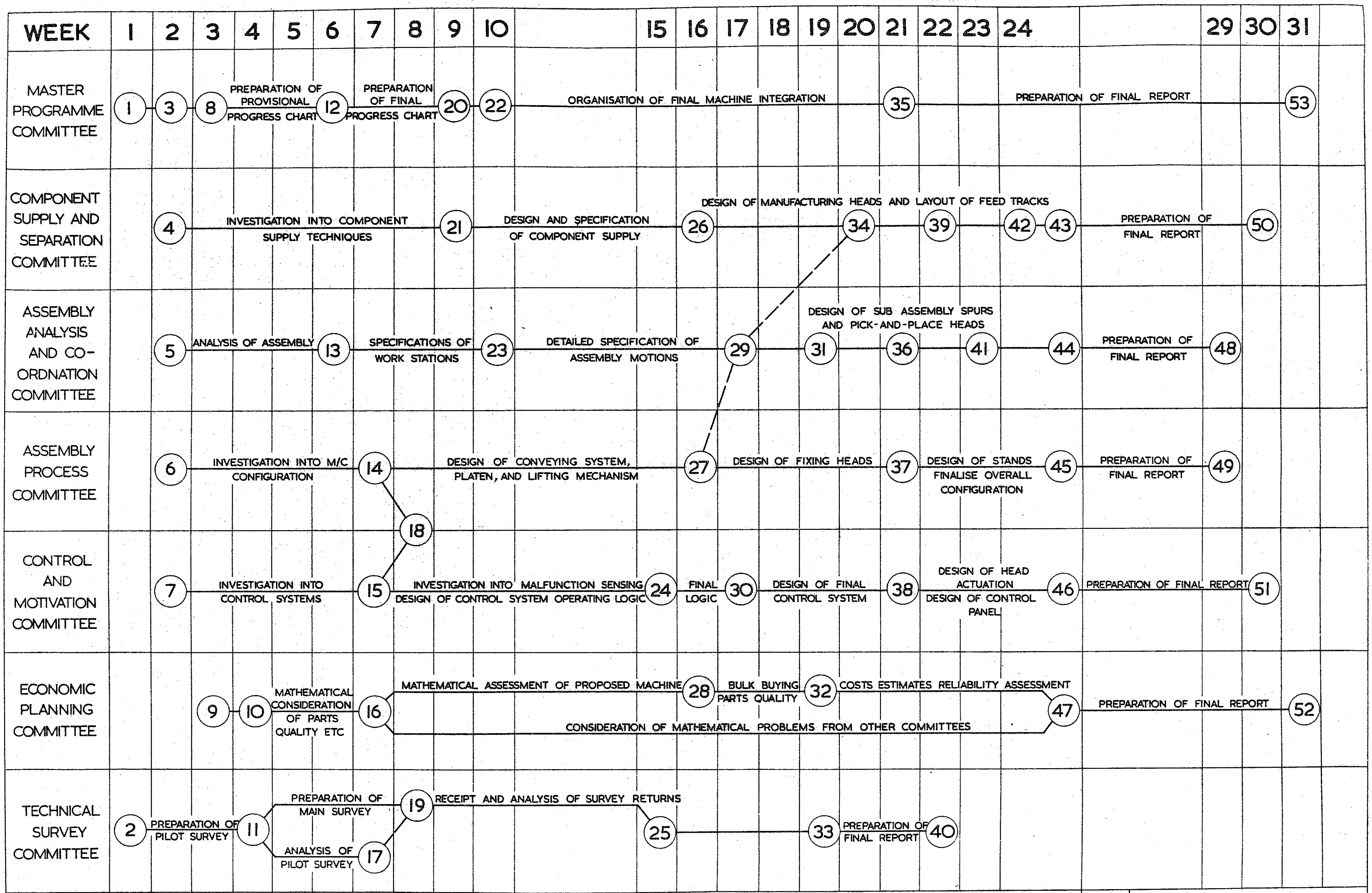
C : Chairman

M : Member

A : Advisor

	Management	Assembly Process	Assembly Analysis	Component Supply	Control and Motivation	Economic Planning	Technical Survey
C. Brindavan	M	M					
A. Gray				C	M		
D. Hayes		C		M			
P. Jones	M			M		C	
U. Kaloo						M	
A. Kimber	C				M		
G. LeHunte					M		C
M. Pettitt			M			M	
C. Shaw	M	M	C				
K. Stout	M	M					M
D. Wrigglesworth			M			C	
Staff Advisors:							
C. J. Charnley	A						A
Dr. D. Leete		A				A	
A. Scarr				A			
S. Ramanathan					A		
A. J. Palmer			A				
R. E. Bidgood					A		
E. Powell					A		A

Fig. M/02



GROUP PROJECT 1968-9 PROGRESS CHART

1968/69 GROUP DESIGN PROJECT	
TITLE :- PROGRESS CHART	DRG. Nº M/03

EVENT LIST

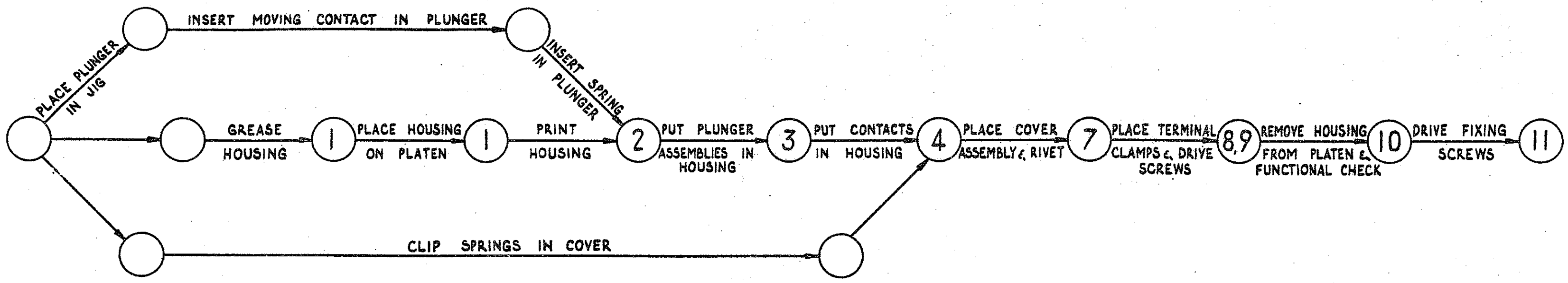
WEEK No.	EVENT No.	COMMITTEE	EVENT
1	1	M.	Formation of Management Committee
	2	T.S.	Formation of Technical Survey Committee
2	3	M.	First report
	4	C.S.	Formation of Component Supply and Separation Committee
	5	A.A.	Formation of Assembly Analysis Committee
	6	A.P.	Formation of Assembly Process Committee
	7	C.M.	Formation of Control and Motivation Committee
3	8	M.	Second Report
	9	E.P.	Formation of Economic Planning Committee
4	10	E.P.	Statement - Cycle time calculation
	11	T.S.	Dispatch of Pilot Survey
6	12	M.	Provisional Project Progress Chart
	13	A.A.	Statement - Assembly analysis charts
7	14	A.P.	Statement - M/C configuration investigation
	15	C.M.	Statement - Control system investigation
	16	E.P.	Statement - Loading times, Quality of parts, Configuration
	17	T.S.	Completion of pilot survey analysis
8	18	A.P. C.M.	Joint statement. M/C Configuration
	19	T.S.	Dispatch of main survey
9	20	M.	Statement - Drawing numbers, future statements
	21	C.S.	Statement - Provisional component supply
10	22	M.	Final progress charts
	23	A.A.	Statement - Detail of work stations, parts orientation
15	24	C.M.	Statement - Malfunction sensing, rejection
	25	T.S.	Progress
16	26	C.S.	Statement - Specification of feeding and orientation devices
	27	A.P.	Statement - Designs for conveying system, platen and lifting mechanism
	28	E.P.	Statement - Preliminary machine assessment

Fig. M/04

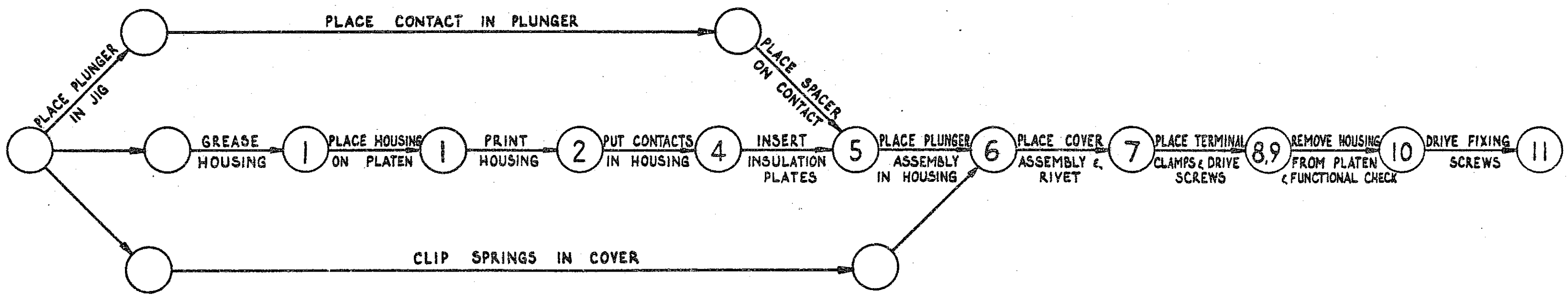
EVENT LIST (cont.)

WEEK No.	EVENT No.	COMMITTEE	EVENT
17	29	A.A.	Statement - Movement and size of each assembly head
	30	C.M.	Statement - Control circuit logic. Outline of four practical systems
19	31	A.A.	Progress - Design of pick and place heads and sub-assembly spurs
	32	E.P.	Statement - Parts quality, bulk buying
	33	T.S.	Statement - General summary of survey returns
20	34	C.S.	Progress - Layout of feed tracks, design of manufacturing heads
21	35	M.	Statement - Final machine integration, standardization of final reports
	36	A.A.	Progress 2
	37	A.P.	Statement - Design of fixing heads
	38	C.M.	Statement - Finalised control system
22	39	C.S.	Progress - Design of escapements
	40	T.S.	Final report
23	41	A.A.	Progress 3
24	42	C.S.	Progress - Design of manufacturing heads
	43	C.S.	Statement - Summary of state of work
	44	A.A.	Statement - Summary of state of work
	45	A.P.	Statement - Summary of state of work
	46	C.M.	Statement - Summary of state of work
	47	E.P.	Statement - Costs estimates; reliability assessment
29	48	A.A.	Final report
	49	A.P.	Final report
30	50	C.S.	Final report
	51	C.M.	Final report
31	52	E.P.	Final report
	53	M.	Final report.

Fig. M/04 (cont.)

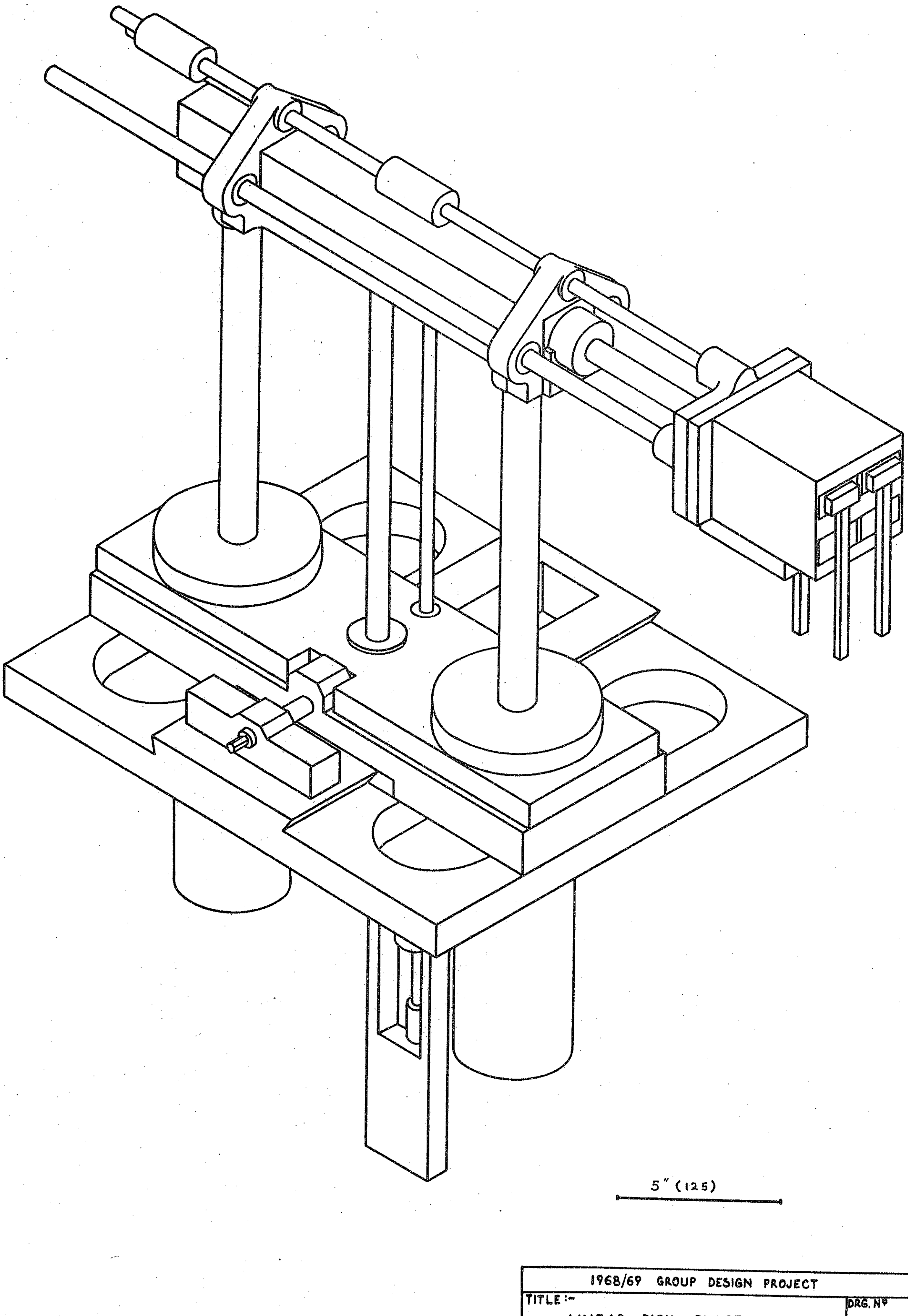


N.O. CONTACT BRIDGE



N.C. CONTACT BRIDGE

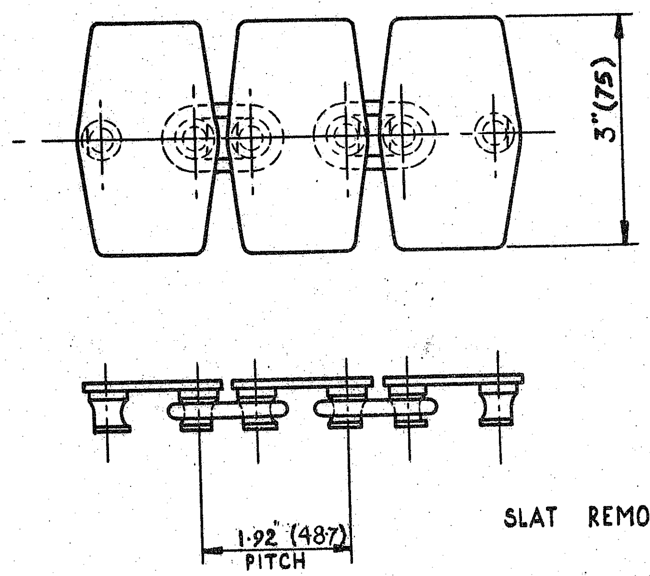
1968/69 GROUP DESIGN PROJECT	
TITLE:- ASSEMBLY FLOWCHART	DRG. No M/05



1968/69 GROUP DESIGN PROJECT

TITLE:- LINEAR PICK & PLACE UNIT

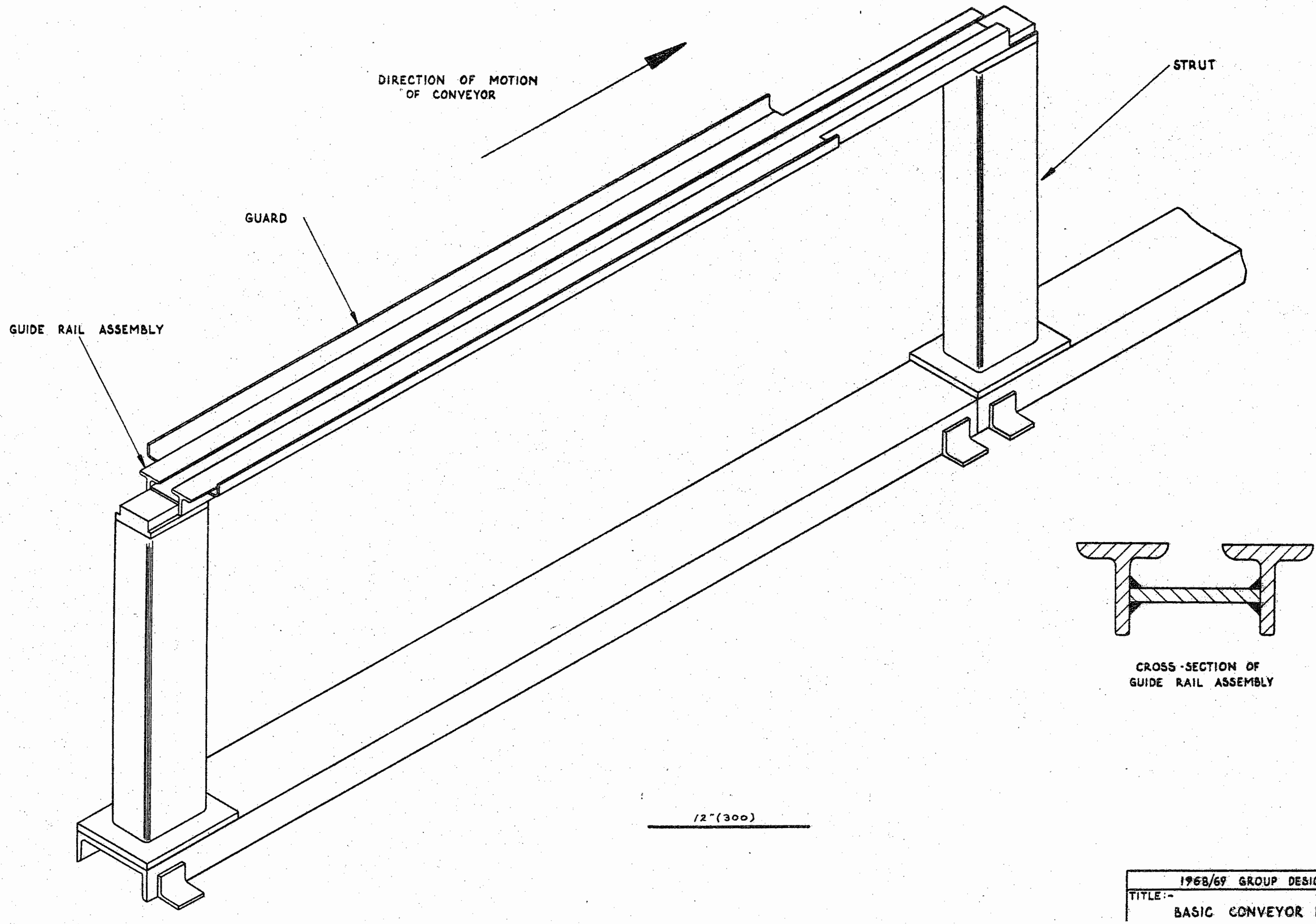
DRG. Nº M/06



SLAT REMOVABLE

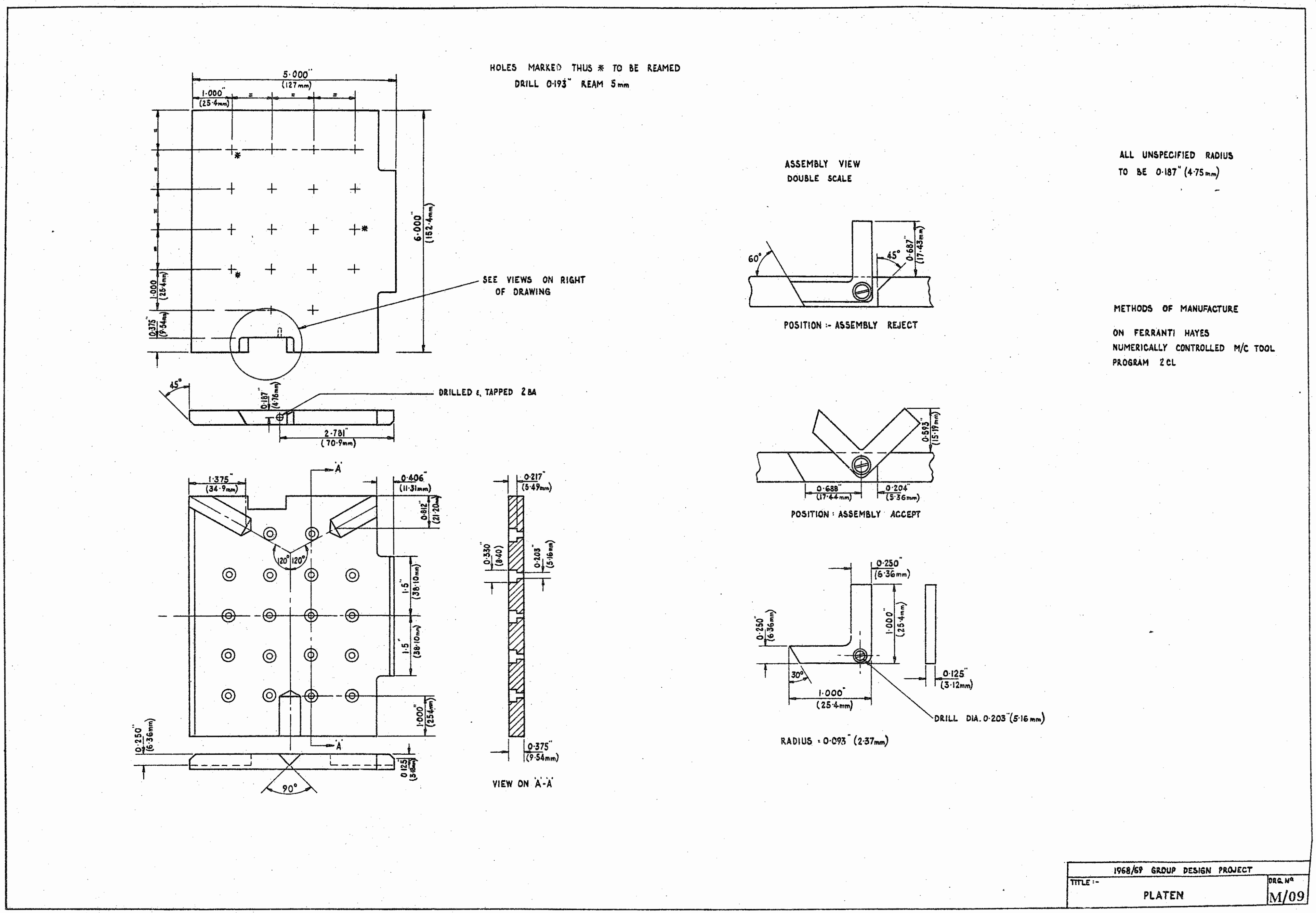
CHAIN IS REQUIRED TO BE SUPPORTED ON UNDERSIDE.

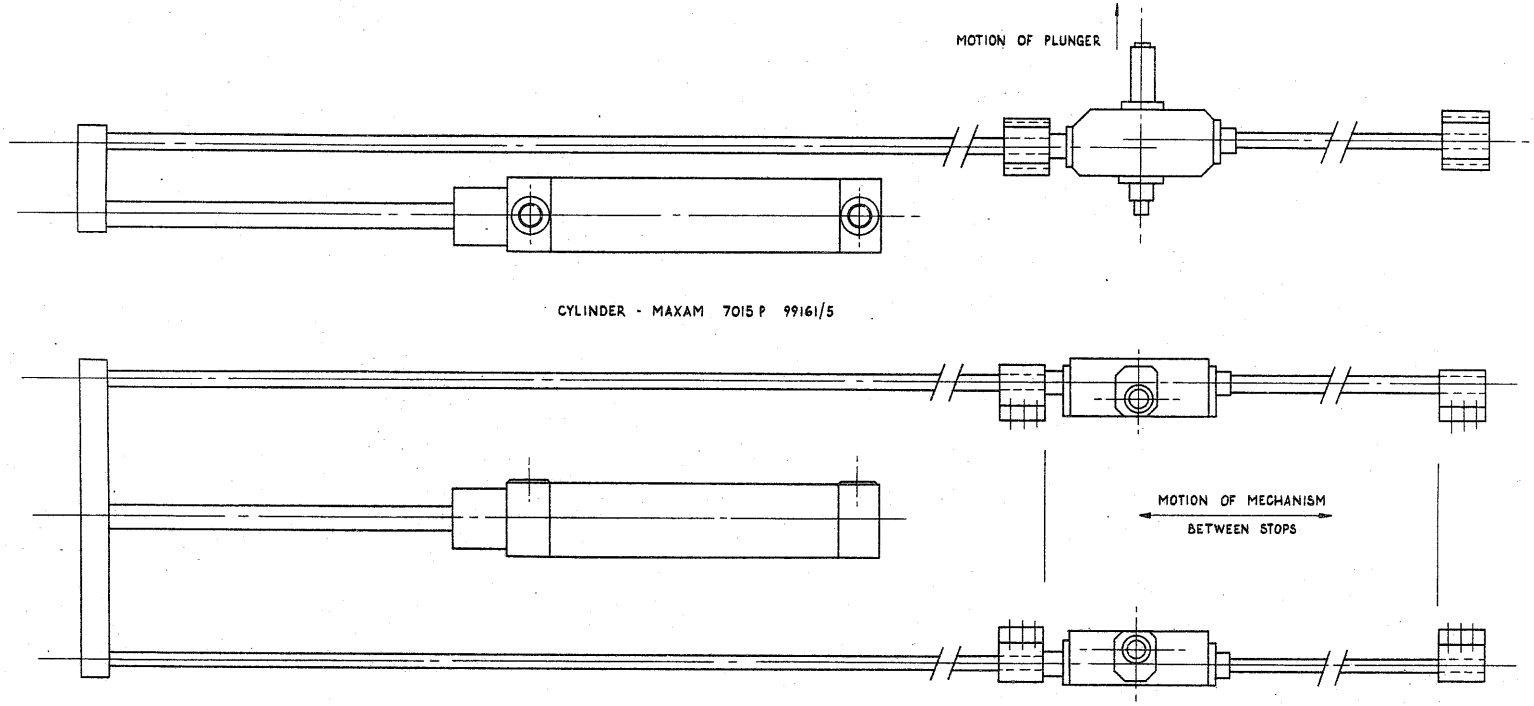
1968/69 GROUP DESIGN PROJECT	
TITLE :- SLAT & LINK ASSEMBLY	DRG. Nº M/07



CROSS-SECTION OF
GUIDE RAIL ASSEMBLY

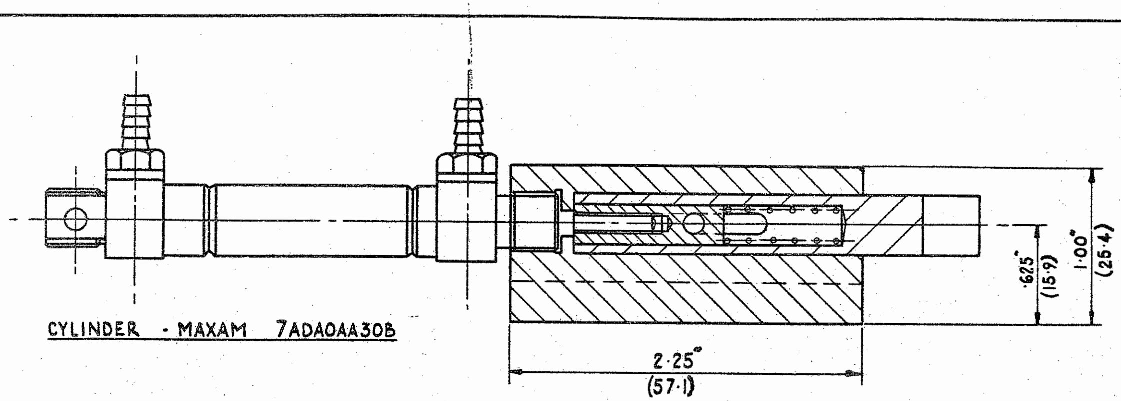
1968/69 GROUP DESIGN PROJECT	
TITLE:- BASIC CONVEYOR MODULE	DRG. Nº M/08


HOLES MARKED THUS ✻ TO BE REAMED
DRILL 0·193" REAM 5mm
5·000" (127mm)
1·000" (25·4mm)
6·000" (152·4mm)
1·000 (25·4mm)
0·375" (9·54mm)
SEE VIEWS ON RIGHT OF DRAWING
45°
0·187" (4·76mm)
DRILLED & TAPPED 2BA
2·781" (70·9mm)
1·375" (34·9mm)
0·606" (11·31mm)
0·812" (21·20mm)
120° 120°
1·5" (38·10mm)
1·5" (38·10mm)
1·000" (25·4mm)
0·250" (6·36mm)
0·125" (3·18mm)
90°
A A
0·217" (5·49mm)
0·330" (8·40)
0·203" (5·16mm)
0·375" (9·54mm)
VIEW ON 'A'-'A'
ASSEMBLY VIEW
DOUBLE SCALE
60°
45°
0·687" (17·43mm)
POSITION :- ASSEMBLY REJECT
0·593" (15·19mm)
0·688" (17·44mm)
0·204" (5·36mm)
POSITION : ASSEMBLY ACCEPT
0·250" (6·36mm)
1·000" (25·4mm)
0·250" (6·36mm)
30°
1·000" (25·4mm)
0·125" (3·12mm)
DRILL DIA. 0·203" (5·16mm)
RADIUS = 0·093" (2·37mm)
ALL UNSPECIFIED RADIUS TO BE 0·187" (4·75mm)
METHODS OF MANUFACTURE
ON FERRANTI HAYES NUMERICALLY CONTROLLED M/C TOOL PROGRAM 2CL
1968/69 GROUP DESIGN PROJECT
TITLE :- PLATEN
DRG. No M/09



NOTE - THIS DRAWING IS NOT TO SCALE

1968/69 GROUP DESIGN PROJECT	
TITLE:- COMPLETE FAST INPUT MECHANISM	DRG. Nº M/10



REQUIRED - PER WORKHEAD

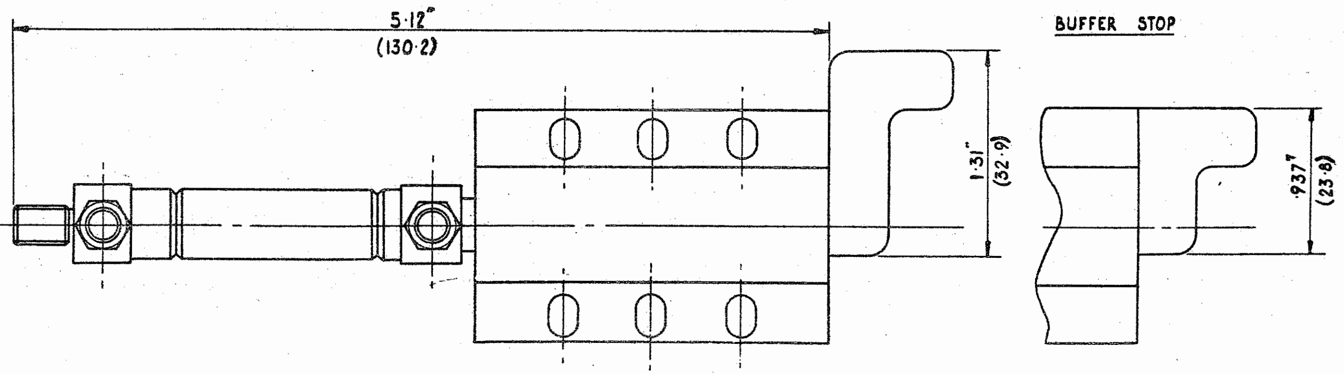
2 STATION STOPS - 1 R.H. & 1 L.H.

2 BUFFER STOPS - 1 R.H. & 1 L.H.

STROKE OF STOPS - 3/8" (9·5)

STATION STOP

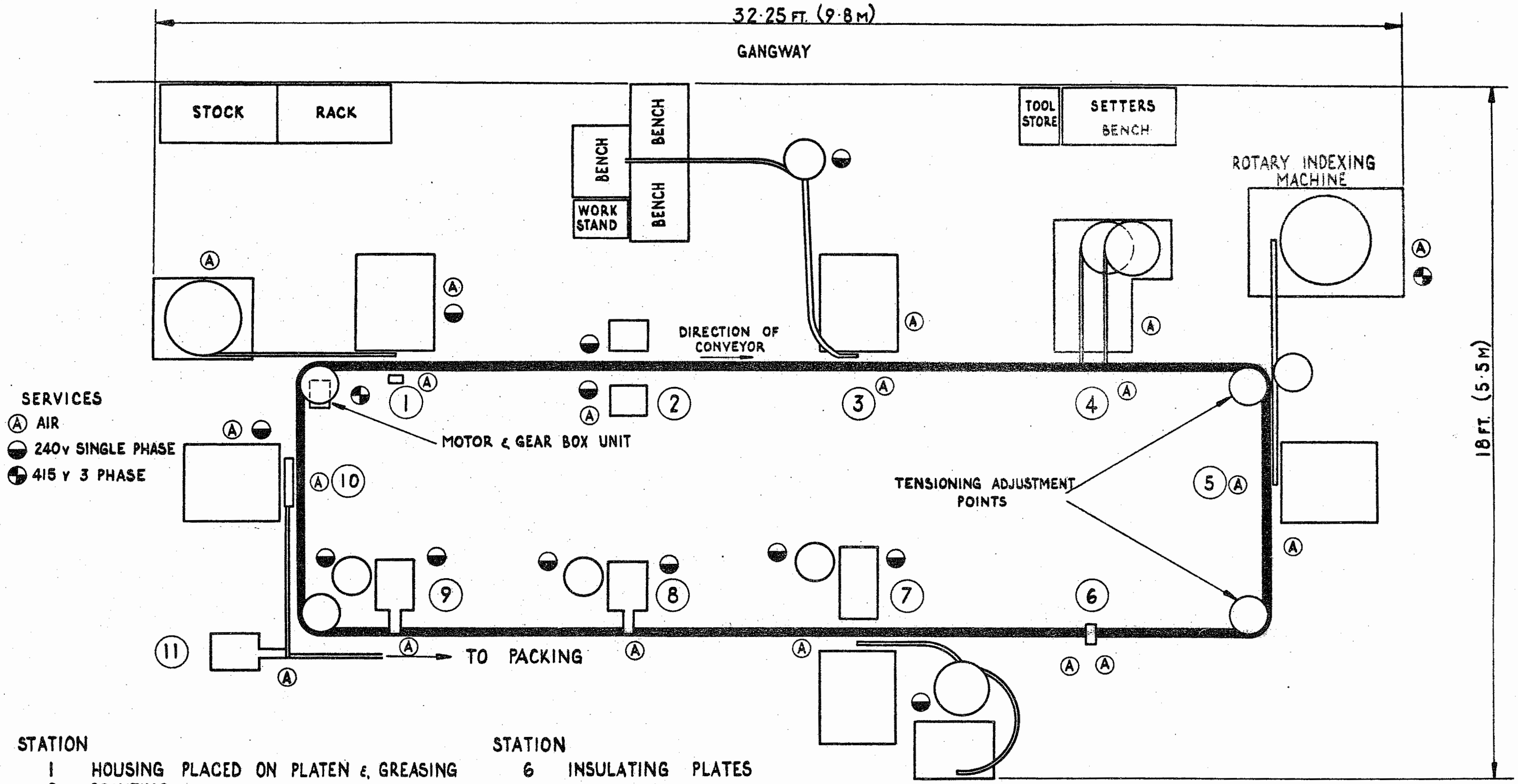
BUFFER STOP



1968/69 GROUP DESIGN PROJECT

TITLE:- BUFFER & STATION STOPS

DRG. Nº M/11



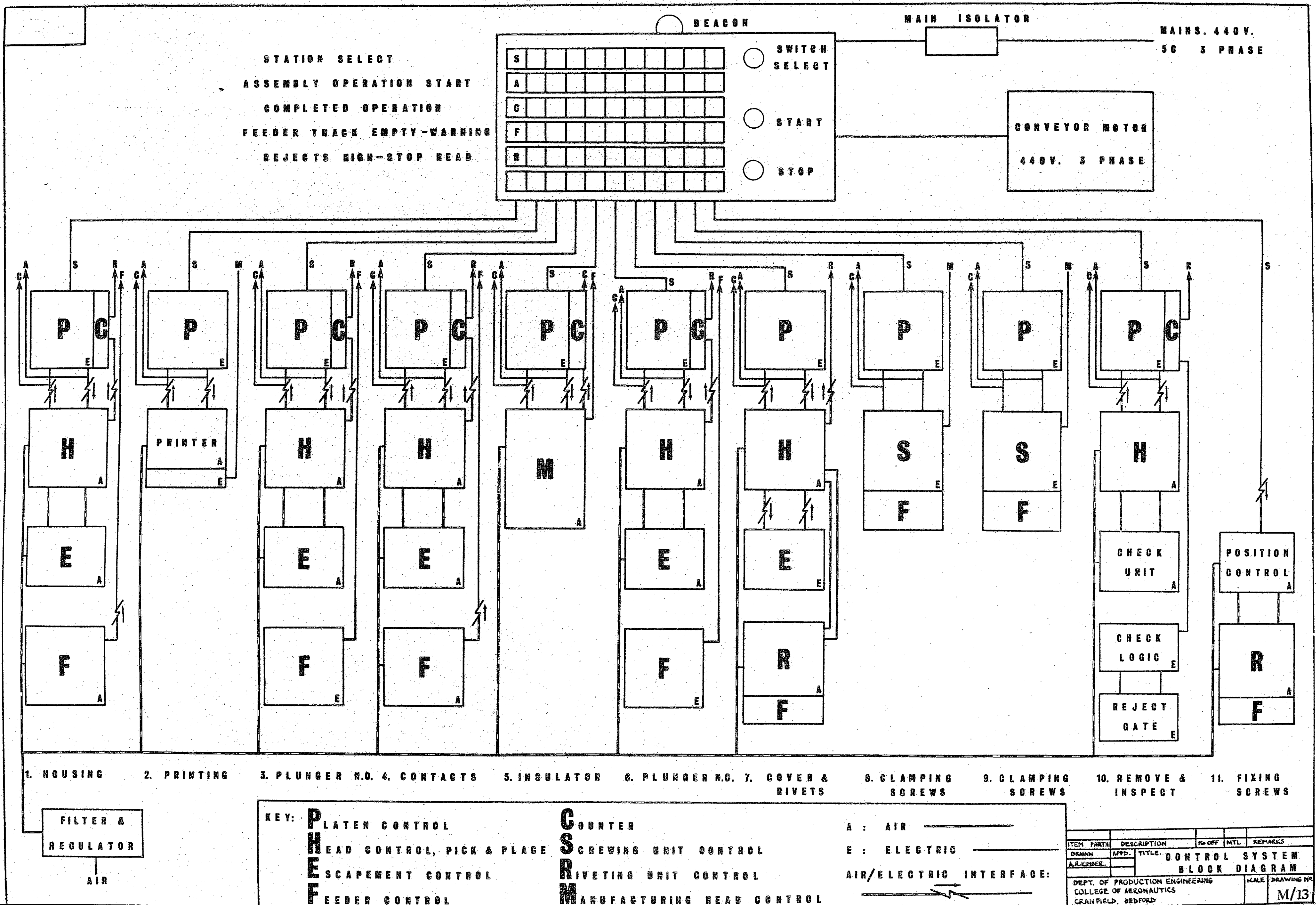
STATION

1 HOUSING PLACED ON PLATEN & GREASING
2 PRINTING
3 N/O PLUNGER
4 N/O AND/OR N/O FIXED CONTACTS
5 N/C PLUNGER

STATION

6 INSULATING PLATES
7 COVER & SPRINGS ~ RIVETING
8 TERMINAL SCREWS
9 TERMINAL SCREWS
10 FUNCTIONAL CHECK
11 FIXING SCREWS

1968/69 GROUP DESIGN PROJECT	
TITLE:- GENERAL LAYOUT OF MACHINE FOR CONTACT BLOCK.	DRG. Nº M/12


BEACON
MAIN ISOLATOR
MAINS. 440V. 50 3 PHASE
STATION SELECT
ASSEMBLY OPERATION START
COMPLETED OPERATION
FEEDER TRACK EMPTY-WARNING
REJECTS HIGH-STOP HEAD
S
A
C
F
R
SWITCH SELECT
START
STOP
CONVEYOR MOTOR 440V. 3 PHASE
PRINTER
CHECK UNIT
CHECK LOGIC
REJECT GATE
POSITION CONTROL
1. HOUSING
2. PRINTING
3. PLUNGER N.O.
4. CONTACTS
5. INSULATOR
6. PLUNGER N.C.
7. COVER & RIVETS
8. CLAMPING SCREWS
9. CLAMPING SCREWS
10. REMOVE & INSPECT
11. FIXING SCREWS
FILTER & REGULATOR
AIR
KEY:
PLATEN CONTROL
HEAD CONTROL, PICK & PLACE
ESCAPEMENT CONTROL
FEEDER CONTROL
COUNTER
SCREWING UNIT CONTROL
RIVETING UNIT CONTROL
MANUFACTURING HEAD CONTROL
A : AIR
E : ELECTRIC
AIR/ELECTRIC INTERFACE:
ITEM PART No. DESCRIPTION No OFF MTL REMARKS
DRAWN A.R. KIMBER. APPD. TITLE. CONTROL SYSTEM BLOCK DIAGRAM
DEPT. OF PRODUCTION ENGINEERING
COLLEGE OF AERONAUTICS
CRANFIELD, BEDFORD
SCALE
DRAWING No M/13