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AUTOMATIC ASSEMBLY DESIGN PROJECT 1968/9

REPORT OF ASSEMBLY ANALYSIS AND COORDINATION COMMITTEE

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SUMMARY

The present assembly method and component parts of a chosen product are analysed. The design of components is investigated, and a workstation sequence is proposed based upon the modified components.

A pick-and-place head is designed, versatility being the main design criterion. A functional check mechanism is designed.

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1.0 INTRODUCTION.

This report is one of a series which give full details of the design project 1968/9. A Management Report (reference 1) is available which summarises the work done and the conclusions reached during the course of the project.

A versatile automatic assembly machine incorporating freely transferred platens on a slat chain motivation mechanism is envisaged, but before any ideas are expounded with respect to the machine workstation layout, 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 redesign for automatic assembly. It must be appreciated that a product that is wholly ideal for manual assembly may be virtually impossible to assemble automatically, and therefore drastic design changes may become necessary; but the component must still function according to its specifications.

The work that the Assembly Analysis and Coordination Committee was directly involved with is therefore outlined as follows:

- a) To break down all varieties of the product chosen and make detailed comparative records of all the parts required. To analyse the assembly and sub assembly motions required.
- b) To prepare a scheme in reproduceable form laying out the operations that the machine must be capable of.
- c) A consideration of possible areas of redesign and implement these redesigns in consultation with the respective committees involved.
- d) To design a pick-and-place head; versatility being the main design criterion.
- e) To design a functional check mechanism.

The title of this particular Committee is Assembly Analysis and Co-ordination. Co-ordination may be defined as the harmonious combination of agents or functions towards the production of a result.

It therefore became a function of the Committee to co-ordinate all actions with respect to design of the components of the product chosen, and to ensure that any information required or used by any other Committee was compatible. Co-ordination was of prime importance if a semblance of results were to be obtained at the termination of the project.

2.0 A PRODUCT FOR VERSATILE AUTOMATIC ASSEMBLY.

Theoretically, before choosing a product for versatile automatic assembly, the replies to the technical survey (reference 1) should have been analysed and the specifications laid down to meet the requirements of industry. However, due to time limitations, advanced estimates of certain parameters of the machine, around which the majority of the design work would be oriented, had to be made. These parameters were:

- i) The workpiece should fit inside a 4 in. cube.
- ii) The maximum number of components should not exceed 30.

To select a product, or more correctly, a range of products, which verified the statement that the machine was versatile, presented somewhat of a problem. It was realised that one could either choose a number of components of similar features, therefore involving similar operations or a component whose basic 'frame' does not alter, but the components placed inside the frame may vary considerably. The latter was chosen because it was felt that the results produced would be far more realistic, and therefore qualify the term 'versatile' to a far greater extent.

A contact block for an oiltight pushbutton appeared to be an ideal component to illustrate the potential of the machine. The contact block is manufactured in eleven basic varieties, the main casing and cover being common to all types.

To simplify the explanation of the breakdown of the different types of the contact block, the following terminology will be used throughout this report:

N.C. This prefix implies that the component prefixed is a composite part of a normally closed type of contact.

N.O. Similarly, this prefix implies that the component prefixed is a composite part of a normally open type of contact.

M.B.B. This prefix implies that the contacts are of the make-before-break variety.

H.M. and B.M. This prefix indicates the type of mounting for the contact block, being respectively hole mounted and base mounted.

Each contact block contains two sets of contacts and therefore the eleven varieties of the contact block are as follows:

N.O.	B.M.
N.O.	H.M.
N.C.	B.M.
N.C.	H.M.
N.O./N.C.	B.M.
N.O./N.C.	H.M.
N.O./N.O.	B.M.
N.O./N.O.	H.M.
N.C./N.C.	B.M.
N.C./N.C.	H.M.
N.O./N.C.	M.B.B.

The first four varieties shown have only one set of operational contacts, the other set being manufactured incomplete, and therefore redundant.

2.1 Analysis of the components of the existing contact block.

N.O. Contacts.

Reference is made to figure AA01, a section through a N.O. set of contacts being shown. The housing (1) is a grade GX black phenolic moulding, mated to a cover (2) of the same material. Clamped between the housing and the cover are the N.O. contacts (3). To effect a closing of the contacts the phenolic plunger (4) is moved in the direction 'A' until the moving contact (5) bridges the two N.O. contacts. Both types of contact are silver-tipped brass stampings. The moving contact is spring loaded in the plunger by means of a small conical-helical compression spring (6), shown as hidden detail in the drawing. The main spring (7), is of similar form to the contact spring, the purpose of this spring being to retain the moving contact-plunger assembly in the normally-open position when no switching action is being effected.

N.C. Contacts.

Reference is made to figure AA02, a section through a N.C. set of contacts being shown. The housing (1) and cover (2), to qualify for being part of the product chosen, are identical to the ones used for the N.O. type.

Part (3) is the N.C. contact and can be seen to have a greater offset than the N.O. counterpart. The plunger (4) is similar in shape and size, but the moving contact (5) is reversed in direction. Shielding the N.C. from the moving contact is an insulating board (6), and an insulating medium between the main spring (7) and the moving contact being effected by an annular fibre washer (8).

The Housing.

Reference is made to figure AAO3, a section and plan view of the housing being shown. As stated previously, two sets of contacts are contained in each housing, the type shown being a N.O./N.C. contact block.

The housing and cover are held together by two steel rivets (1) which pass right through the mouldings. Each N.O. or N.C. contact is fitted with a steel 4 B.A. terminal screw and clamp (2) for the attachment of the electrical inputs and outputs. Two steel 4 B.A. fixing screws (3) are retained in the housing by fibre washers and locked on tightening by steel shakeproof washers.

If the contact block is base mounted (B.M.), the terminal screws and clamps, and fixing screws are fed from the top face as shown, whilst if the contact block is to be hole mounted (H.M.) feeding in the opposite direction is required.

As stated previously, the eleven varieties of the contact block are made up by the combination of the two types of contact, and the method of mounting.

3.0 THE PRESENT METHOD OF ASSEMBLY

The nine main operations of the manual assembly of the contact block are as follows:

1. The housing is placed under the head of a heated-foil printing machine, which labels one of the longer sides of the housing with the respective N.O. or N.C. The housing is turned through 180° and the operation is repeated on the laterally opposed side. The housing is held in a sliding work holder, the printing process being actuated by a manually operated lever system.

2. The housings are manually fed onto two nozzles especially shaped to fit the plunger slides of the housing, depression of the nozzles injecting a small quantity of grease (Alvania plus MoS₂) into the housing.

3. For the N.O. contact bridges the plunger assembly must be built up prior to the main assembly in the housing. Eight plungers are placed in a jig with the pointed end providing the location in the jig. The moving contact is placed diagonally through the opening with the contact faces upwards, and then returned to the horizontal plane to secure it on a locating peg. Using a special pair of long-nosed pliers the small conical-helical spring is positioned between the contact bridge and the plunger. A small button on the upper leg of the pliers releases the spring into its seating.

Figure AA04 shows the N.O. plunger sub-assembly in its component and assembled forms. The difficulties encountered in assembly can be realised by observation of the size of the components, and the intricacies of shape.

4. Two rivets are passed from the bottom through the two holes in the housing, and then the housing is placed in a jig which provides anvils for the rivets, and also supports the bottom of the housing, location being provided by two taper pegs passing through the fixing screw holes. The rivets in place in the housing are shown in figure AA05.

5. In the N.C. contact bridge, the N.C. contacts are fitted in the cutouts in the housing followed by the placing of the insulating boards in their slides. The N.C. plunger is placed next, followed by the N.C. moving contact and fibre spacer. Finally the spring is balanced on the projection on the top of the plunger. These components in position in the housing are shown in figure AA06.

6. In the N.O. contact bridge the plunger assembly as outlined in 3 is dropped into its slides followed by the placing of the N.O. contacts in their cutouts and the balancing of the spring on top of the plunger. The components in place are shown in figure AA07.

7. The cover is positioned carefully on top of the springs, and pressed down between the locating faces of the housing. The rivets are upset. The housing with the cover in position is shown in figure AA08.

8. The assembled housing is removed to another jig which supports the housing around the periphery of its base; the fixing screws are fitted with a shakeproof washer and then placed in the holes in the sides of the housing, finally being pressed through a small fibre washer with a small hand press.

9. Removed from the jig, the terminal screws and clamps are secured using a pneumatic screw driver.

Figure AA09 shows the housing with the internal components in place, and arranged around it the components which are fitted external to the housing.

The product is now complete and is despatched to a section for packing in cardboard boxes.

3.1 Important points to note in the assembly of the product.

In the singularly N.O. or N.C. contact blocks the operational contacts must be fitted in the pocket farthest from the housing centre line.

Terminal screws and fixing screws must be fitted in the correct direction depending upon whether the contact block is to be hole or base mounted.

Lips of the terminal clamps are to face outwards.

The small conical-helical spring is correctly located in its seating in the plunger.

4.0 COMPONENT DESIGN

The design of the product, its component parts and the means used to fasten it together, exert a powerful influence on what can, or cannot be done by way of easy automatic assembly.

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 assembling automatically.

Therefore when designing for automatic assembly, the following points should be and were carefully considered:

(i) Component accuracy.

For automatic assembly, component accuracy should normally be higher than for manual assembly. The main reason for this is that the problems of part tolerance all focus at the assembly stage. Product design should therefore allow the widest possible mating tolerances, and if plastics are involved, these may well have to be of the thermoplastic variety to allow some degree of physical distortion. Alternatively, if the parts to be mated are very accurate, then automatic selective assembly may be the only answer.

Accuracy may also be required on surfaces which do not have to be at all accurate for manual assembly. This particularly applies to external surfaces used for part location in an automatic machine where consideration must be given to tapers and chamfers to allow for the maximum of self-centralisation.

(ii) Component positioning.

The original orienting of the part in the feeder and its subsequent positioning in the assembly machine may often be made easier by incorporating in the part some special geometrical feature which the machine can 'recognise'. This may be an additional flat, lug, notch, groove, etc., which will easily register with some sensing head.

This subject is dealt with in detail in the report of the Component Supply and Separation Committee (reference 2).

(iii) Part presence

The four normal sensing devices used for presence detection are electrical limit switches, photocell beams, magnetic proximity detectors, and pneumatic back pressure and interrupted jet sensors. Nowadays, of these, the pneumatic sensors and the photocell beams are probably the most universally useful. Their detecting ability is substantially unaffected by the nature of the materials of the parts, and signals from several sensors can be easily combined using logic to sense that all parts are present, and sequences working correctly.

This subject is dealt with in detail in the Report of the Control and Motivation Committee (reference 5)

(iv) Fastenings

Wherever possible, parts should be fastened together in the assembly machine by means of devices that require a simple, straight, plunging motion, rather than a rotational motion. This makes for speed and simplicity, rivets, pins, pressure adhesives, interference fits, etc., are far better than screws, nuts and bolts, although efficient nut and bolt running machines are now available.

(v) Finishing

Parts which have been through automatic feeders and orienters tend to come out with surfaces showing signs of the handling method. Whenever possible, the parts should have an all-through finish, or should be finished after assembly.

A complete redesign of the product was a feasible proposition, but a request was made by the manufacturer that the external dimensions of the component remain unchanged, the reason being that replacements are required for the many millions in service in industry.

It was also stated by the manufacturer that any modifications made, would have to be thoroughly investigated and then be subjected to nine months proving tests. This therefore suggested that it would be advisable to modify as few parts as possible, in particular components directly associated with the contacts.

Each component will now be analysed in detail, and the proposed modifications with the reasoning for the modifications will be expounded.

4.1 The Housing.

Reference is made to figure AA10, where it will be apparent that the component shown is a symmetrically shaped grade GX phenolic moulding, whose function is to contain the various components of the contact block.

The external profile of the housing is designed to be resistant to tracking, and along with the stipulation made by the manufacturer, that the major dimensions of the contact block were not to be changed, no changes could be made to the external features of the component.

The internal profile is of rather complex shape as it provides locating faces for the contact plates, the plunger assemblies and the insulating plates. Size tolerances are large, and therefore clearances between mating parts are large. It will also be observed that certain surfaces are specified flash-free, to ensure smooth motion of the components.

The top face of the housing provides locating bosses for the cover, which is retained by two rivets which pass through the two holes shown. These holes pass right through the moulding, two recesses being provided on the bottom face to accept the upset rivet.

At each end, a boss is provided, with a hole to accept a fixing screw.

Figure AA11 shows how the housing was modified to provide easier location of components.

In the existing contact block the contact and insulating plates were located in parallel sided 'pockets', which for automatic assembly would require either tight tolerances or large clearances.

Originally, the cutouts in the walls of the housing were at marginally different distances from the centreline of the housing and the Component Supply and Separation Committee found it very difficult to orientate the component. Therefore, the cutouts were made equi-distant from the centreline, which necessitated the modification of the contact plates.

Figure AA12 shows how the pockets were modified to accept the new design of contact plates (explained in section 4.10), the old and new locating faces being shown in figure AA13.

Three sides of the pocket were tapered to provide a self centralising effect and for the same purpose the slides for the insulating plates were slightly modified.

The modified fixing screw holes are also shown in figure AA11, having been reduced in diameter, the reason behind this modification being explained in Section 4.8.

The rivet was originally fed from the bottom of the housing and upset on the cover side, but because feeding from the bottom was considered impracticable by the Assembly Process Committee, and to turn the housing over could be a costly operation, it was decided to feed the rivet from the cover side. This manoeuvre therefore necessitated the redesign of the rivet recesses as shown.

4.2 The Cover.

Reference is made to figure AA14. The cover shown is also a phenolic grade GX moulding of a rather complex shape. The external profile is also designed to resist tracking across the surfaces, and therefore simplifications of this profile could not be attempted.

The component is symmetrical in shape about the plane of the plan view shown, the only criterion determining the correct way of fitting the cover being the manufacturers name and part specifications moulded on the top face. In discussion with the manufacturer, the Component Supply and Separation Committee determined that the direction of the writing with respect to the housing was not critical, and therefore orientation of the housing was restricted to obtaining the correct face and side, both details being easily recognisable to an orientation mechanism.

Reference is made to figure AA15. Two modifications to the cover were made necessary by components which are associated with the cover. As already stated, the direction of feeding of the rivet was reversed, and therefore the modification involves the deepening and reduction in diameter of the rivet seating as shown in the section 'A-A'.

The second modification was necessitated by the virtually impossible task of feeding the main springs singularly and in the correct orientation as detailed in section 4.9. A manual assembly was the only solution, and it was therefore decided in collaboration with the Component Supply and Separation Committee to 'clip' the springs into a recess in the cover, and then feed the cover and springs as a sub-assembly to the main assembly line. Details of the modification to the cover are shown in the section 'B-B' of figure AA15.

4.3 The Rivet.

Reference is made to figure AA16. The rivet is steel and hollow at the shank end. On consultation with the contact block manufacturer it was discovered that difficulty was being encountered with the steel rivets not upsetting correctly. Therefore, the firm is to revert to aluminium rivets of the same dimensions, which from the automatic assembly point of view are preferred, in so much as the force required to upset the rivet correctly is greatly reduced. The proportions of the rivet allow for comparatively easy feeding and orienting and therefore, with all the factors considered, no redesign of the rivet was thought necessary.

4.4 The Spacer.

Reference is made to figure AA17, where the fibre spacer is shown. The function of this component is to give correct main spring loading and to insulate the spring from the M.C. moving contact.

No difficulties were envisaged from the points of view of feeding and orientating and therefore the design was not changed.

4.5 The Moving Contact.

Reference is made to the drawings of the N.O. and N.C. moving contacts, figures AA18 and AA19.

The N.O. contact is a brass, silver tipped component which is to be subjected to manual assembly of the N.O. plunger, and therefore no modifications were deemed necessary.

The N.C. contact is very similar in shape and dimensions, but is required to be fed into an assembly head. This assembly head is detailed in Appendix I, and since no difficulty was envisaged in feeding and orienting of this component by the machine supplier, again no modifications were deemed necessary.

4.6 The N.C. Plunger.

Reference is made to figure AA20, where four views of the plunger are shown. The material is again specified as grade GX phenolic, and as shown, tolerances are fairly wide; ± 0.005 in (0.10mm) being the smallest. The slides in the housing into which the plunger fits, have tolerances equally large and therefore it was considered futile to change any dimensions.

Orientation is reasonably easy due to a well-defined profile and a biased free resting position.

The N.C. plunger as a completed sub-assembly is shown in figure AA21.

4.7 The N.O. Plunger.

Reference is made to figure AA22 where three views of the plunger are shown. The plunger is very similar in all respects to the N.C. plunger, and the same comments outlined above apply.

4.8 The Fixing Screw.

Reference is made to the drawings of the present and modified fixing screw, figure AA23 and figure AA24, respectively.

The present fixing screw is a turned mild steel component with the head drilled and tapped to accept another screw of the same type i.e. so that more than one contact block can be operated by the same switch by screwing blocks together.

The dimensions of the component are such that orientation and feeding are relatively easy, a standard screw running machine being toolable to accept it. The problem then arose of feeding the locking washer, figure AA25, and the shakeproof washer, figure AA26, the first before feeding into the housing and the second afterwards, to retain the screw.

To overcome these problems the non-threaded portion of the screw was reduced in diameter as shown, and the hole in the housing correspondingly reduced, to give an interference fit on the threaded diameter. This simple function retains the screw.

Also, the method of manufacture of the screw was changed to a cold heading operation, so that the locking serrations are formed on the underside of the head of the screw, thereby obviating the necessity of the shakeproof washer. This modification was carried out by the Assembly Process Committee.

Therefore, the number of components required for each contact block is reduced by four.

4.9 The Compression Springs.

An ideal spring for automatic assembly should conform to the following specifications:-

1. The pitch of the coils should be greater than $1\frac{1}{2}$ times the wire diameter.
2. The ends must be close coiled.
3. The outside diameter of the coils should be constant.
4. The pitch spacing should be constant.
5. The length to diameter ratio must be well defined.

Any major deviation from these specifications is likely to cause unsolvable problems in feeding of the springs.

Therefore, considering the two springs specified in figures AA26 and AA27, the feeding of these components in their present form was considered to be unrealistic.

Detailed examination of the plunger spring resulted in it becoming a component part of the manual assembly of the N.O. plungers, as described in section 6.0 in this report.

The main spring presented almost the same problems, except that this spring is considerably larger, and more open-coiled. It was thought by the Component Supply and Separation Committee (reference 2) that it may be possible to feed the springs if the ends were made close-coiled. The problem then arose of positioning the springs on top of the plunger assemblies, placing the cover on top of the springs and then upsetting the rivets. This operation was considered to be almost impossible and therefore it was decided to mount the springs in the cover as a sub-assembly operation; this is also outlined in section 6.0.

Therefore the spring is to be modified at the larger end to provide one full flat turn of wire, to engage in the slot in the modified cover, shown in figure AA13.

4.10 The Contact Plates.

The contact plates are silver-tipped brass stampings of an irregular shape, manufactured in N.O. M.C. and M.B.B. types in left and right-hand forms. As explained previously, to facilitate orientation of the housing, the cutouts for the contacts have been made symmetrical with the centreline of the housing. This necessitated the redesign of the contact plates, but the external offset of the protruding terminals must be retained to allow for access to the terminal screws when stacking the contact blocks.

The contact plates are shown in figure AA28 and AA30 in their existing forms. To realise a M.B.B. contact the spacer shown in AA32 is interposed between the brass and silver to produce a larger contact.

The modified forms are shown in figures AA29 and AA31. A consequent reduction in the required volume of silver needed for efficient contacting was a by-product of the modification.

The tolerances of the contact plates were considered sufficiently small and were therefore not altered. This modification was instigated by the Component Supply and Separation Committee.

4.11. The Terminal Clamp and Screw.

The terminal clamp and screw are shown in figures AA33 and AA34.

The screw is a 4 B.A. cheese-headed cadmium plated component, easily fed by screw running machines.

The terminal clamp is a cadmium plated steel stamping of rather intricate shape, being difficult to orientate, as none of the features are outstanding.

It was learnt from the contact block manufacturer that firms already using automatic assembly on electrical equipment have been using a combined terminal clamp and screw.

The redesigned components are shown in figure AA35, where the clamp will now be observed to be symmetrical, and is supplied as a component-part of the screw.

4.12. The Insulating Plate

Reference is made to figure AA37. The function of this component, as may be realised from the name, is to provide an insulating medium between the N.O. contact and the moving contact. The plate is held in two parallel sided slides in the housing.

Orientation is difficult due to the small size differential of 0.079in (2 mm) between the sides. It was therefore decided that the plate should either be made square or be manufactured on the machine. The Component Supply and Separation Committee in fact chose the second alternative (reference 2).

Slight modifications were also made to the housing to facilitate easier entry of the plate, as described earlier in the text, section 4.1.

Each component has been analysed in detail, and the modifications explained. Figure AA38 shows the relationship between the six basic varieties of the contact block in its original form, and the components involved. The arrows, showing the number of components required per type, lead from the name of the component and its figure number, to the respective types.

Figure AA39 shows the same relationships for the modified form of the contact block. The number of different types of components can be seen to have been reduced by three, due to the redesign of components.

5.0 THE PROPOSED ASSEMBLY SEQUENCE.

In section 3.0 of this report, the manual assembly sequence was explained. The automatic assembly sequence must necessarily include all of the manual operations, excepting any operations obviated by the redesign of components. The assembly flowchart shown in figure AA40 depicts the required assembly motions for the assembly of a N.O. or a N.C. contact bridge, inclusive of the housing external components.

Two sub-assembly motions are shown on each diagram feeding into the workstations on the main assembly line, which are numbered in the circles 1 to 11. The fact that the numbers do not run consecutively will be better understood if reference is made to figure AA41.

On this diagram and for the purpose of this analysis, the make-before-break contact block can be assumed to be the same as the N.O./N.C. and therefore five basic types are shown.

The numbers in the circles again represent the workstation numbers. The large circles incorporating a number represent workstations at which all five types are operated on, whereas the two small circles mated to a rectangle represent the type named in the rectangle. The absence of a number in one of the small circles, means that this particular half of the contact block is not operated on at that particular workstation shown by the number in the other small circle. The circles and ovals containing alphabetic letters represent the components that are being fed into the workstation. Therefore, following the N.O./N.C. contact block through the stages of assembly:-

Workhead

Function

1. The housing is placed on the platen and greased.
2. Housing is printed N.O. N.C. on both sides in the respective places.
3. The N.O. plunger assembly is placed in the slides in the housing.
4. The N.O. and N.C. contacts are positioned in the cutouts.
5. The insulation plates are placed in their slides.

6. The N.C. plunger assembly is placed in its slides.
7. The spring-cover sub assembly is positioned and riveted in place.
- 8&9. The terminal screws and clamps are fitted.
10. The housing is removed from the platen and fed into the functional check.
11. The fixing screws are pressed into place in functionally correct assemblies.

The workstation layout shown applies for hole mounted contact blocks, the base mounted blocks requiring stations 8,9 and 11 to be omitted to allow for manual assembly of the terminal screws and clamps and fixing screws. The reason why the machine was not designed to assemble base mounted contact blocks, lies with the fact that with the relatively small number of this type that are assembled, the manufacturer felt that the extra expense incurred was not warranted.

Note that in the singly N.O. or N.C. type of contact block, in the redundant side of the housing, the plunger and spring are the only two components placed.

6.0 SUB-ASSEMBLIES

Referring again to figure AA40, it is apparent that three sub-assemblies are required. In consultation with the Assembly Process Committee it was learnt that components could be presented to the main assembly line from either a manual assembly station, an automatic assembly station, or possibly a component manufacturing machine.

The case of coupling a manufacturing machine to the assembly line was investigated by the Component Supply and Separation Committee with regard to the feeding of the springs to the machine. The idea was found to be feasible from the engineering point of view, but an investigation carried out by the Component Supply Committee (reference 2) suggested that the idea was not acceptable on the grounds of cost, and probably more important, on the fact that the machines are very complicated and therefore require trained supervisors and maintenance facilities.

The choice of sub-assembly method was therefore between manual and automatic assembly. The three sub-assembly stations are therefore considered as follows:-

(1) N.O. Plunger Assembly.

As explained in detail previously, the N.O. plunger is caused to be a sub-assembly because of the small springs.

The manual assembly layout may be seen by reference to the Component Supply and Separation Report (reference 2).

(2) N.C. Plunger Assembly.

This assembly comprises the N.C. plunger, the D.C. moving contact and the fibre spacer washer. When utilising manual assembly, it is possible to assemble this component in the housing, but due to the lack of room around the components in the housing it was not possible to assemble it there using automatic assembly. Also, the lower the number of workstations on the main assembly line, theoretically higher is the overall efficiency of the machine.

A cost comparison between a manual sub-assembly and an automatic assembly station was carried out by the Economic Planning Committee at the request of this Committee

The result was that an automatic machine was justified, and was therefore incorporated into the overall floor plan of the machine given in the report of the Assembly Process Committee.

(3) Cover and Springs.

The reasons for this sub-assembly have already been expounded in section 4.2.

Again by reference to the Component Supply and Separation Committee (reference 2) the sub-assembly station layout can be seen.

7.0 THE PICK-AND-PLACE UNIT.

In the present field of mechanised assembly, the tooling is mostly special purpose, costly and often complex. It was a function of this Committee to design a versatile machine to transport components from 'A' to 'B' keeping in mind that minimum cost and retooling time of the machine were of prime importance.

A 'pick-and-place' unit was chosen as the basis of the design, because the Committee felt that the available motions were in themselves versatile, and the Committee hoped therefore that the final unit would also be versatile.

The specifications laid down by this Committee were therefore as follows:-

- (1) To transport components not greater than a 4in. cube of varying shape and size.
- (2) The maximum weight of the component was not to exceed 10lbf. (4.5Kgs).
- (3) To position repeatably within ± 0.001 in (0.025mm).
- (4) To place components from two faces i.e. the front and top.
- (5) All motions must be smooth, but as fast as possible.
- (6) The motivation mechanism was to be pneumatics as specified by the Control and Motivation Committee.
- (7) The unit was to be made sufficiently rigid to guarantee the required positioning accuracy.
- (8) The unit must be capable of placing parts within a 4 inch cube.
- (9) The unit must be capable of picking and placing 1,2,3 or 4 components simultaneously.
- (10) Maintenance of the unit should be as simple as possible.

7.1 Motions of a pick-and-place unit.

The transport of parts from point 'A' to point 'B' may be undertaken by two methods:-

(1) Rotational Motion.

Rotational motion is produced about a fixed axis in a horizontal plane, motion in the vertical plane being effected for the pick-up and placing of the component.

There are two basic types; double-headed where components are picked up and placed simultaneously, i.e. a fixed rotation of 180° ; and a single head where rotation takes place through an angle depending upon the positions of the pick-up point and the placing point.

Referring to figure AA42, where a double headed type is shown, head A picks up a component from the feed escapement; the unit rises vertically and rotates through 180° to the placing position, and lowers the component into position. As head A releases the component, head B simultaneously grips another part and the sequence is repeated with B placing and A picking up.

In the single headed type, the motion is the same, but possibly through a smaller angle, and with a lower rate of placing.

To meet the specifications, the mechanism and its control system for rotational motion would have to be relatively complex, negating one of the specifications that the mechanism should be simple. The complexity is involved with the variable radius, and side placing motivation mechanisms. Also to meet the required positioning accuracy a complex system of stops is required, as it is undesirable to have the stops on a small radius.

It is possible that the pick and place motions may require motions in different planes and therefore the control system is correspondingly complicated.

(2) Linear Motion.

The linear head is theoretically slower than the double headed rotary, but has the distinct advantage of being less complex and yet be able to place in two faces with the same mechanism. Figure AA43 shows how the component could be picked up between the base of the pick-and-place head and the track with the same 'x' and 'z' coordinates as the placing point.

When placing in the top of a product the component is lifted vertically from the escapement to a point where the bottom of the component will just clear the top of the product. It is then moved horizontally in the y-plane to a point in space vertically above the place position, and then lowered into position. The head returns along the same path to the pick position.

When placing in the side of the product the unit will pick up the component and rise vertically to a point in space which is coincident with the placing position. It then moves horizontally in the y-direction, placing the part over the latter part of the stroke. The head returns along the same path to the pick position.

7.2 The Chosen Motion.

The linear motion was chosen for the following reasons:-

- (1) It is significantly easier to produce a simple design by linear motions than by rotational.
- (2) Versatility with simplicity
- (3) The motivation mechanism need only provide linear motion, rather than convert to rotational motion through some mechanical linkage.
- (4) Due to its inherent simplicity, it would tend to be less expensive.

7.3 Design of the linear pick-and-place unit.

The linear pick-and-place head was designed to cover all the requirements given in the specification.

For the purpose of this report, the head is divided into three sections:-

- (1) The base which contains the motion in the 'x' and 'z' directions.
- (2) The head which contains the motion in the 'y' direction.
- (3) The claw and the claw-head interface.

Each section will now be explained in detail.

7.4 The Base.

Reference is made to figure AA44, four views of the base being shown.

The hand adjusted cross slide has been primarily designed for mounting of the pick-and-place unit, but can be used for mounting of other types of auxiliary equipment, such as a riveting machine. It consists of a dovetail slide motivated by a 25 t.p.i. (1.0mm pitch) leadscrew giving a total movement of 1.125in. (28.5mm). To obtain the required movement of 4in (100mm), the fixed nut can be clamped in four positions spaced 1in (25mm) apart.

The slide is locked using a grub screw whose thread is formed by the top part of the cross slide and the tapered insert which forms part of the dovetail. When the screw is tightened, a wedging action occurs between the top and bottom parts of the cross slide, thus locking takes place.

The base also encompasses the mechanism for providing the vertical motion of the head. This mechanism must provide true linear vertical motion, free from any unduly large deflections or twisting moments when under load.

The unit consists of a single acting pneumatic cylinder with two guide rods, one on either side of the cylinder, on the cylinder centreline. These guide rods eliminate deflections and twisting moments on the cylinder as far as possible by being mounted in linear ball races, giving a total vertical movement of 4.25in(108mm).

Various types of bearings were considered for this application, being as follows:-

- Air bearings
- Hydrostatic bearings
- Cross roller tracks
- Plain bearings
- Linear ball races

The latter were chosen for the following reasons:-

- (1) Low friction properties, which are little affected by load.
- (2) Less expensive and smaller in size and weight than comparative plain bearings.
- (3) True linear motion can be obtained and maintained.
- (4) There is no heat produced, with no lubrication being required and therefore maintenance is eliminated.

Figure AA45 shows the layout of the bearings in the cages, and the method of attachment to the baseplate.

Screw in caps containing 'O' rings are fitted in the bearing housings to prevent the ingress of dirt and foreign particles into the bearings.

The guide rods and the housings must be manufactured to the bearing manufacturers specifications, and preloading is advised to provide a greater accuracy of alignment and to compensate for wear.

The pneumatic cylinder and the bearing housings are mounted on a baseplate which is attached to the cross slide. Motion in the vertical plane is restricted by stops shown in figure AA44 and in detail in figure AA46. These stops are mounted between the linear ball race housings, and are actuated by a vertical rod attached to the head of the unit.

The stops consist of two adjustable blocks mounted on a rod, and two fixed stops which provide the deceleration period before the final stop. The adjustable stops act in opposite directions and can be clamped in movements of .50" (12.7mm). Final positioning is by the 25 t.p.i. (1mm pitch) thread and locking nuts.

Clamping these stops in varying positions enables a stroke of any length to be obtained anywhere within the specified range.

The fixed stop for the downward motion is to provide a deceleration period, and a period of slow constant velocity before bringing it to rest. To obtain varying lengths of slow constant velocity, the length of the piston rod in the lower cylinder has to be changed. This is undertaken by removing the lower cover. As this is a small and relatively inexpensive part to produce, piston rod lengths of 1" (25.4mm), 2" (50.8mm), 3" (76.2mm) and 4" (101.6mm) should be provided with each unit. The fixed stop for the upward motion provides a fixed deceleration period before bringing it to rest.

As indicated by asterisks, certain changes in motion are sensed fluidically. This was a requirement of the Control and Motivation Committee, a typical sensor being shown in figure AA47.

7.5 The Head.

The head is mounted on the top of the vertical motion guide rods, and envelopes the provision for horizontal motion of the claw.

As shown in figure AA48, the head consists of a pneumatic cylinder mounted in a cast aluminium frame. Motions of the cylinder are stabilised by two guide rods running in linear ball races and a third rod running in plain bushes, which mounts the end stops for the y-direction. These stops are moveable in increments of .50" (12.7mm), final positioning being attributed to a 25t.p.i. (1mm pitch) thread and locknut.

Cushioning of the end stops is again provided by springs of varying length and stiffness, the final stop being provided by the collar within the spring. This collar is not part of the end stop and is designed to match the spring rate and length. The overall speed of the pneumatic cylinder is regulated by a restrictor on the exhaust of the cylinder.

A cast aluminium end plate is mounted on the end of the cylinder rod and guide rods, to provide the interface between the y-direction motivation and the claw mechanism.

Figure AA49 shows the aluminium frame with the positions for the control sensors.

7.6 The Claw.

Plane of Motion of the Claw.

Consider the cube, shown in figure AA50, which has to be picked up by the claws. The cube could be picked up on any one of its pairs of faces, AA, BB, or CC. With the claw casing interface in the position shown, the cube could be picked up on faces BB. If the direction of motion of the claws is rotated through 90° the cube could be picked up on faces CC. To pick up on faces AA, the cube will have to be rotated through 90° , and this could easily be achieved with correct layout of the feeding track. Therefore, the planes of motion of the claws are a straight line motion of each claw in direction 'yy' and 'zz' then the slides are rotated through 90° .

Component Dimensional Variances.

Because components will vary in their standard dimensions, it is necessary for the claws to centralise the components being picked up with a predetermined datum position, relative to the claw casing interface.

Sensors.

A sensor should indicate whether the claws have picked up a component.

The Casing.

The casing consists of the main casting which houses the slides, claw operating mechanism, and sensors. A keyway on the housing locates with the end plate slot on the 'y' slide and enables accurate and quick location of the casing with the pick-and-place unit. The centre acts as a manifold for the air which is used to operate the clamping pistons, the pistons fitting in bored holes which enter into the manifold. The system is shown in figure AA51.

The Slides.

Each slide carries one claw which is located on a standard dowel location. The slides move in straight lines relative to one another, and are of the roller bearing type. There are eight similar slides which each can carry a claw which makes it possible for four components to be picked up, if each slide is used.

Four slides are positioned on the front face, and a further four underneath. This enables the pick-and-place unit to be used for assembling from the top and also the side of an assembly.

Each slide has eight 0.125in (3.2mm) diameter roller bearings which are located by case hardened vee grooves. The rollers are mounted at 90° to one another and are distributed as shown in figure AA51, to give slide travel of ± 0.062 in (1.6mm). Play in the slide is eliminated by adjusting the position of the slide rail.

To enable the claw to pick up on different faces of a component, the complete slide assembly can be removed and rotated through 90°.

Roller slides have been used because of their low coefficient of friction, which is necessary to give fast response time and low clamping and un-clamping forces.

Clamping Mechanisms.

Figure AA52 shows the clamping mechanism which is designed to self centralise the component being gripped with some predetermined position on the claw arm interface. The components are clamped under air pressure and are spring released by a compression spring between the two slides when the air is exhausted.

Each pair of slides has one clamping piston which is moved outwards when the chamber is pressurised. 'O' rings around the piston are used as the sealing method, reducing the friction between the piston and the housing.

The piston has a conical recess which fits into two specially shaped cams on each slide. Thus, when the chamber is pressurised, the piston moving in causes the slides to come together. The calculations to determine the angle of the conical recess and the clamping forces required are shown in Appendix 1

The clamping force may be varied by adjusting the input pressure.

The Sensors.

To check the jaw position for the sequencing control system, a back pressure sensor was positioned in the housing to detect whether the slides are open or closed.

The Claws.

The location design is such that the claws can only locate in one position on the slide. This avoids ambiguities when changing claws, but means that no adjustment can be made to the claw relative to the slide, therefore necessitating a high manufacturing accuracy on the claw. It means, however, that the claw can be interchanged with the minimum amount of set up time.

In Appendix 1 the calculations to determine the claw stiffness are given, for the N.O. contact plates.

The claw designed for the N.O. contact plate is shown in figure AA53. For some types of switch it is only necessary to pick up two contacts instead of four. For this condition the claws that are not required are removed.

An isometric drawing of the complete pick-and-place unit is shown in figure AA54.

Versatility was realised in the design of the pick-and-place unit by consideration of the following points:-

- (1) Pick up and place can occur anywhere within a 4in. (100mm.) cube.
- (2) The movement from the pick to the place position is speed controllable, as well as having the capacity of variable deceleration rates.
- (3) 1,2,3 or 4 components can be picked up and placed by the claws, and placed in two planes.
- (4) The claws are interchangeable between heads.

It was also realised during the design work of the pick-and-place unit that it was possible to fit a different type of casting to the head. For example, a magnetic or suction head could be fitted or even a small screw runner.

The facility is also available of fitting a rotational interface between the head and the claw casting, thereby providing a rotational motion of the component.

Unfortunately, the full potential of this unit could not be realised in its application to the assembly of the contact block.

8.0 THE FUNCTIONAL CHECK.

The inspection station has four functions:-

- (1) To remove the assembly from the platen and transport it to the check unit.
- (2) To inspect the assembly for continuity between the output terminals with the plungers in the normal and operating positions.
- (3) To detect a reject assembly, by inspection, and also when the platen is marked as carrying a reject.
- (4) To reset the reject marker on the platen.

The transporting of the assembly from the platen is effected by using a standard pick and place head with the control system modified as described in the Control and Motivation Report (reference 5).

Reference is made to figure AA54. The checking unit is pneumatically activated and consists of two slides on which the inspection probes are mounted. These move in and out under control of the clamp cylinder, the slide stops being incorporated in the slot which is clearance for the cylinder anchor arms.

The plungers are operated by the plunger cylinder, which is mounted under the slides. The eject cylinder is mounted in the centre of the track and has a rubber end to absorb the input as it hits the assembly during the ejection cycle.

The inspection probes are electrically isolated from the rest of the inspection unit. Wires are attached to each probe and from there to the inspection logic circuits.

To check for completion of operation of the actions performed by the cylinders, and also to ascertain when the assembly is present, back pressure fluidic sensors are positioned as shown in figure AA55.

Sequence of Operations.

The Initial Conditions of inspection unit are as follows:-

- (1) Plunger cylinder extended.
- (2) Eject cylinder retracted.
- (3) Clamp cylinder extended.

The contact block is picked up by the pick and place unit from the platen and transported to the inspection unit. As the contact block is moving downwards to the inspection unit, the plungers hit the extended plunger cylinder and are compressed.

When the contact block is detected, the clamp cylinder retracts, causing the slides to move together, which they continue to do until they hit the stop. When the sensor in the track is activated by the assembly, which has been placed above it, the pick and place claws release, leaving the contact block in the operated condition, trapped under the top of the slide.

At the same time as the slides are moving in, the inspection probes make contact with the terminal clamps, ready for the continuity check. Simultaneous to the pick and place jaws being released, the inspection is carried out with the plungers operated.

A time delay is built into the control circuit, which gives sufficient opportunity for the inspection logic to complete its sequencing. Then the plunger cylinder is moved in, allowing the plungers to travel to their normal position, and then, with the same time delay as the previous operation, the clamp cylinder is withdrawn.

On completion of the slide movement, the assembly is ejected to the next station. If, during the inspection, it is detected as a reject, a chute is opened to allow the reject assembly to fall into a bin. The inspection unit is then automatically recycled to its initial conditions.

If the assembly is a reject before the inspection station, a signal is received from the platen control which causes the plunger cylinder to retract. It also inhibits the inspection sequence and opens the reject shute so that when the assembly is detected in the inspection station, no test is performed and the eject cylinder is extended, pushing the reject assembly down the reject shute.

The inspection unit is then recycled to its initial condition.

The plunger cylinder is retracted to minimise the chance of loose parts falling into the station and causing jams to the mechanism.

9.0. WORKSTATION LAYOUT.

This section deals with the machine units required to assemble the contact block, each workstation being dealt with in order. Information was supplied to the Component Supply and Separation Committee with respect to the direction of feeding of the component to the pick-and-place unit to provide the simplest transfer motion from the feed escapement to the assembly point.

Workstation 1.

A pick-and-place unit transfers a housing from the feed escapement to the platen. The claws are shaped to fit in the plunger slides, a small quantity of grease being injected into the slides during the transfer motion. The grease unit can be supplied by Binks-Bullows Ltd.

Workstation 2.

The housing is printed N.O. or N.C. using a heated foil printing machine (reference 4).

Workstation 3.

A pick-and-place unit transfers either one N.O. plunger and one N.O. plunger assembly or, two N.O. plunger assemblies from the feed track to the housing. The plungers are gripped on the spring locating projection.

Workstation 4.

A pick-and-place unit transfers two or four N.O. or N.C. contact plates from the feed track to the housing. The contacts are gripped on the three outward facing sides of the terminal.

Workstation 5.

Two or four insulating plates are fed from a manufacturing head (reference 2).

Workstation 6.

This workhead is identical to workhead 3.

Workstation 7.

A pick-and-place unit transfers the cover assembly from the feed track to the housing, and the rivets are inserted and upset (reference 4). The cover is gripped on the two longer sides, the cover being held down whilst the riveting operation takes place.

Workstations 8 & 9.

An investigation carried out by the Assembly Process Committee proved that the pitch of the terminal screws was too close for a multiple screw running head and therefore two screw running machines are required (reference 4).

Workstation 10.

A pick-and-place unit transfers the assembled housing from the platen and places ~~it in the functional~~ check mechanism.

Workstation 11.

A A screw running machine places two fixing screws in functionally correct assemblies (reference 4).

Using this workstation layout, and feeder track layouts from the Component Supply & Separation Committee, the Assembly Process Committee laid out the machine plan (reference 4).

10.0 CONCLUSIONS

A contact block for an oiltight pushbutton has been chosen as the product to provide the basis for the design of an automatic assembly machine and also to prove the versatility of the system devised.

A detailed analysis of the contact block in its existing form has been carried out, including the present method of manual assembly.

In order to exploit assembly by machine to the fullest, the product to be assembled must be suited to the method. The design of the product, its component parts and the means used to fasten it, exert a powerful influence on what can, or cannot be done by way of easy automatic assembly. With the introduction of machinery for assembly, the product designer must recast his thinking to suit the simple actions of the machine, the complete redesign of components being an expected operation when a component has previously been subjected to manual assembly.

It was realised that the design of all the components of the contact blocks had to be carefully analysed and modifications suggested, to make the product suitable for automatic assembly. It was also felt that with a proven article such as the contact block that it would be wrong to attempt any modification unless it was deemed absolutely necessary and, or, a distinct material advantage was gained. An important point to note is that any modification which simplifies any operation tends to tarnish to some extent the machine's label of being versatile.

To illustrate these points it was found necessary to modify eight components of the contact block to make it more suitable, although not completely suitable, for automatic assembly. These modifications also led to a reduction in the numbers of components, and consequently the assembly time. However, in certain areas of the contact block, manual assembly was found to be the only possible means of assembly.

A pick-and-place unit has been designed based upon pre-Technical Survey criteria. The unit therefore meets industrial requirements to the following degrees; the information being extracted from the Technical Survey (reference 1).

- (1) Assembling products within a 4in (100mm) cube meets 59% of industrial requirements.
- (2) Assembling products with greater than twenty components meets almost 98% of industrial requirements.
- (3) Assembling on the two chosen planes meets 85% of industrial requirements, the additional facility of being able to turn the product over being required by 63%.
- (4) Positioning to ± 0.001 in (0.02mm) caters for 87% of industrial requirements.

The facilities of quick and easy tool changing with simple and effective parts positioning have been provided at a relatively low cost. The unit is fully controlled and fail-safe. It was felt by this Committee that the full potential of the pick-and-place unit could not be realised in its application to the contact block.

The pick-and-place unit has been utilised for motivation of all components from the feeding system to the platen although it was realised that many other simpler and cheaper methods were available, the choice of the pick-and-place unit being solely on the basis of its versatility.

A functional check mechanism has been designed in close collaboration with the Control and Motivation Committee, no degree of versatility being possible to integrate into this design.

Close communication between all Committees has been maintained with respect to the design of components, and the workstation layout.

The Assembly Analysis and Coordination Committee feels that the contact block has shown the degree of versatility of the machine but wishes that a product had been available which did not require any manual assembly, as the necessity for manual assembly does to some extent tarnish the image of versatility.

11.0 RECOMMENDATIONS FOR FUTURE WORK.

Recommendations for future work can only be made on further design changes. Two possible areas of investigation are as follows:-

- (1) The lid could be moulded out of thermoplastic incorporating the fixing device in the form of moulded rivets. Heating the ends of the 'rivets' would provide the fixing function. Thereby, the number of components per product is reduced by two.
- (2) An insulating medium such as p.v.c. could be sprayed or moulded onto the N.O. contacts to make the insulating plates unnecessary, and therefore reduce the number of components by two or four. A workstation would also be obviated by the modification and therefore the overall machine cost would be reduced.

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3. Report of Economic
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4. Report of Assembly
Process Committee,
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CoA Memo No.
5. Report of Control
and Motivation
Committee, Design
Project 1968/9. CoA
Memo No.

Bibliography.

- Boothroyd and Redford 1968 Mechanised Assembly
Dr. David Foster 1963 Modern Automation

FIGURES

The following nomenclature is used on all the following drawings.

All dimensions are to tolerance $\pm 0.003\text{in}$ (0.08mm) fractional $\pm 1/64\text{in}$ (0.4mm) unless otherwise stated.

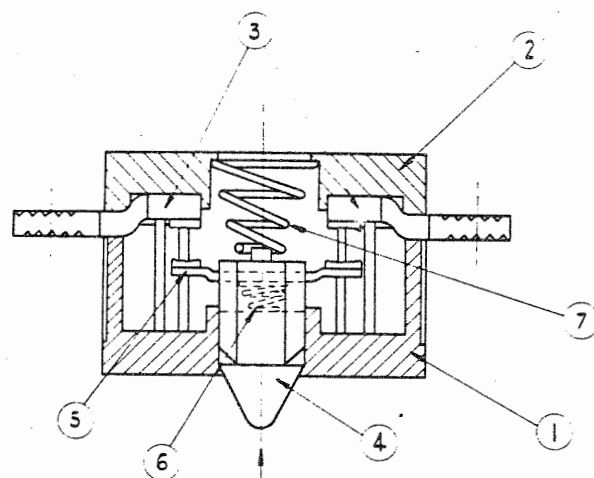
Metric equivalents are given in millimetres in brackets.

On drawings of modified components, only dimensions which have been changed are shown.

Drawings are scaled but may not be true fractional reductions.

<u>TITLE OF FIGURE.</u>	<u>FIGURE REFERENCE</u>
N.O. contact bridge	AA01
N.C. contact bridge	AA02
Housing	AA03
N.O. plunger assembly	AA04
Housing with rivets	AA05
N.C. contact bridge	AA06
N.O. contact bridge	AA07
Housing with cover fitted	AA08
Housing with external components arrayed	AA09
Housing	AA10
Modified housing Modified housing	AA11
	AA12
Modified contact location faces	AA13
Cover	AA14
Modified cover	AA15
Rivet	AA16
Spacer	AA17
N.O. moving contact	AA18
N.C. moving contact	AA19
N.C. plunger	AA20
N.C. plunger assembly	AA21
N.O. plunger	AA22
Fixing screw	AA23
Modified fixing screw	AA24
Locking washer	AA25
Shakeproof washer	AA26
Plunger spring	AA27

Main spring	AA28
N.O. contact plate	AA29
Modified N.O. contact plate	AA30
N.C. contact plate	AA31
Modified N.C. contact plate	AA32
Spacer for M.B.B. contact plate	AA33
Terminal screw	AA34
Terminal clamp	AA35
Modified terminal clamp & screw	AA36
Insulating plate	AA37
Component chart	AA38
Modified component chart	AA39
Assembly flowchart	AA40
Component-workstation analysis	AA41
Double-headed rotary pick-and-place unit	AA42
Linear pick-and-place motion	AA43
Base for pick-and-place unit	AA44
Bearing housing	AA45
Vertical stops	AA46
Sensor	AA47
Head assembly	AA48
Carrier casting for head	AA49
Planes of motion of claw	AA50
Claw casing and slides	AA51
Clamping mechanism	AA52
N.O. contact plates claws	AA53
Complete pick-and-place unit	AA54
Functional check	AA55

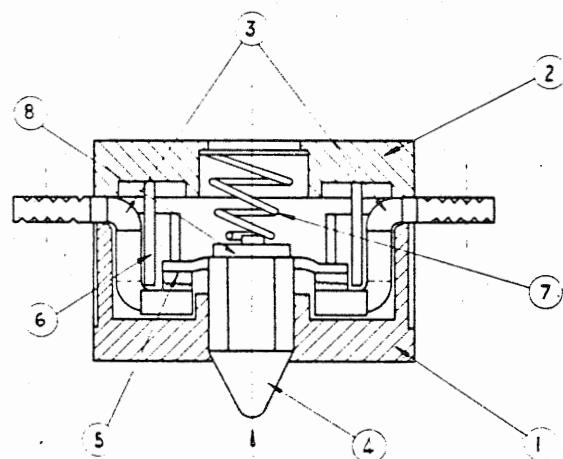


DIRECTION A

1968/69 GROUP DESIGN PROJECT

TITLE:-
NO CONTACT BRIDGE

DRG. N°
AA01

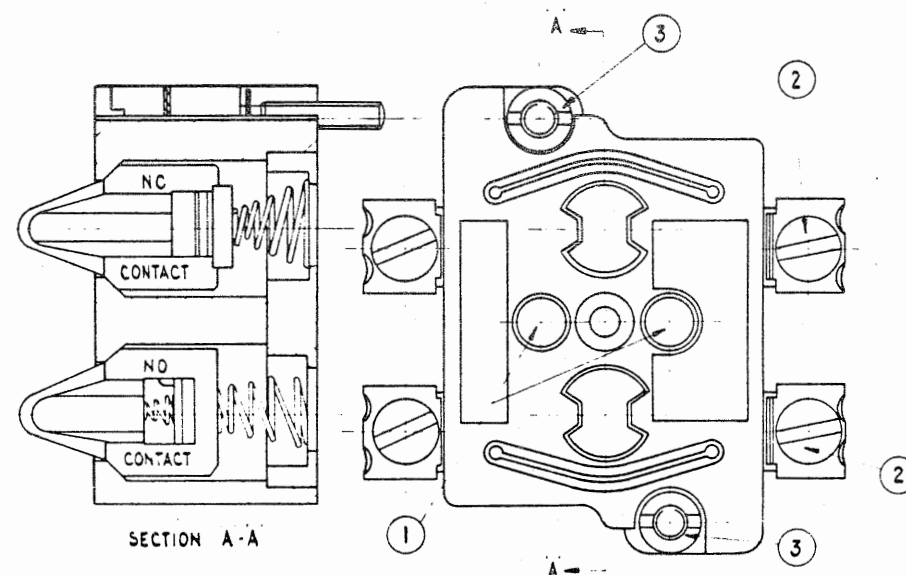


DIRECTION A

1968/69 GROUP DESIGN PROJECT

TITLE:-
NC CONTACT BRIDGE

DRG. N°
AA02



SECTION A-A

A - -

1968/69 GROUP DESIGN PROJECT

TITLE:-
SECTION A, PLAN VIEW OF HOUSING

DRG. N°
AA03

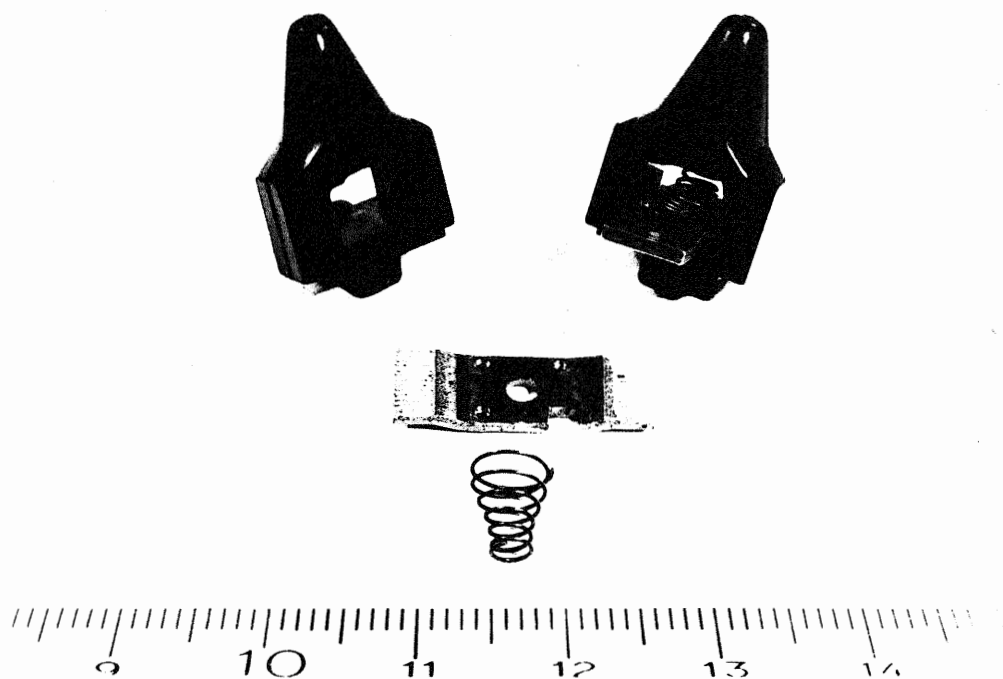


FIGURE AA04 - N.O. PLUNGER ASSEMBLY

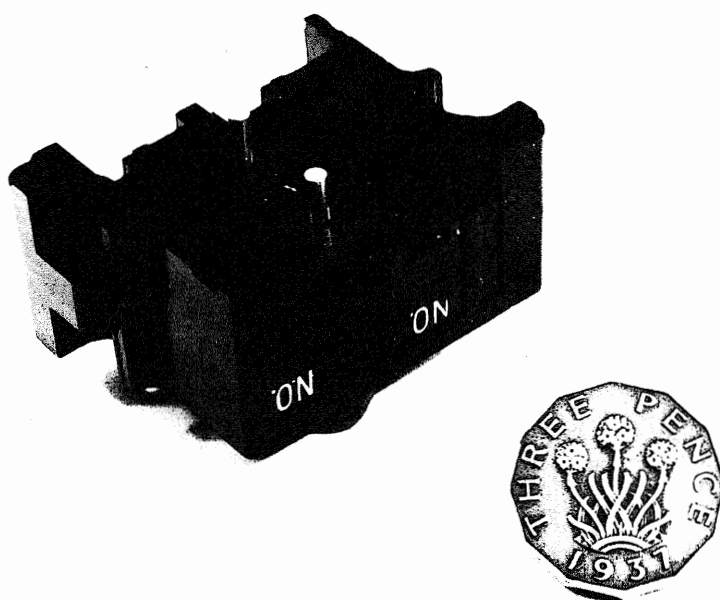


FIGURE AA05 - THE HOUSING WITH RIVETS INSERTED

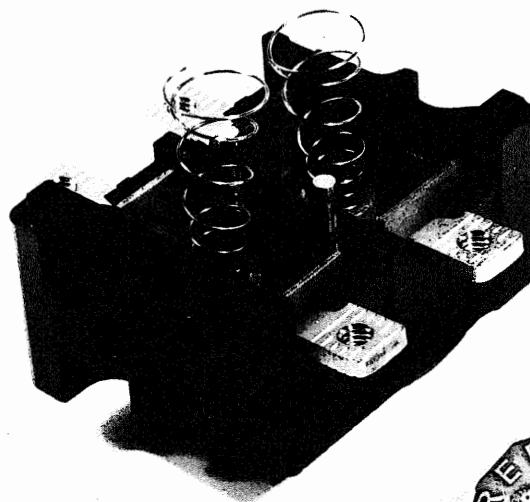


FIGURE AA06 - N.C. CONTACT BRIDGE

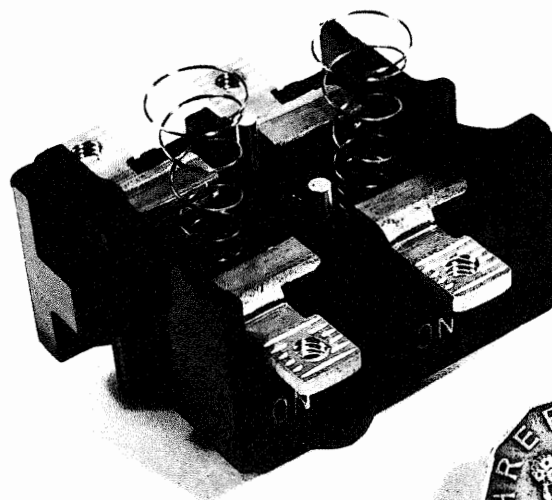


FIGURE AA07 - N.O. CONTACT BRIDGE

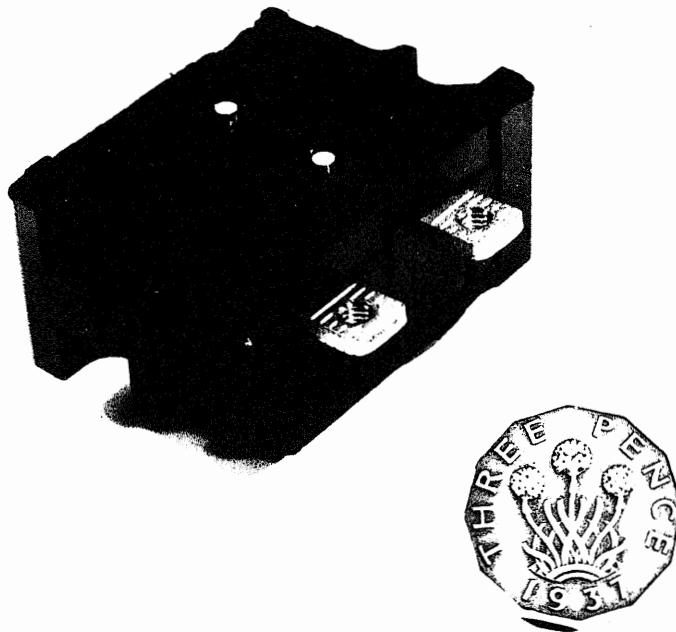


FIGURE AA08 - THE HOUSING WITH COVER FITTED

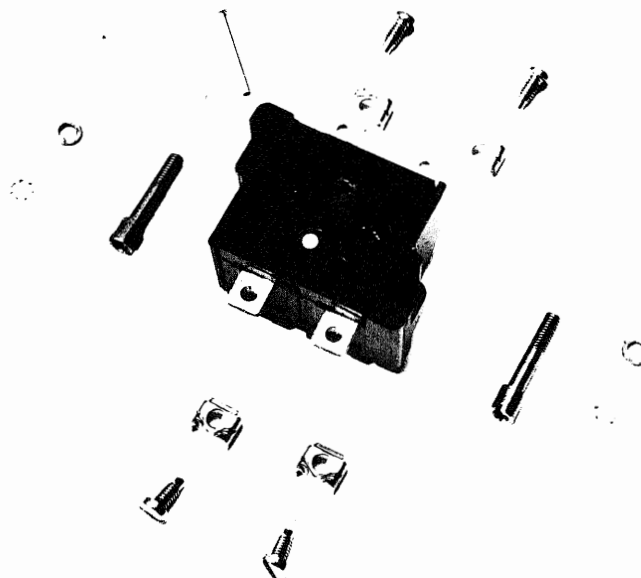
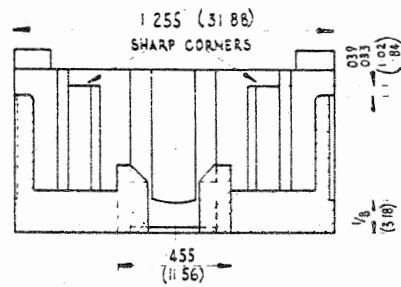
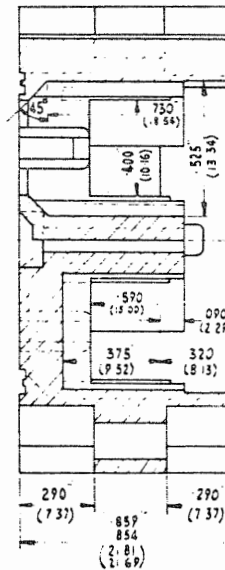
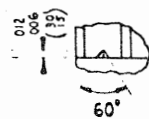
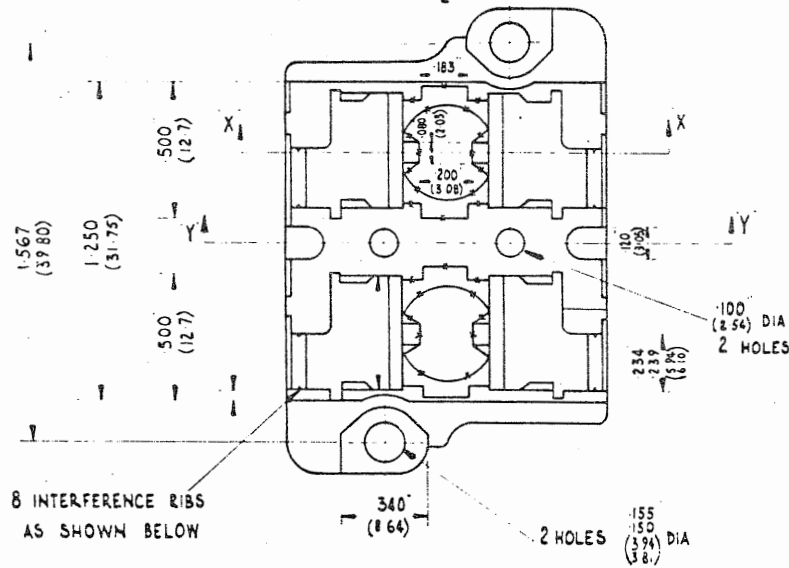
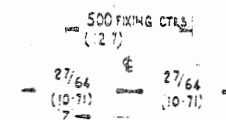
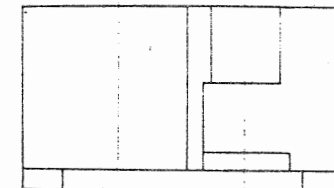
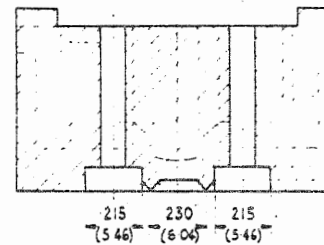


FIGURE AA09 - THE HOUSING WITH THE EXTERNAL COMPONENTS ARRAYED

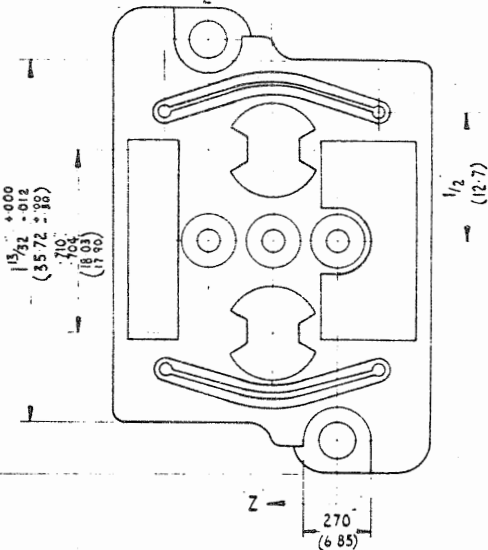
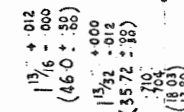
SECTION X-X



SECTION Y-Y



SECTION Z-Z



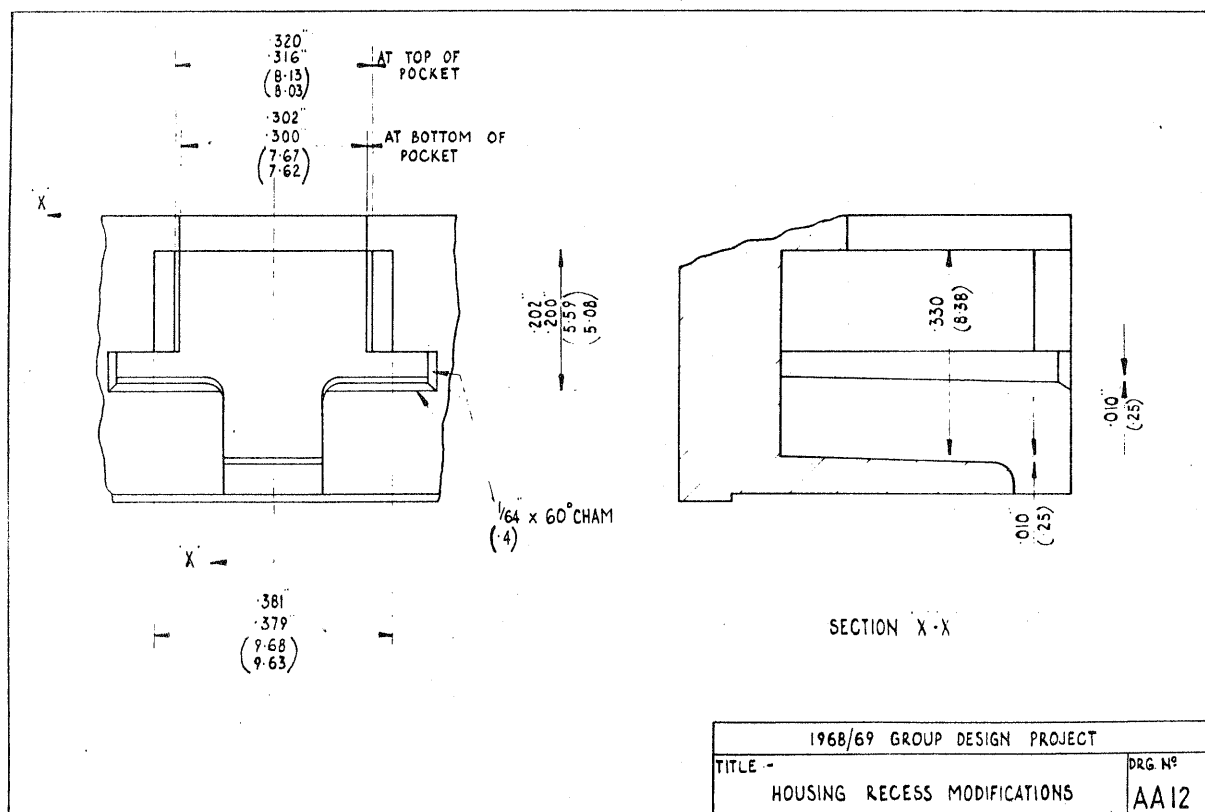
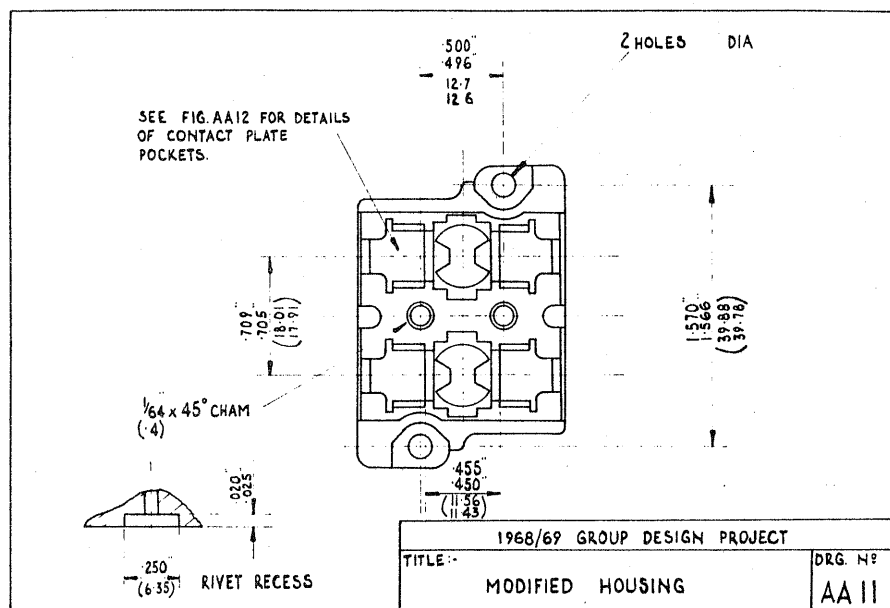
1968/69 GROUP DESIGN PROJECT

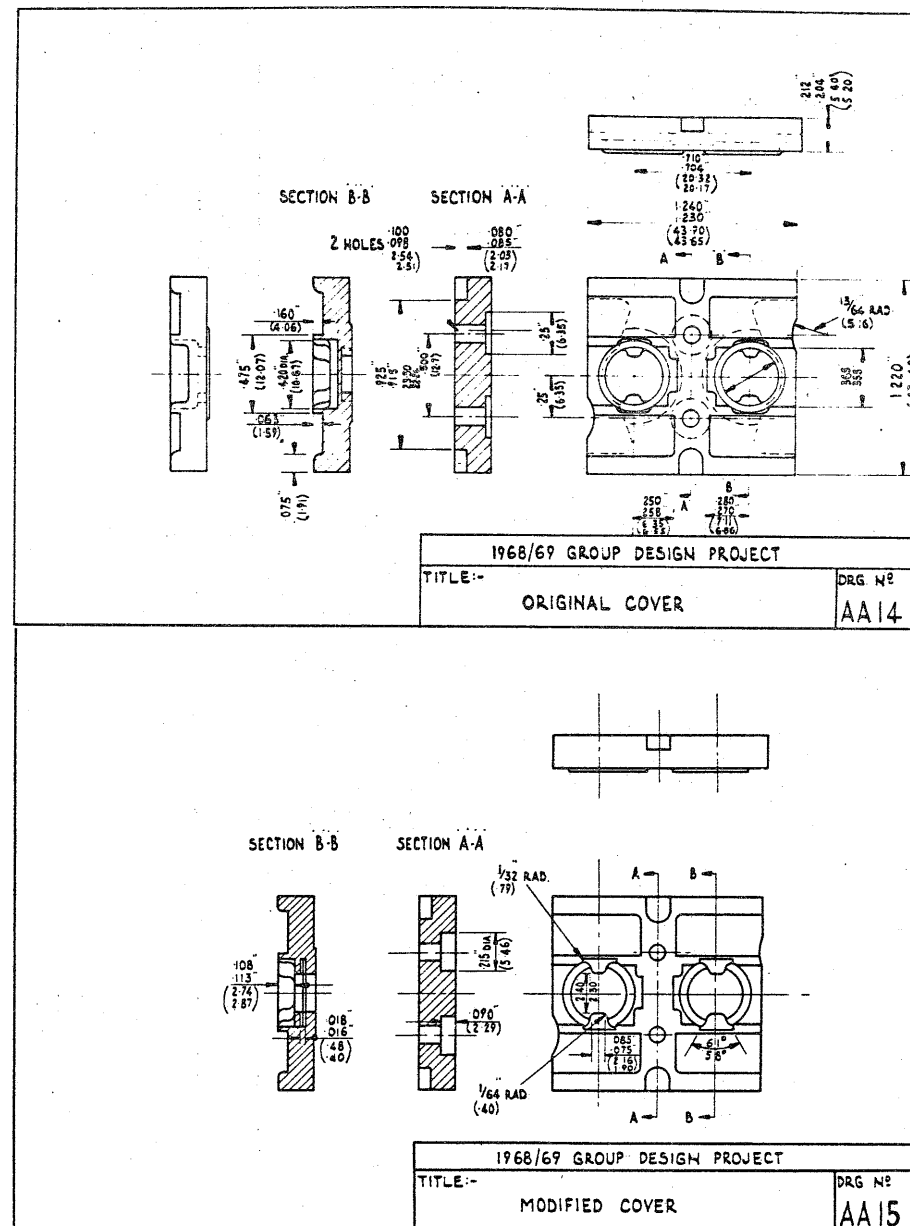
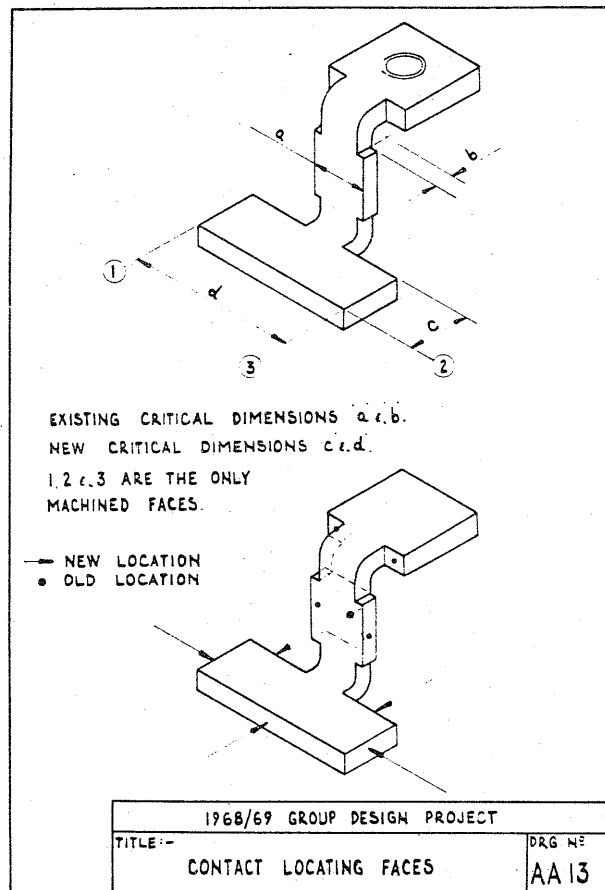
TITLE:-

HOUSING

DRG N°

AA 10





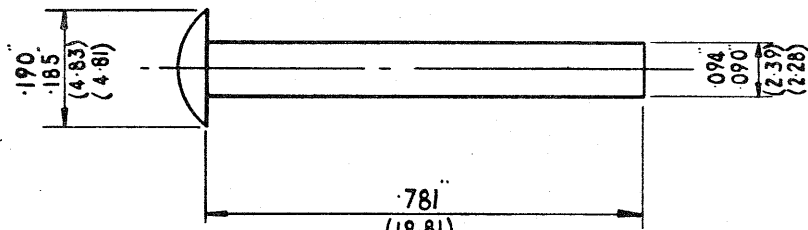


FIG. 16

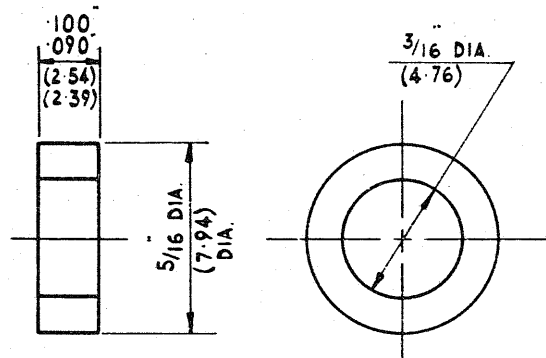


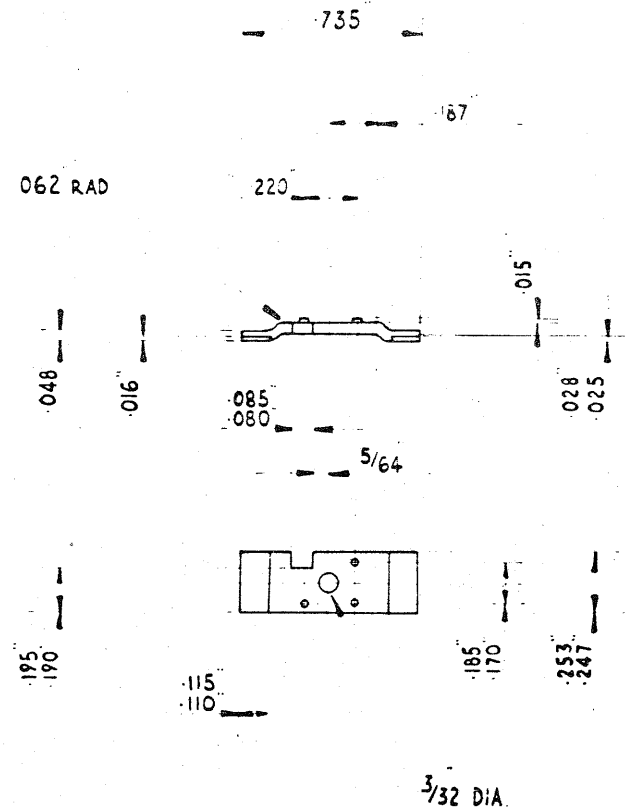
FIG. 17

1968/69 GROUP DESIGN PROJECT

TITLE :-

RIVET &
SPACER

DRG. N°
AA 16
AA 17

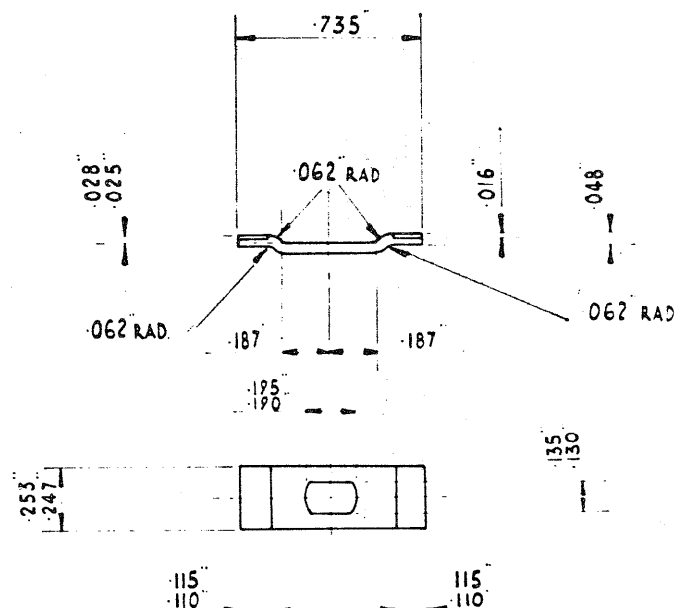


1968/69 GROUP DESIGN PROJECT

TITLE :-

N.O. MOVING CONTACT

DRG N°
AA 18



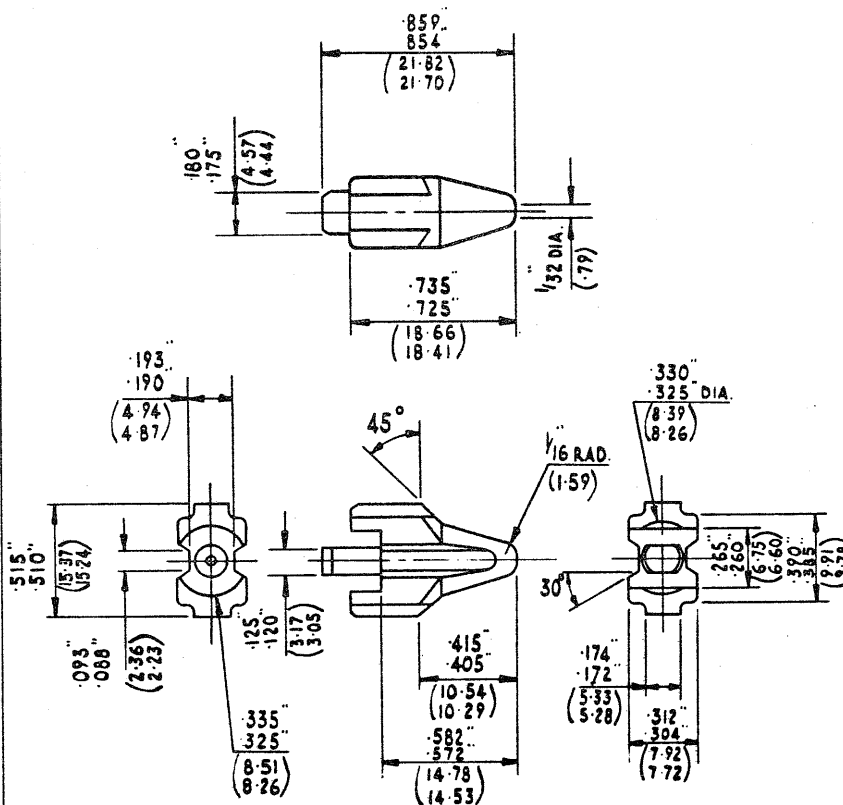
1968/69 GROUP DESIGN PROJECT

TITLE:-

N.C. MOVING CONTACT

DRG. N°

AA19



1968/69 GROUP DESIGN PROJECT

TITLE:-

NC PLUNGER

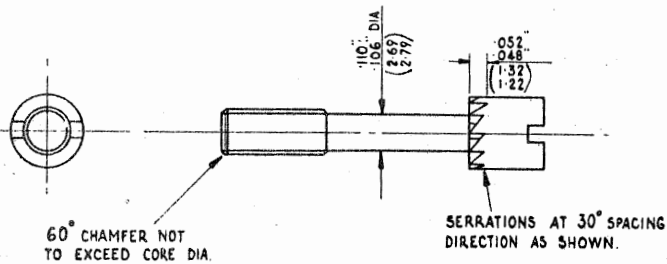
DRG N°

AA 20

DRG N°	AA 21
--------	-------

DRG. №
AA 22

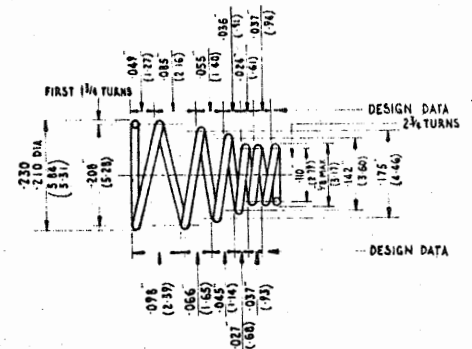
DRG. N°
AA 23



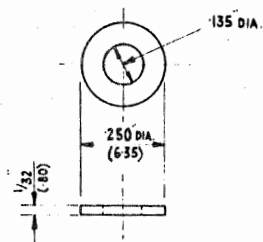
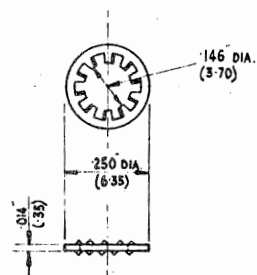
1968/69 GROUP DESIGN PROJECT

TITLE:-
REDESIGN OF CONTACT BLOCK
FIXING SCREW

DRG. N°
AA 24



MATERIALS & MODULUS USED	SPECIFICATIONS	DESIGN DATA
DIAMETER OF STOCK	STAINLESS SPL.	013 (3.3)
INSIDE DIA.	SEE ABOVE	
OUTSIDE DIA.	SEE ABOVE	
MEAN DIA.	SEE ABOVE	
FREE LENGTH	042 (MAX)	298 (7.57)
SOLID LENGTH	042 (MAX)	298 (7.57)
CALCULATED STRESS AT SOLID LENGTH	100,000 LBS PER SQ IN	5 1/4
ACTIVE TURNS	5 1/4	6 3/4
TOTAL TURNS	6 3/4	6 3/4
TYPE OF END	3/4 TURN FLAT EACH END	
COATING	NOT GROUND	
DIRECTION OF WINDING	R.H. OR L.H.	
INITIAL WORKING LOAD	4.2 TO 5.2 OZ	
INITIAL WORKING LENGTH	9/64	
STRESS		
FINAL WORKING LOAD	13 OZ MAX	
FINAL WORKING LENGTH	3/64 TO 5/64	
STRESS	100,000 LBS PER SQ IN	



1968/69 GROUP DESIGN PROJECT

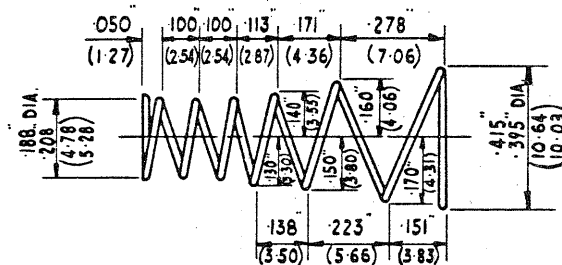
TITLE:-
SHAKEPROOF & LOCKING WASHERS

DRG. N°
AA 25
AA 26

1968/69 GROUP DESIGN PROJECT

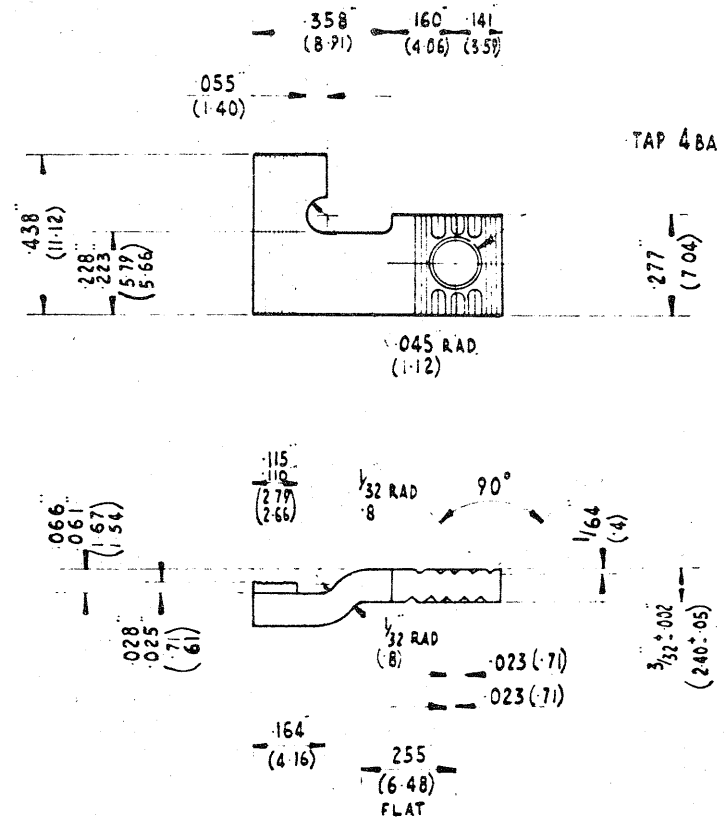
TITLE:-
PLUNGER SPRING

DRG. N°
AA 27

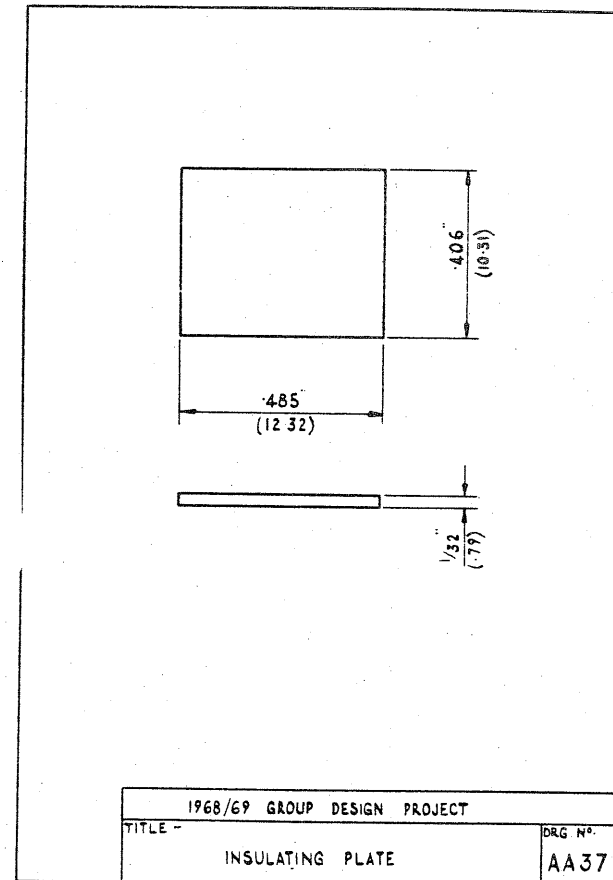
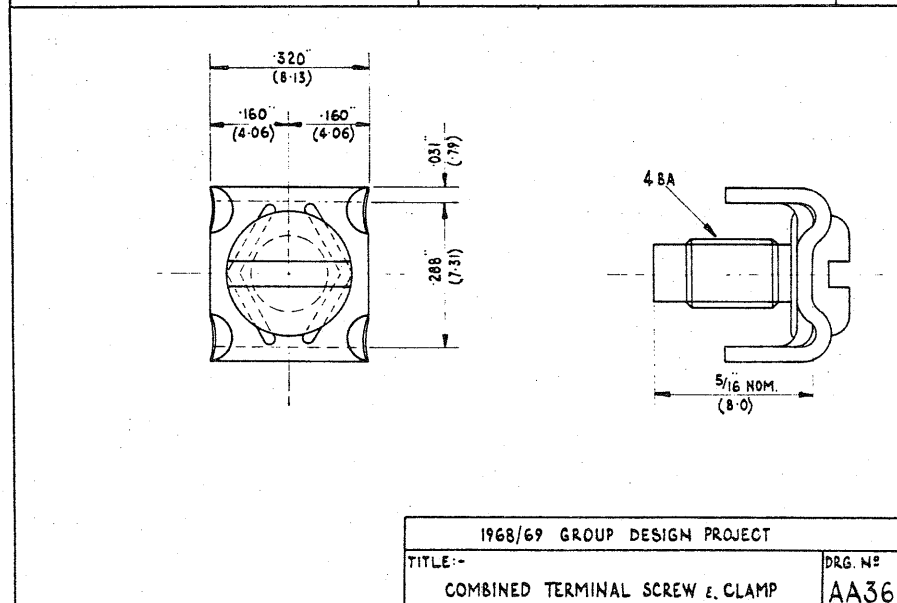
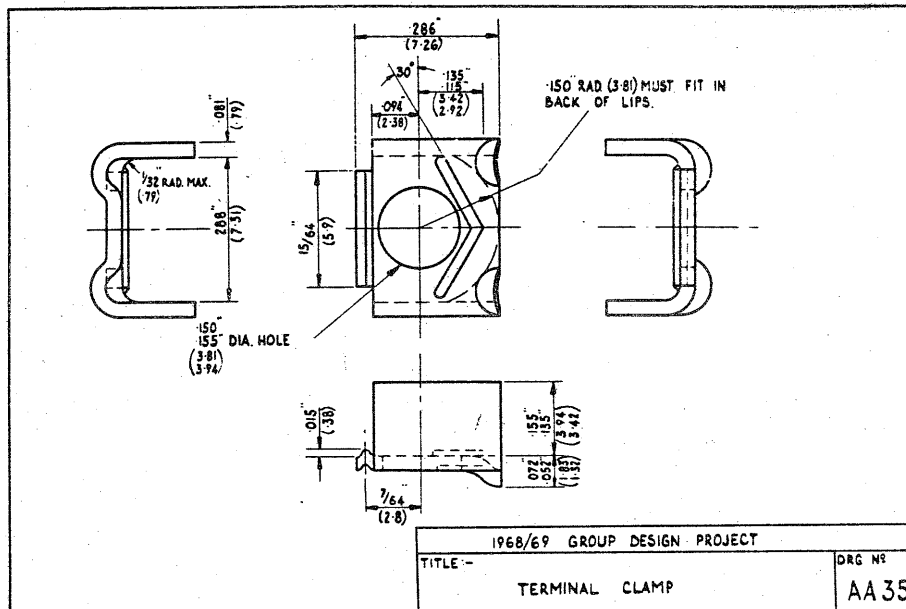


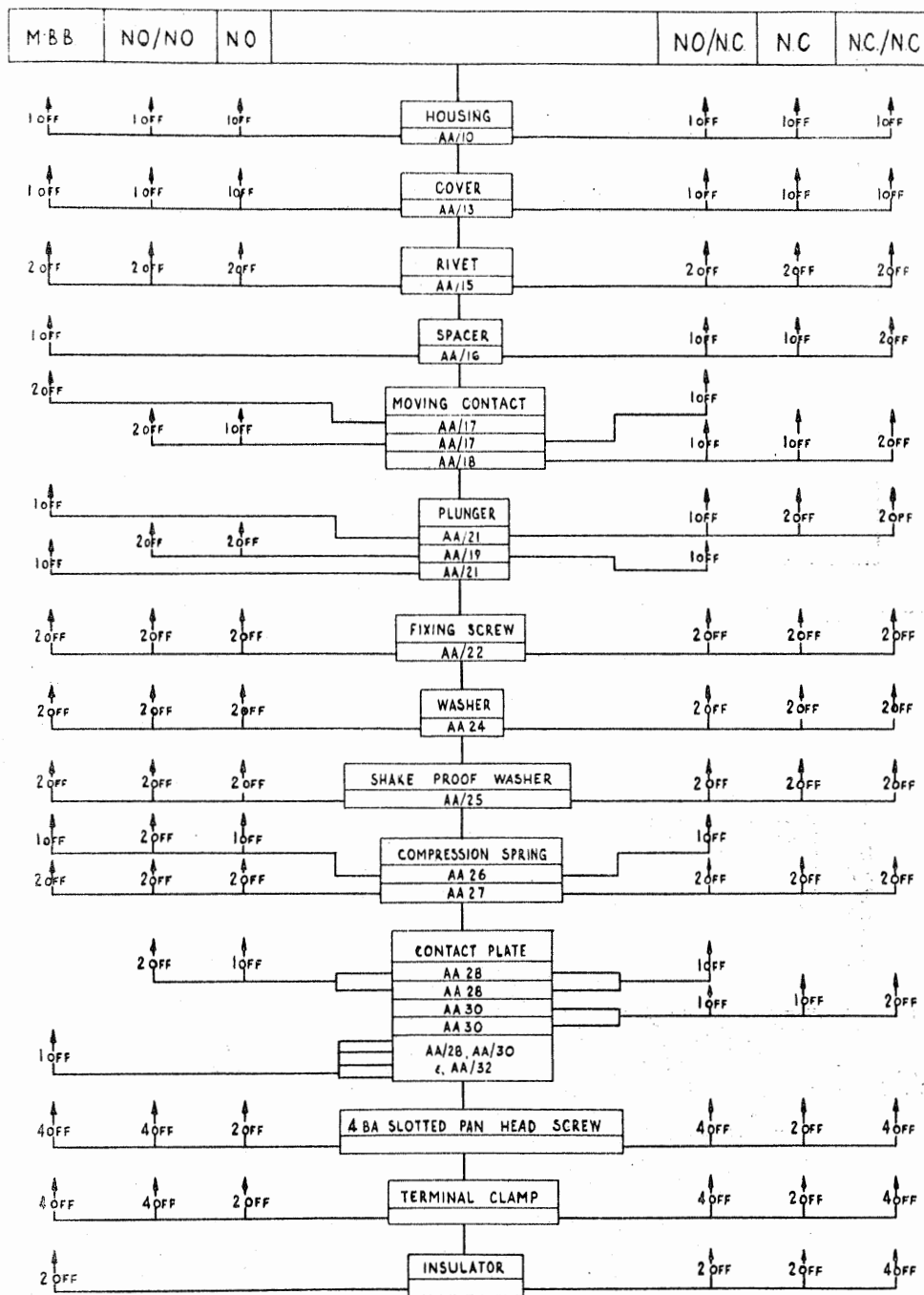
MATERIALS & MODULUS USED	SPECIFICAT. NO.	DESIGN DATA
DIAMETER OF STOCK	STAINLESS STL.	-
INSIDE DIA.	-	.015
OUTSIDE DIA.	SEE ABOVE	-
MEAN DIA.	-	-
FREE LENGTH	-	13/16"
SOLID LENGTH	.070 (MAX)	-
CALCULATED STRESS AT SOLID LENGTH	- LARGE SMALL TURN 115,000 TURN 11,000	-
ACTIVE TURNS	-	5 1/2
TOTAL TURNS	-	7
TYPE OF END	3/4 TURN FLAT EACH END	NOT GROUND
COATING	-	-
DIRECTION OF WINDING	R.H. or L.H.	-
INITIAL WORKING LOAD	4.5 TO 5 oz.	-
INITIAL WORKING LENGTH	5/16	-
STRESS	- LARGE SMALL TURN 18,000 TURN 18,000	-
FINAL WORKING LOAD	-	8 TO 10 oz.
FINAL WORKING LENGTH	-	.070

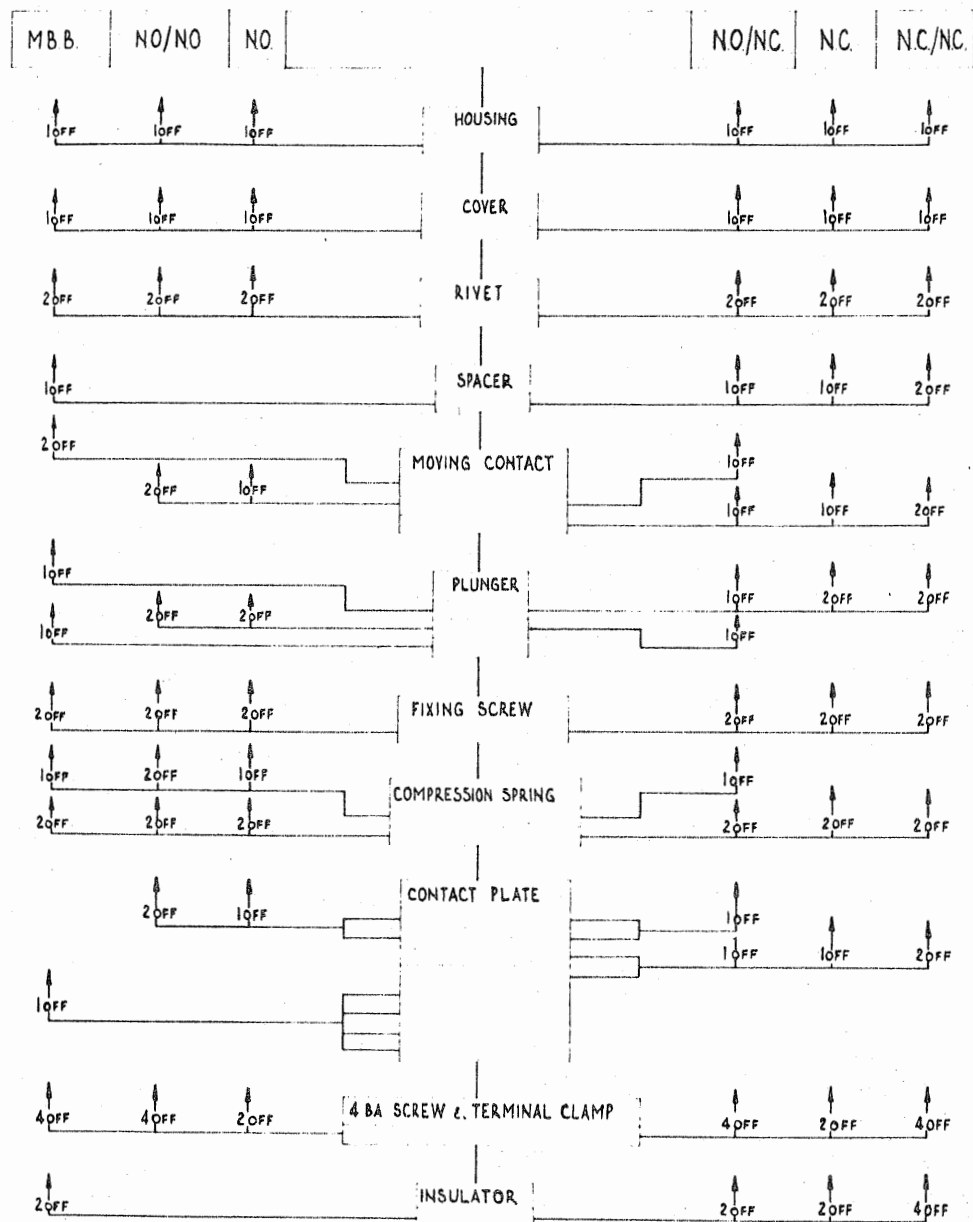
1968/69 GROUP DESIGN PROJECT	
TITLE:-	DRG. NO.
MAIN SPRING	AA 28



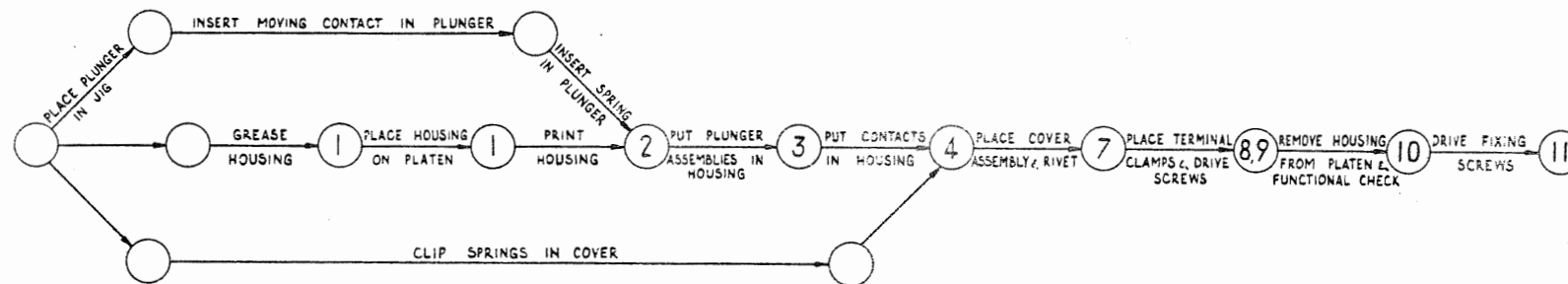
1968/69 GROUP DESIGN PROJECT	
TITLE:-	DRG. NO.
RIGHT-HANDED N.O. CONTACT PLATE	AA 29



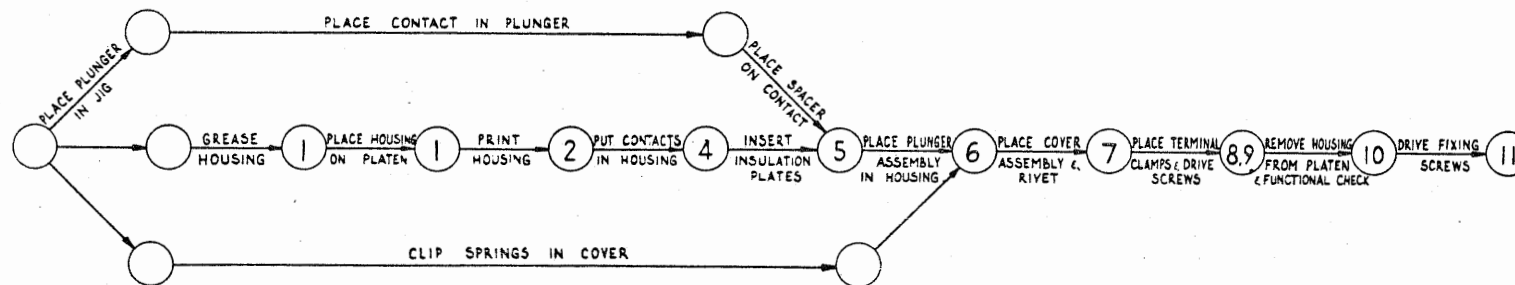




1968/69 GROUP DESIGN PROJECT	
TITLE--	DRG. N°
PARTS REQUIRED FOR MODIFIED CONTACT BLOCK.	
AA39	



NO CONTACT BRIDGE



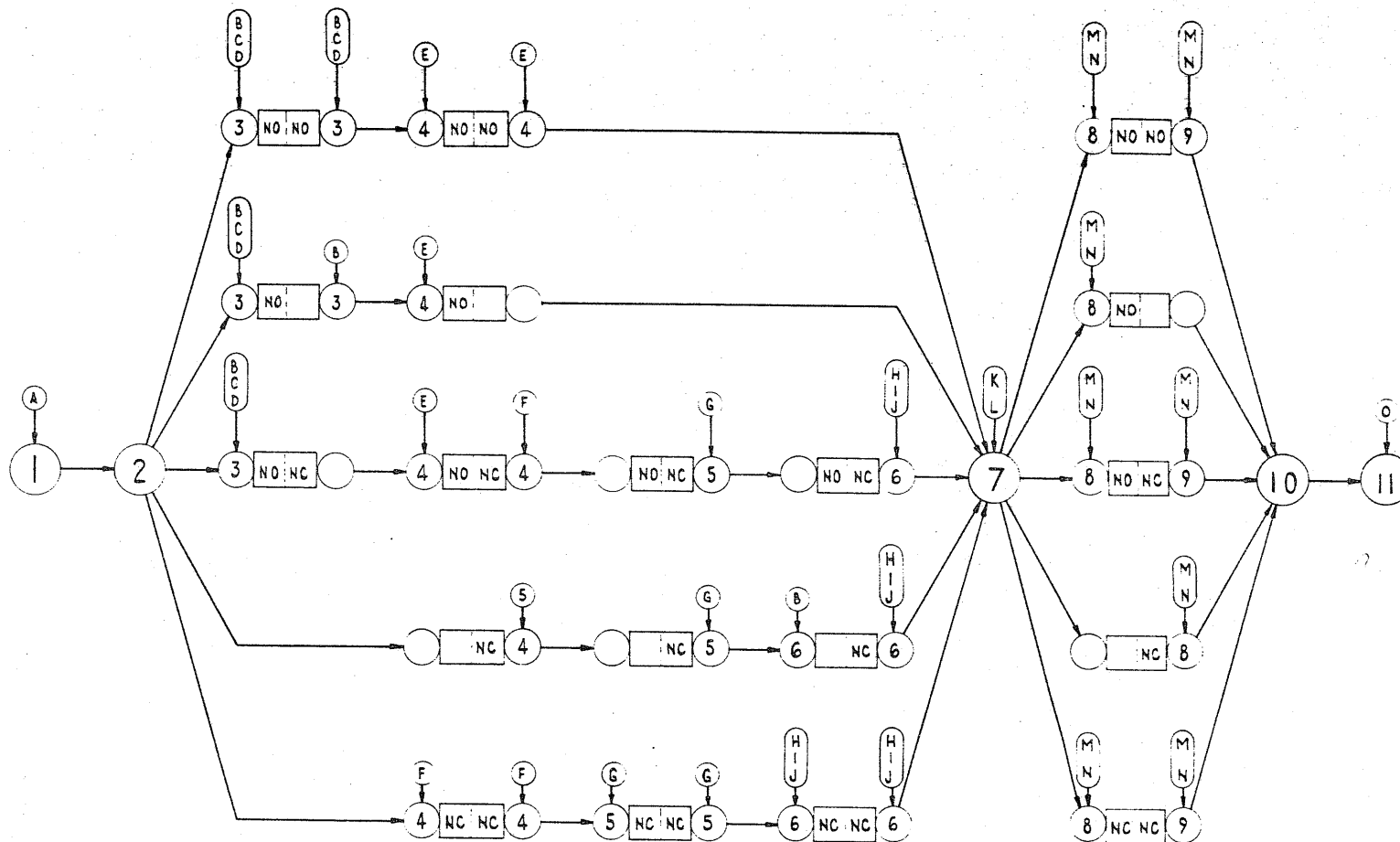
NC CONTACT BRIDGE

1968/69 GROUP DESIGN PROJECT		
TITLE -	ASSEMBLY FLOWCHART	DWG NO AA 40

NOMENCLATURE FOR FIGURE AA 41.

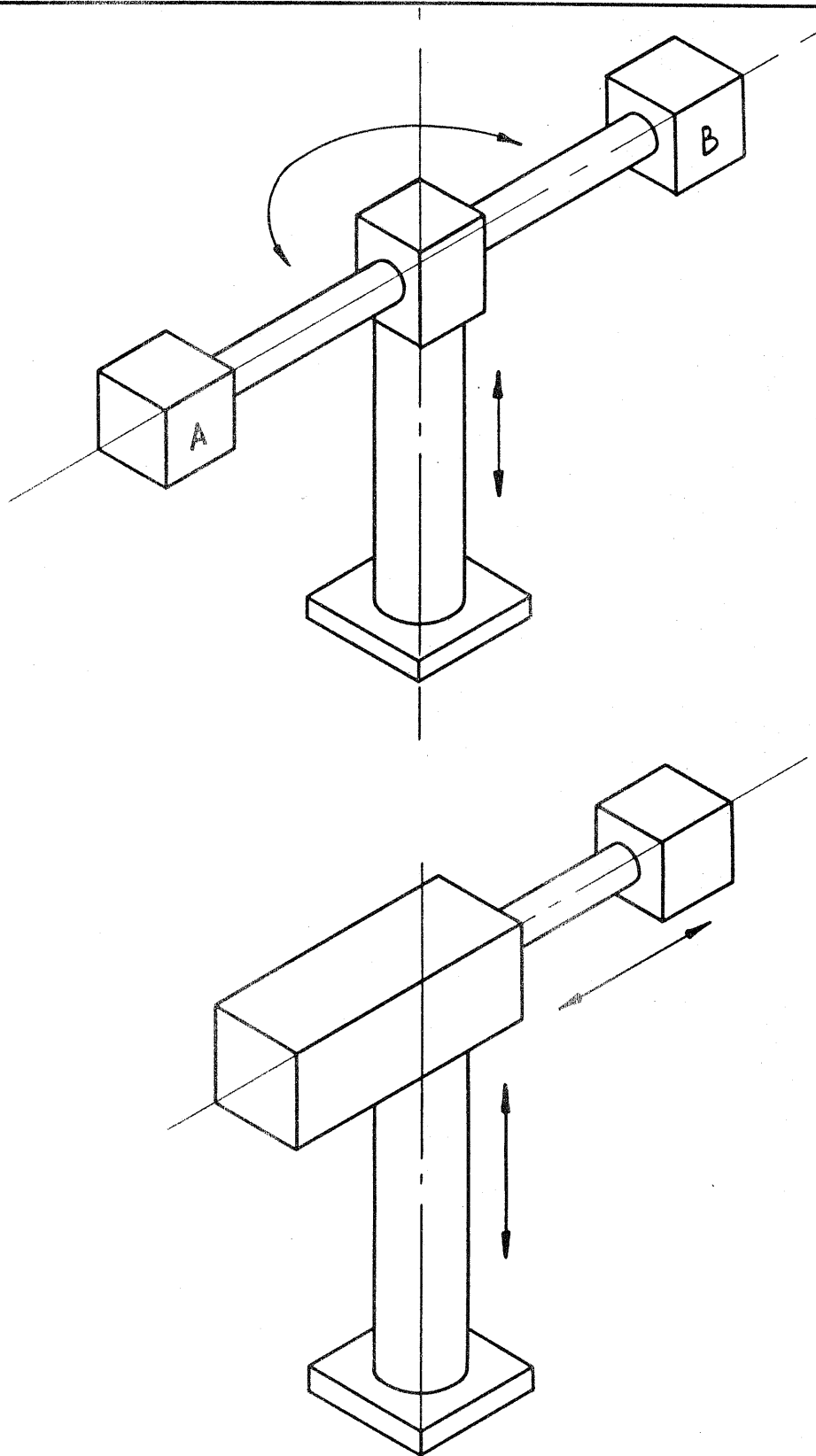
- | <u>Workstation Number</u> | <u>Function.</u> |
|---------------------------|---|
| 1. | Place the housing on the platen and grease slides. |
| 2. | Print the respective N.O. and/or N.C.'s on the housing. |
| 3. | Feed N.O. plunger and one N.O. plunger assembly, or two N.O. plunger assemblies. |
| 4. | Feed two or four N.O. or N.C. contact plates. |
| 5. | Feed two or four insulating plates. |
| 6. | Feed one N.C. plunger and one N.C. plunger assembly or two N.C. plunger assemblies. |
| 7. | Feed cover and spring sub-assembly and rivet. |
| 8. | Feed two terminal clamps and screws. |
| 9. | Feed two terminal clamps and screws. |
| 10. | Remove housing from platen and place in functional check. |
| 11. | Feed two fixing screws. |

<u>Part Letter</u>	<u>Part Name.</u>
A	Housing
B	N.O. plunger
C	N.O. moving contact
D	Spring
E	N.O. contacts
F	N.C. contacts
G	Insulating plates
H	N.C. plunger
I	N.C. moving contact
J	Fibre spacer
K	Main springs
L	Cover
M	Terminal screw
N	Terminal clamp
O	Fixing screw



NOTE - FOR BASE MOUNTED BLOCKS, STATIONS 8, 9 & 11 ARE OMITTED

1968/69 GROUP DESIGN PROJECT	
TITLE -	DRG N ^o
COMPONENT-WORKSTATION ANALYSIS	AA 41



1968/69 GROUP DESIGN PROJECT

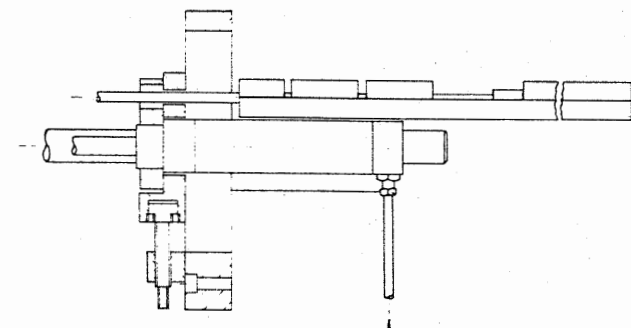
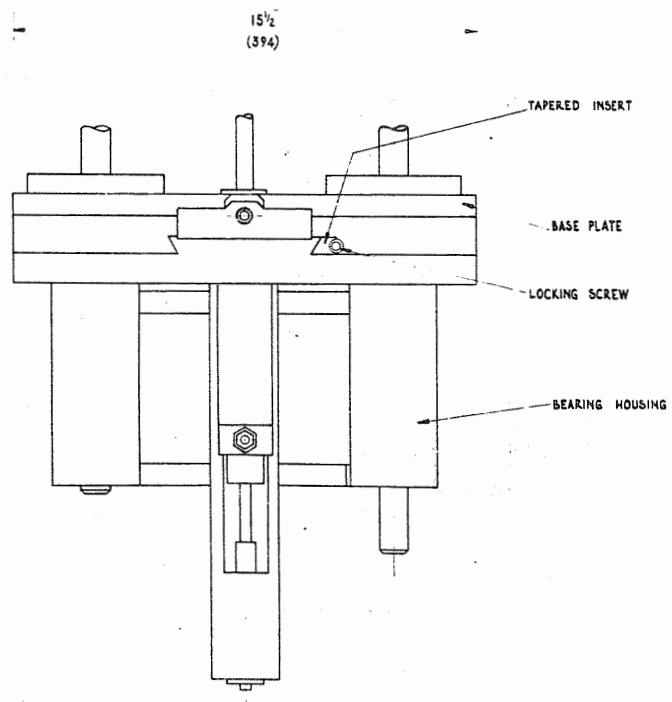
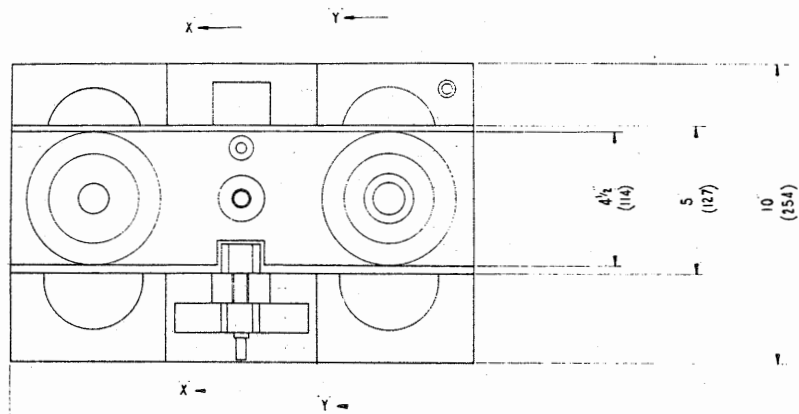
TITLE:-

DOUBLE-HEADED ROTARY PICK & PLACE UNIT
 LINEAR PICK & PLACE MOTION.

DRG. NO.

AA 42

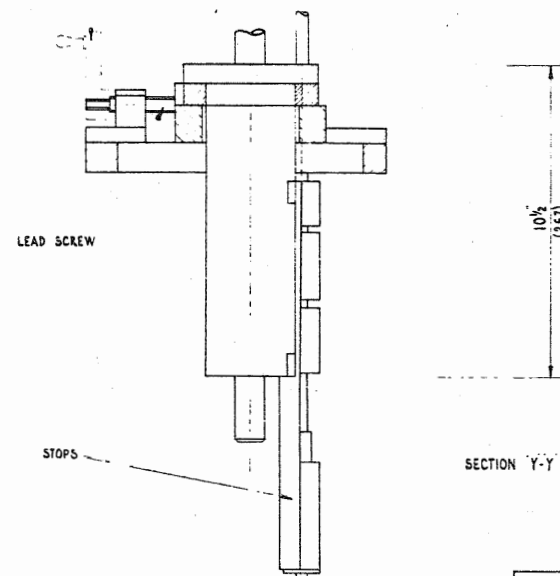
AA 43



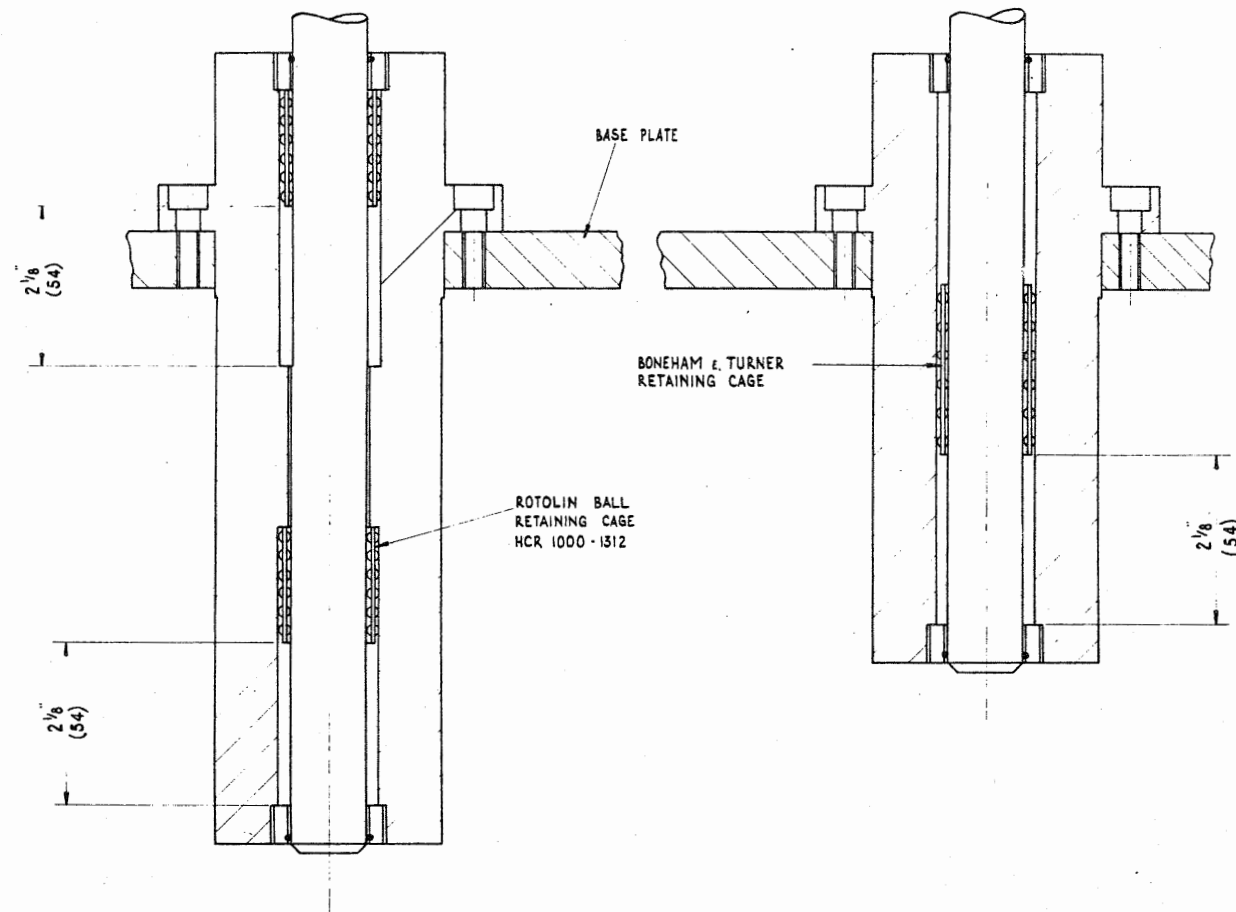
SECTION X-X

AIR SUPPLY

RATCHET HOUSING



SECTION Y-Y



1968/69 GROUP DESIGN PROJECT

TITLE:-

BEARING HOUSING

DRG. N^o

AA 45

* BACK PRESSURE SENSOR

FIXED STOP

ADJUSTABLE STOPS

FIXED STOP

PISTON ROD

5
(12.7)

2 1/4
(57.2)

ACTUATING ROD

CLAMPING SCREWS

4 1/4 (108)

+ CLOSED LENGTH OF SPRING

UPWARD MOTION

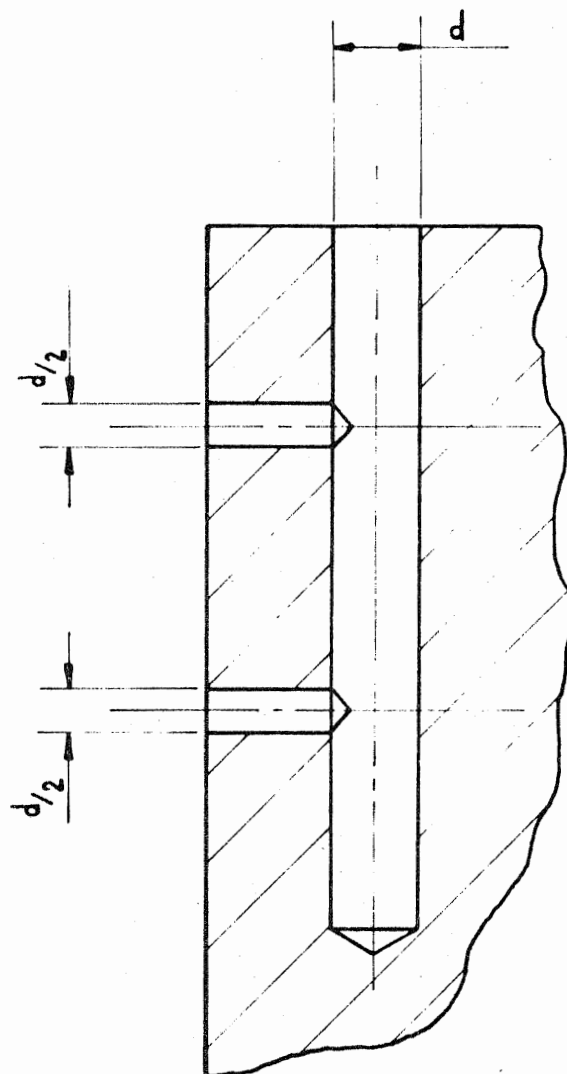
1968/69 GROUP DESIGN PROJECT

TITLE:-

VERTICAL STOPS

DRG N^o

AA 46



SUGGESTED VALUE OF $d = \frac{1}{16}'' (1.59)$

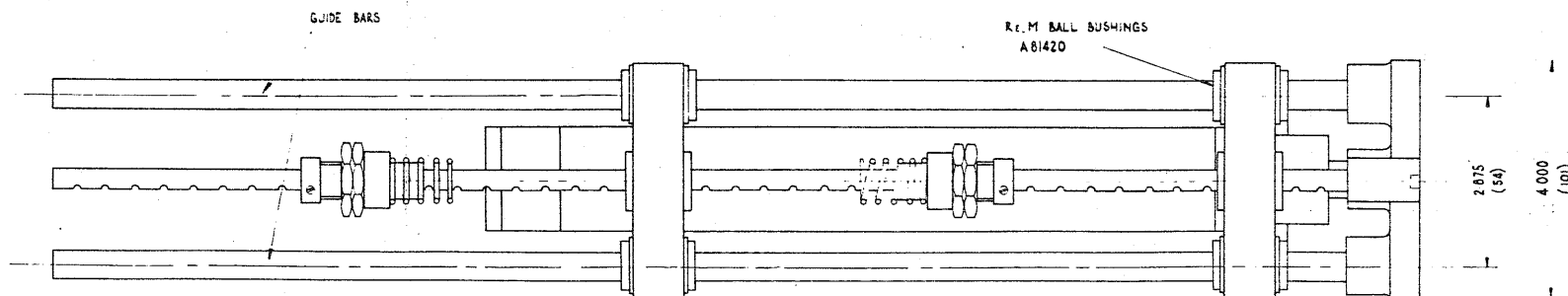
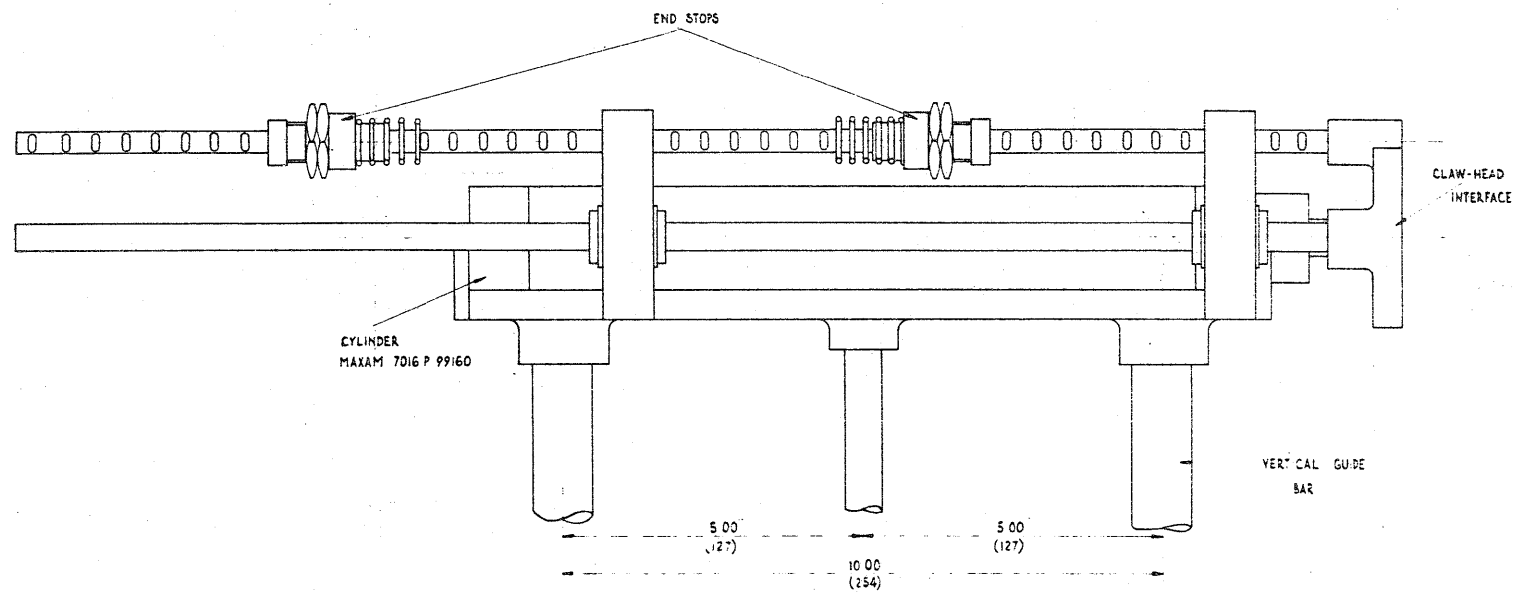
1968/69 GROUP DESIGN PROJECT

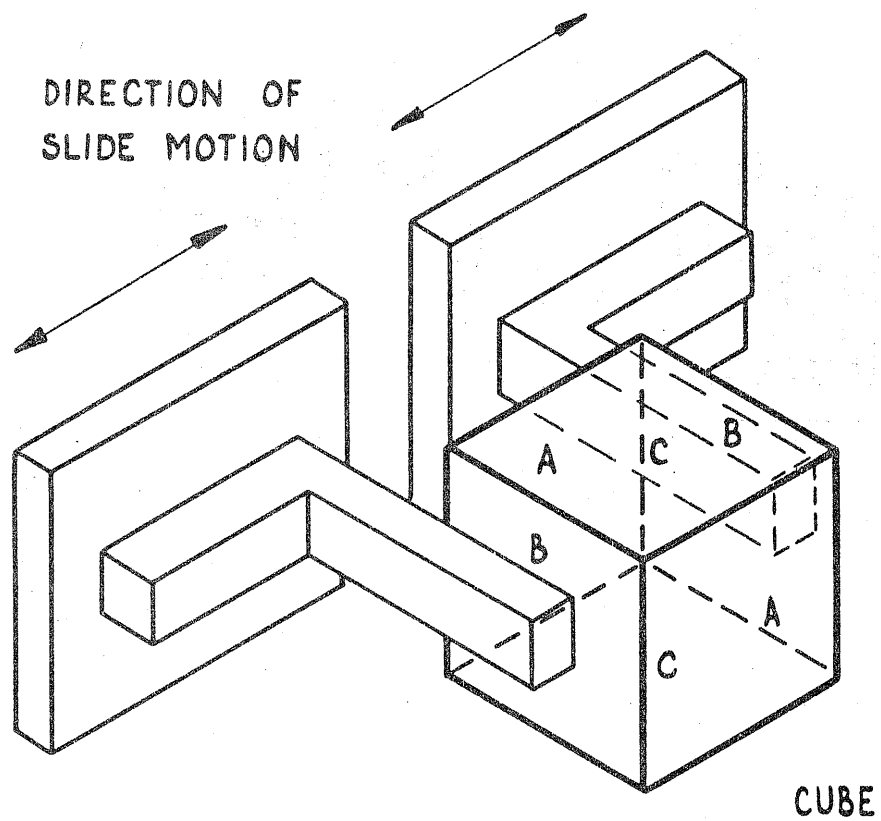
TITLE:-

TYPICAL FLUIDIC SENSOR

DRG. N°

AA 47





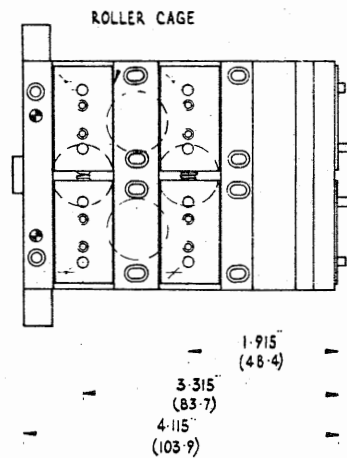
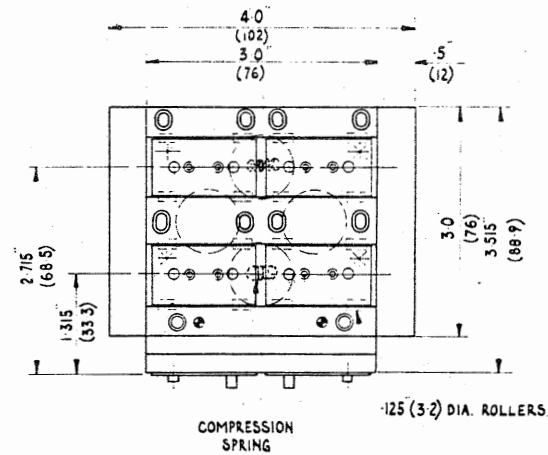
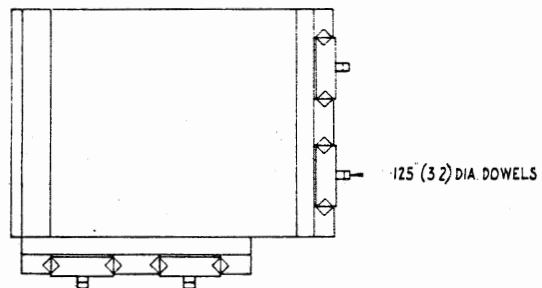
1968/69 GROUP DESIGN PROJECT

TITLE:-

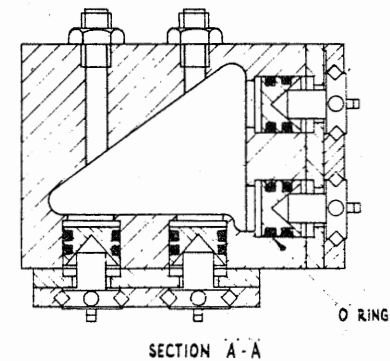
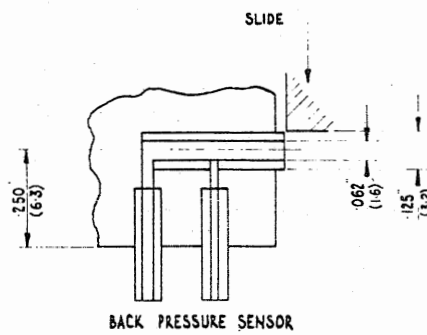
PLANES OF MOTION
OF THE CLAW

DRG. N°

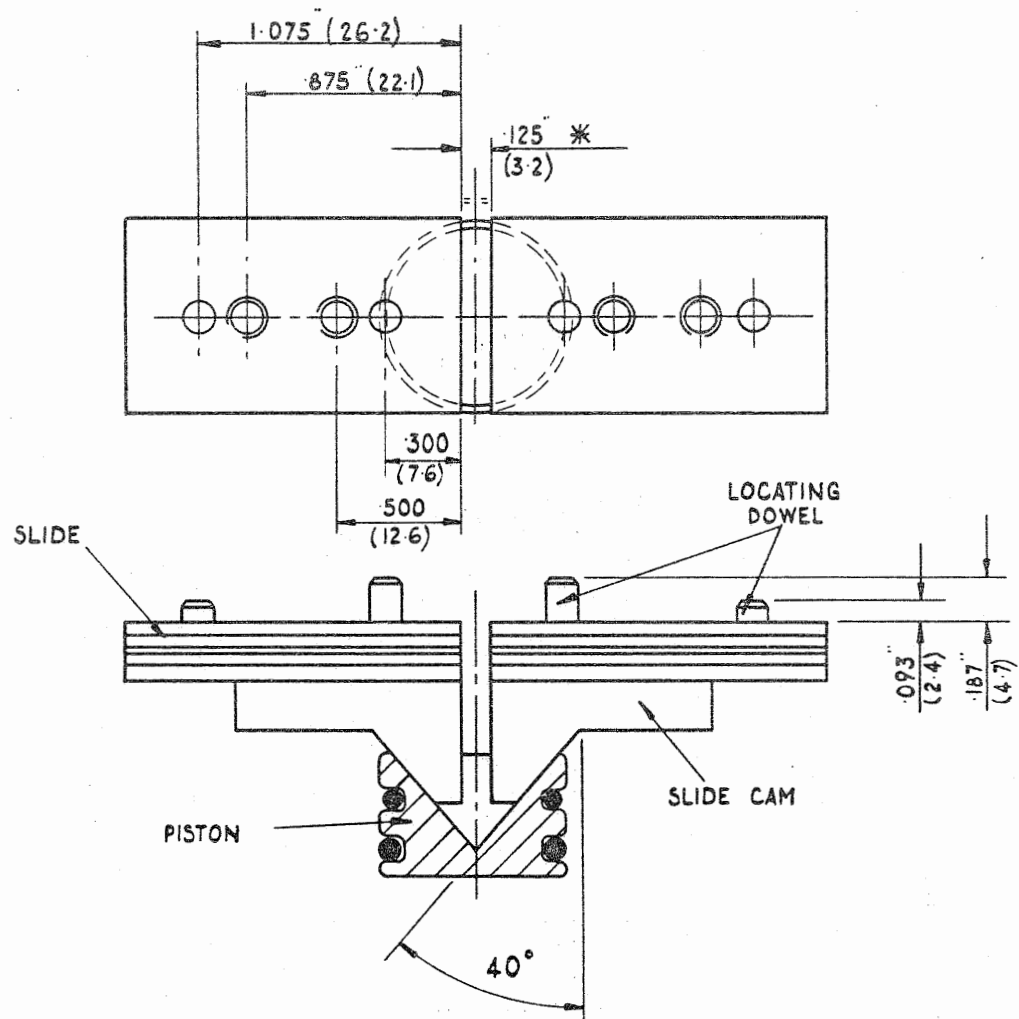
AA50



* BACK PRESSURE SENSOR

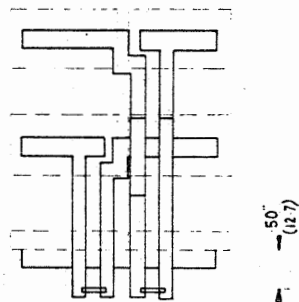
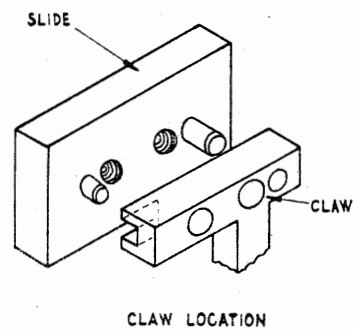


1968/69 GROUP DESIGN PROJECT		
TITLE --	CLAW CASING & SLIDES	DRG N° AA 51

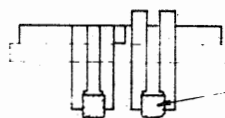


* EACH SLIDE HAS $\pm .062$ " (1.5mm) TOTAL TRAVEL
SLIDES ARE SHOWN IN MID POSITION OF TRAVEL

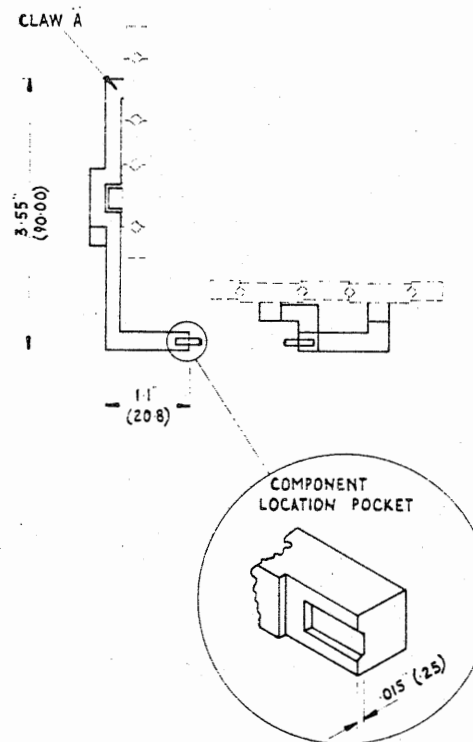
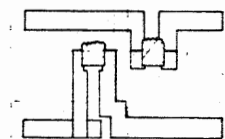
1968/69 GROUP DESIGN PROJECT		
TITLE:-		DRG. N°
CLAMPING MECHANISM		AA 52



50°
(12.7)



NORMALLY OPEN
CONTACT PLATE



NOTE -

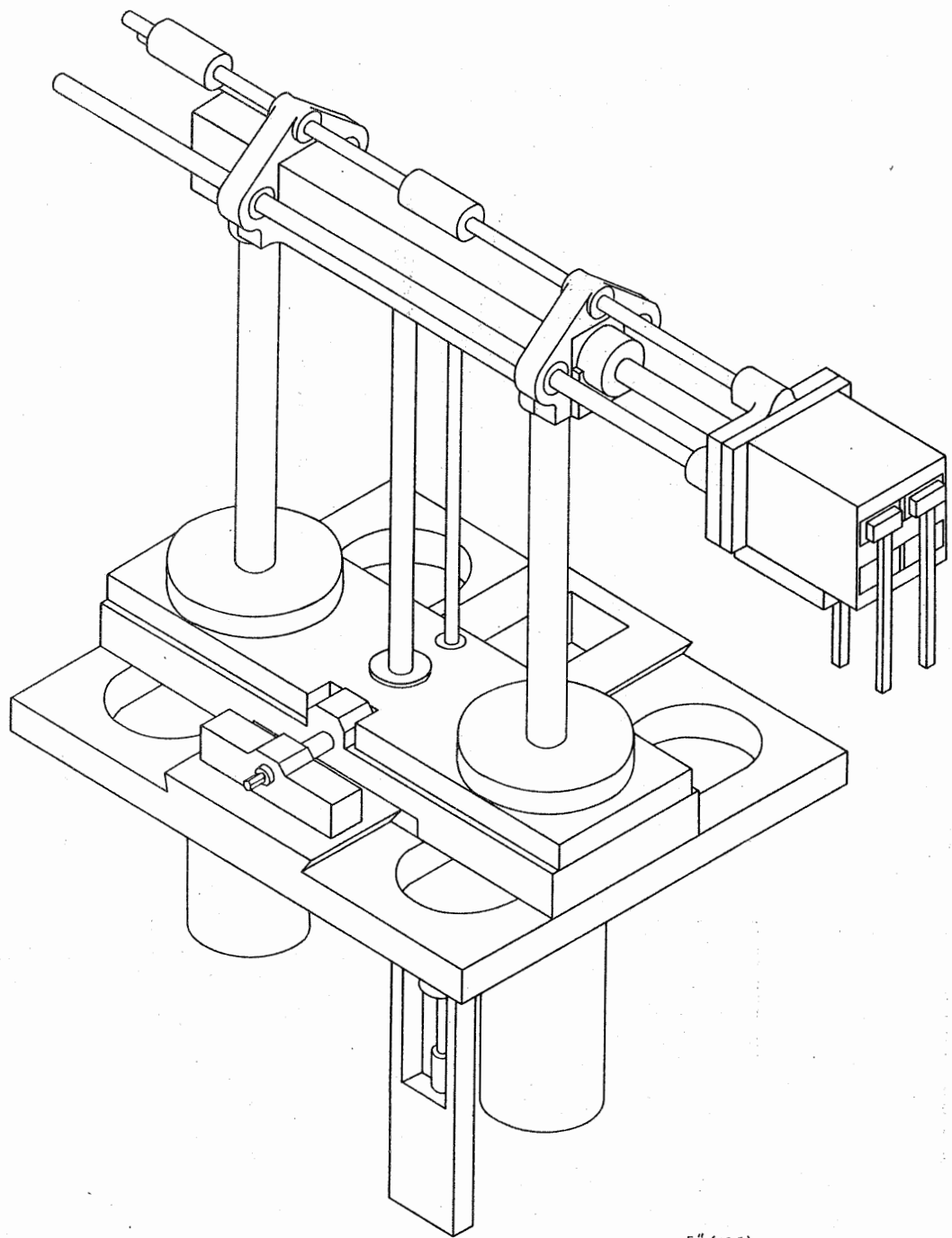
CLAW LOCATION
SLIDES

1968/69 GROUP DESIGN PROJECT

TITLE -
CLAW DESIGN FOR
NORMALLY OPEN CONTACT PLATE

DRG. NO.

AA53



5" (125)

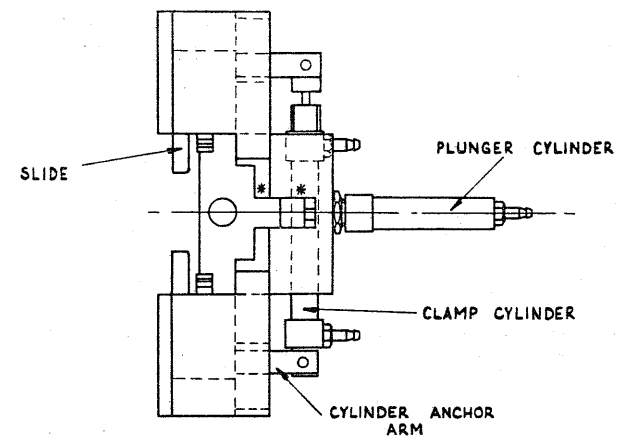
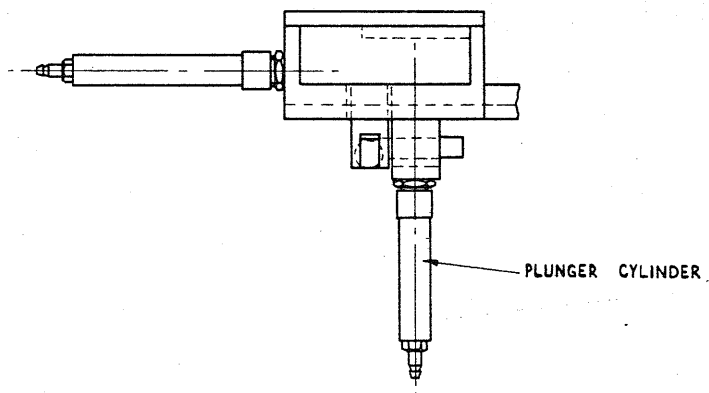
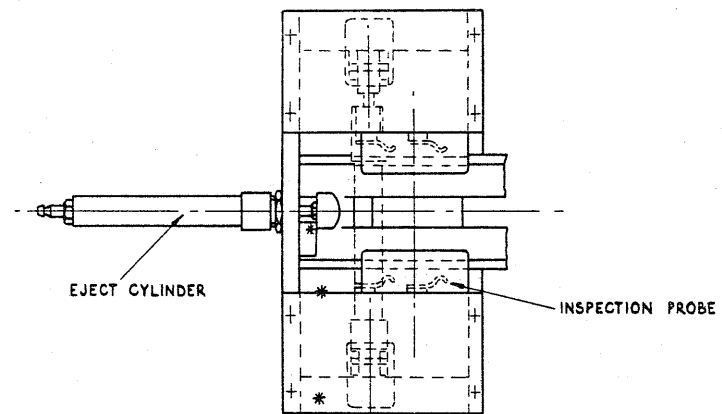
1968/69 GROUP DESIGN PROJECT

TITLE -

LINEAR PICK & PLACE UNIT

DRG. NO.

AA54



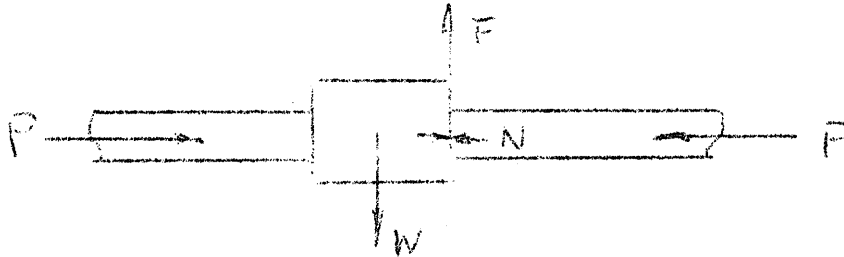
* BACK PRESSURE SENSOR

1968/69 GROUP DESIGN PROJECT	
TITLE:-	DRG. N ^o .
INSPECTION UNIT	AA55

APPENDIX 1

Determination of the clamping forces required for the claw and clamping mechanism, and determination of the claw clamping force.

Consider two claws clamping a component, then the forces in the system are:-



Where W = Weight of the component.
 P = Force exerted by the claws.
 F = Friction Force.
 μ = Coefficient of friction.
 N = Normal force.

Assuming a maximum component weight of 101bf (4.5Kgs.) and a coefficient of friction of .3.

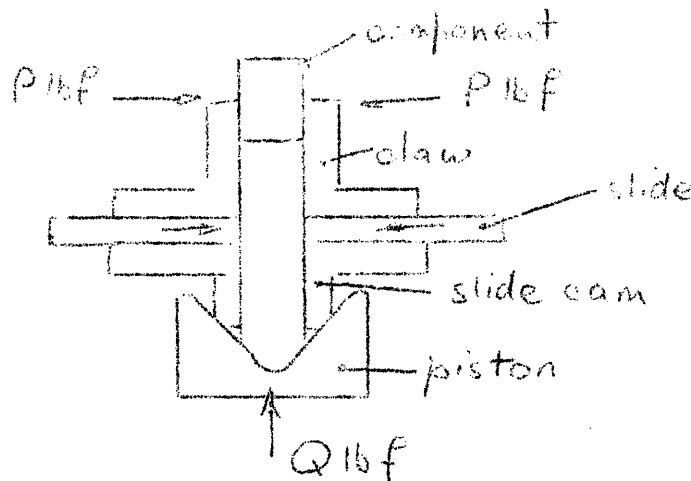
$$F = \mu N$$

$$\text{but } F = W/2 \text{ and } N = P$$

$$\text{therefore } P = 5/3 = 16.61\text{bf.}$$

Therefore the required force to be exerted by the claws to lift a 101bf. (4.5Kgs.) component must be $\geq 16.61\text{bf.}$ (7.5Kgs.)

Now considering the clamping mechanism:-



Assuming that (1) the claw deflection is to be no greater than .0005'' (.012mm.)

(2) the maximum load on the claw for N.O. contact plates is .20lbf. (.09Kgs.)

$$\text{Therefore stiffness} = \frac{.20}{.0005} = 400\text{lbf./in.}$$

$$\text{Therefore, claw stiffness must be } \geq 400\text{lbf./in.} \quad (713\text{Kg./mm.})$$

Considering claw 'A' which has the greatest values of $a=1.1''$ and $b=3.55''$.

$$\text{Stiffness in direction } x = \frac{EI}{a^3/3 + a^2b}$$

and assuming that section of claw is .2x.2

$$\begin{aligned} \text{moment of inertia} &= \frac{b^4}{12} \\ &= 1.335 \times 10^{-4} \text{ in.}^4 \end{aligned}$$

$$\begin{aligned} \therefore \text{Stiffness} &= \frac{30 \times 10^6 \times 1.335 \times 10^{-4}}{1.33/3 + 1.21 \times 3.55} \\ &= 845\text{lbf./in.} \quad (1505\text{Kg./mm.}) \end{aligned}$$

$$\begin{aligned} \text{Stiffness in direction } y &= \frac{2EI}{ab(a+b)} \\ &= \frac{2.30 \times 10^6 \times 1.335 \times 10^{-4}}{1.1 \times 3.55 \times 4.65} \\ &= 442\text{lbf./in.} \quad (786\text{Kg./mm.}) \end{aligned}$$

Both values are greater than 400lbf./in. (713Kg./mm.) and therefore the claw is acceptable as designed.

APPENDIX 11

Determination of the claw stiffness for the N.O. contact plate.

$$\text{Stiffness} = \frac{\text{Load}}{\text{Deflection}}$$

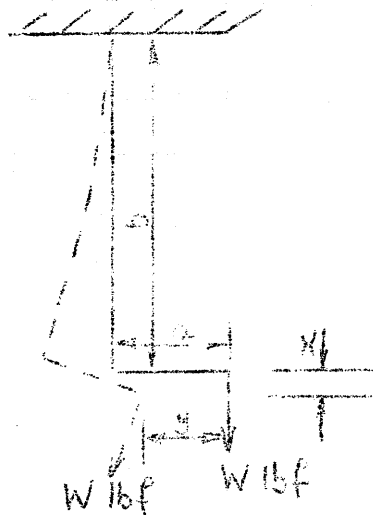
From Castigliano's theorem,

$$\text{Deflection } dy = \int \frac{M dM dx}{EI dW}$$

Where

- M = Bending moment
- E = Elastic constant
- I = Moment of inertia
- W = Load

From figure AA53 it can be seen that the deflection occurs in the plane shown below:



Using Castigliano's theorem the deflections in the direction of the load, and at 90° to the load are now calculated:

Deflection in the direction of the load

$$x = \frac{W}{EI} (a^3/3 + a^2b)$$

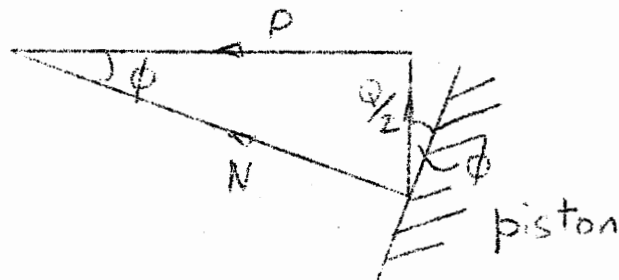
Deflection at 90° to the load

$$y = \frac{Wab(a+b)}{2EI}$$

Cross-sectional area of piston = $.44 \text{ in.}^2$ and
 assuming an air pressure of 80 lbf/in.^2 (551 KN/m^2).

Therefore piston force $Q = 80 \times .44$
 $= 35.2 \text{ lbf.}$

Considering the forces on one slide cam:



$$\tan \phi = Q/2P$$

$$\text{therefore } \phi = \tan^{-1} \frac{35.2 \times .8}{2 \times 16.6} = 40^\circ 24'$$

Therefore let ϕ be 40° .