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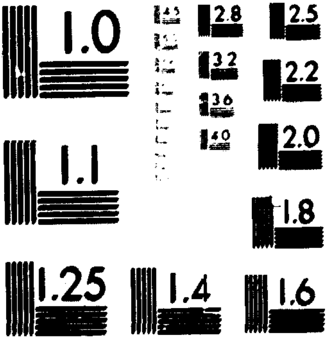

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United Nations Industrial Development Organization

Seminar on Wood Based Panels and Furniture Industries

Beijing, China, 20 March - 4 April 1981

MECHANIZATION AND AUTOMATION POSSIBILITIES IN THE PRODUCTION OF PANEL FURNITURE *

by

Horatio P. Brion**

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Corrigendum

Page 47, line 8

For buffing platforms *read* buffing platform

Page 57, line 1

For OPTION 3(b) *read* OPTION 3(c)

Page 58, line 7 from bottom

For possible totally eliminating *read* possibly, by total elimination of

Page 66, line 14

For US$ 3,700,00 *read* US$ 4,700,00

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I. INTRODUCTION

The tremendous increase in the world's population during the last half century brought about a corresponding increase in the demand for wood materials required by the building construction and furniture manufacturing industries. The world consumption of wood materials could not be matched by the reforestation programs of the world's timberlands. The burden of bridging the gap between supply and demand of wood was taken up by technologists with a view to attaining more intensive utilisation of the remaining timber stands of the world. Their efforts resulted to the development of wood-based panels (particle boards, fibreboards, wafer boards, chipboards, etc.) which made possible the utilisation of wood waste from wood processing plants, and branches, faggots and barks of trees. The furniture industry responded by developing techniques in furniture construction using wood-based panels as the primary raw material.

From the technological point of view, panel-based furniture manufacture presents less of the joinery constraints encountered in the production of solid wood based furniture. A major share of the joinery functions of components in panel-based furniture has been taken over by the use of wooden dowels, metal or plastic fasteners (such as corner braces, brackets and other ancillary items). However, this technique requires a higher precision in machining operations for hinge seats, lock seats, hardware clearances, screw holes and provisions for other non-wooden fittings.

As in the case of wood-based panels production, equipment in modern panel-based furniture plants are highly mechanised and automated as supplied by the manufacturers. Even materials-in-process transport systems are automated to match the high volume outputs of the production machinery. There is therefore little to discuss on the possibilities of further automation in such modern manufacturing systems. This paper concerns more with the possibilities of applying ICA in furniture plants with simple and basic production machinery. These furniture plants belong to the small and medium size group and are usually found in developing countries.

The furniture industry in developing countries are usually highly fragmented, multi-product operations. Specialisation is not known or rarely practiced in those countries. Manufacturing standards are not usually observed, and perhaps, they are even non-existent. Thus, products from such small and medium furniture plants may vary from one batch to another and the components are not universally interchangeable due to an inadequate degree of manufacturing precision. These conditions make their furniture products less competitive in the world market.

In many instances, the introduction of wood-based panels as a principal furniture material, coupled with the ever-increasing high prices of solid wood materials, has forced governments to encourage, and even subsidise, the erection of wood-based-panels plants and panel-based furniture plants, as complementary parts of their housing development programmes.

II. ICA SYSTEMS AS APPLIED TO PANEL - BASED FURNITURE CONSTRUCTION

A. GENERAL PROCESS FLOW IN PANEL - BASED FURNITURE PRODUCTION

In general, the flow process for panel-based furniture production starts with two major lines :

1) The preparation of solid wood components ; and
2) The preparation of wood-based panel components.

Figure 1 shows the operations involved in the manufacture of panel-based furniture, using lumber, veneer flitches (or sheets) and wood-based panels as the principal input materials.

Both lumber and veneer inputs have been sufficiently dried before being processed in the furniture plant. Sanding of both solid wood

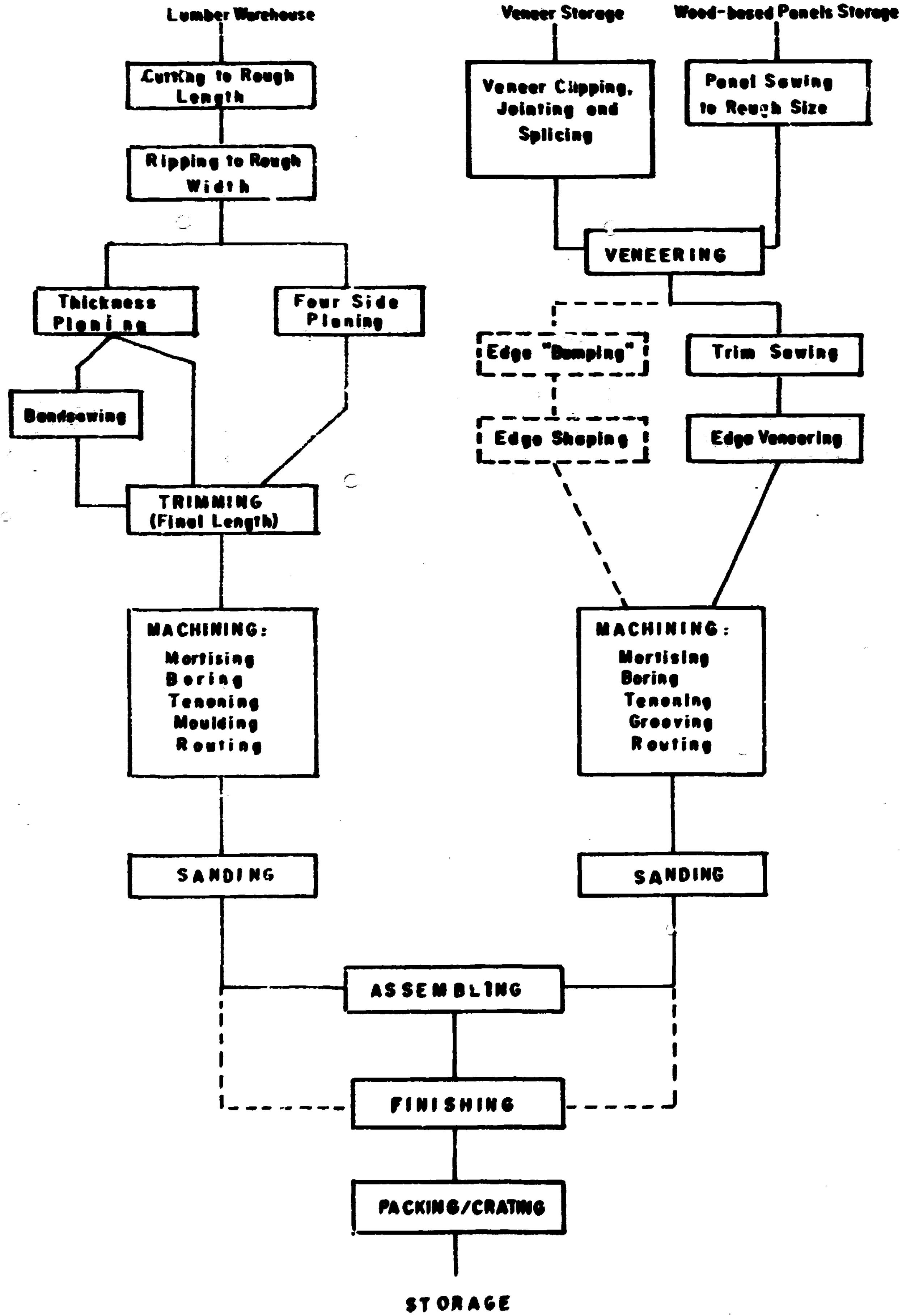

FIGURE 1

General flow process, panel-based furniture manufacturing and panel components is done before they are finally assembled to form the complete furniture item. The last operation, of course, is finishing (applying lacquer, polyurethane, epoxy, polyester pigmented paint, and such other coating materials to provide protection in use and enhance the beauty of the wood grain patterns in the furniture).

However, in the case where the panel-based furniture piece is to be transported in "knock-down" (dis-assembled) condition, finishing is done on the components or sub-assemblies of components, before packing and shipping, and then final assembling is done at the customer's or user's location.

An examination of the general flow process to determine situations for possible ICA application will be made in the following sections. This investigation will be guided by the same guidelines and general considerations used in the other document presented at the seminar 1/

1. Objectives :

   a. Improvement of product quality ;
   b. Better utilization of labour;
   c. More intensive utilisation of materials (lower wastage);
   d. More efficient utilisation of available machine time ; and
   e. Safer operating conditions for workers.

2. Considerations :

   a. Possibility of designing, fabricating and installing ICA systems in the user's factory ;
   b. Use of available standard ICA component parts ;
   c. Use of the existing simple and basic machines ;
   d. Use, wherever possible, of non-conventional parts available in the factory's inventory stock of maintenance supplies and junk pile ;
   e. Flexibility of design to allow dismantling components of the ICA set-up and their use in another set-up whenever required and allowed by factory situations.

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3. Procedures in ICA Adoption

a. Identification and definition of the problem situation ;

b. Exploration of all available options to solve the problem ;

c. Confirmation of the option that ICA is the most preferable among the solutions proposed, thru value analysis or similar studies ;

d. Review, finalization and costing of the ICA system proposed to be adopted ; and

e. Managerial decision to adopt and install the recommended ICA system.

B. POSSIBILITIES OF ICA APPLICATION IN THE PREPARATION OF SOLID WOOD COMPONENTS

1. Trimming To Rough Length

The basic machine for this operation is a saw mounted on a horizontally sliding platform above it. Cutting is done by pulling the saw across the board by hand, and then pushing it back to its original position after the cut is made. This machine is commonly known as the horizontal radial saw. Feeding and off-loading the boards on the dead-roll conveyors before and after the saw are done by hands. This is a very slow operation and requires at least two lumber handlers and one saw operator.

With the use of ICA the output of this basic machine can be increased and the number of workers reduced to only one, in the following manner :

a. Install a pneumatic cylinder on the sliding platform to move the saw forward and backward ;

b. Install an electric motor to drive the infeed conveyor ;

c. Install "scissors-lift" on the infeed and outfeed conveyors, so that the top boards of the lumber pile can be made always at a level which will allow the boards to be pushed (by sliding action) onto and off the conveyor by properly placed pneumatic cylinders ; and

d. Install stoppers with limit switches (or pneumatic valves) to control the forward and edgewise movements of the lumber boards.

Figure 2 illustrates this solution.

2. Ripping Operations

The basic machine in this operation is a single blade edger saw with a chain type of feed device. The boards are fed to and off-loaded from the machine by hand. Small size work-pieces require one worker at each end of the saw. However, bigger and thicker boards will require at least two men at each end of the machine. It is thus obvious that several pieces of the same width can be cut on the machine only by passing the same board several times thru the machine.

In more modern factories, ripping operations capacity is increased by the use of a multi-rip saw. This machine works in the same manner as the single blade edger saw, except that there are several sawblades mounted on the same shaft. This machine feature allows ripping several pieces at one pass on the machine.

Nevertheless, should it be desired to increase the capacity of the single blade edger saw with less number of workers, a "merry-go-round" set-up as shown in Figure 3 will do the job with only one man needed.

3. Bandsawing

This operation is basically intended to give the work-piece non-linear shapes or non-square surfaces in preparation for further machining operations such as edge shaping, routing, box-planing, etc. The design of the basic machine involves the use of two pulleys (or bandwheels) mounted vertically one above the other. The band-saw blade is mounted on the outer segments of the two pulleys. The bottom pulley is driven by an electric

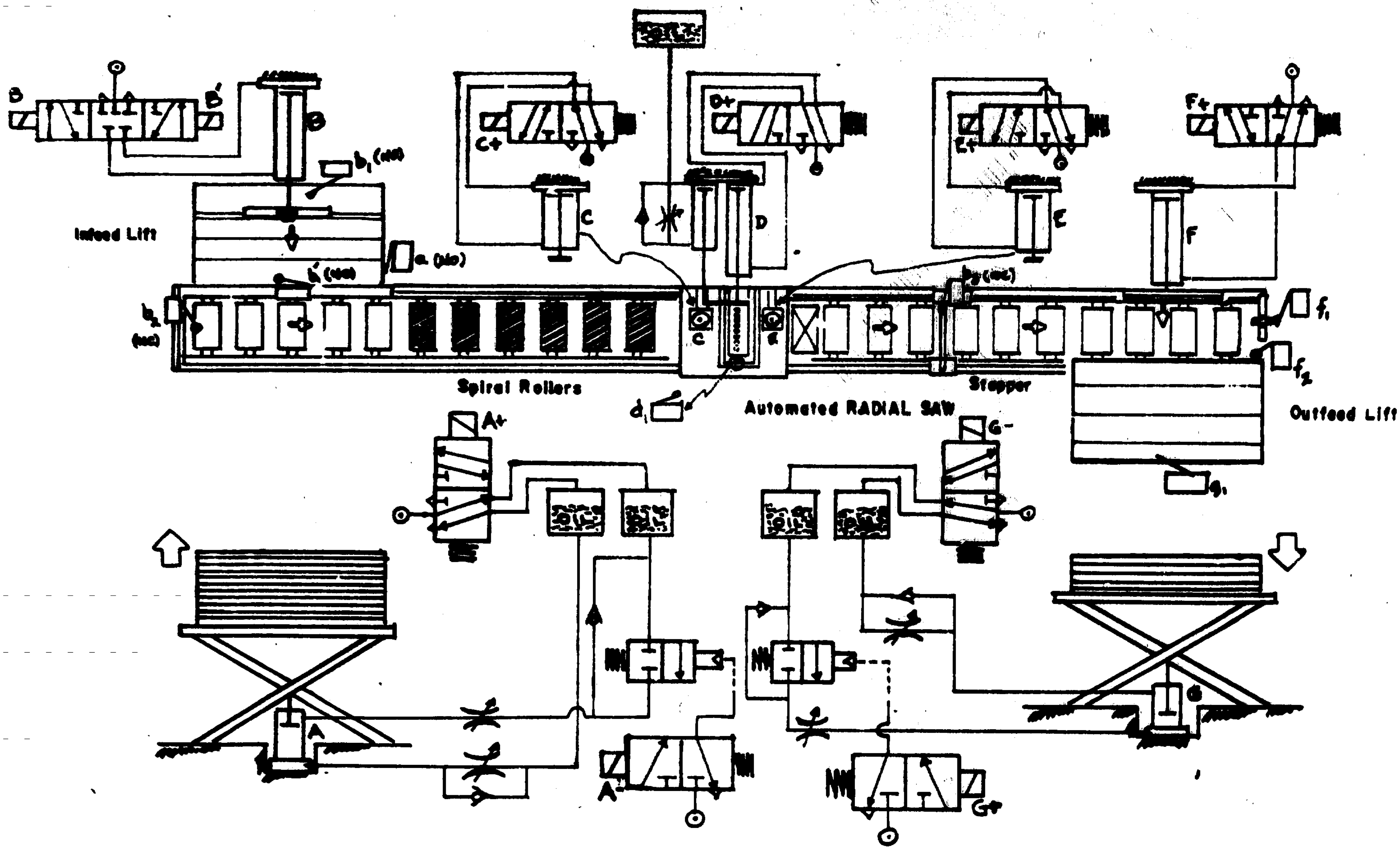

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FIGURE 2

COMPLETE AUTOMATION OF ROUGH TRIMMING OPERATIONS, SOLID WOOD COMPONENTS motor. The upper pulley is mounted on a movable shaft allowing movement of the pulley nearer or farther from the bottom pulley, thus making it possible to obtain the proper tension on the band-saw blade.

The work-piece is hand fed to the sawblade on a table fixed to the bandsaw column supporting the pulleys.

The newer models of this machine include a tilting table, while others have both tilting table and serrated feed rolls driven by an electric motor.

The work load per type or shape of cut on this machine is usually low and the shapes to be cut are so many that set-up costs may over-ride any benefits to be gained by the automation of this operation. However, quality and output can be improved by the use of template jigs. These sawing jigs will assure that all work pieces done on the machine will be of the same shape and size. Use of the jigs will also speed up the operation.

4. Surface Planing

Surface improvement of the work-piece is normally done on a planer. The simplest type of planer has a single cutterhead, in-feed and out-feed rolls, and a table that can be raised (or lowered) manually to obtain the desired thickness of the work-piece.

More advanced models of this machine include in their design the following features :

a. Top and bottom cutterheads ;
b. Powered lifting or lowering of the planer table ;
c. "Anti-kickback" fence and other safety devices ;
d. Infinitesimally variable feedspeed ; and
e. Such other features that transfer the skill from the worker to the machine.

It is thus obvious that application of ICA to this operation is limited to the work-piece feeding and off-loading phases of the planing operation. In the situation where only a single-head planer is available and both surfaces of the work-piece have to be planed, a system similar to that illustrated in Figure 3 will help speed-up the operation and reduce the manpower required to one man.

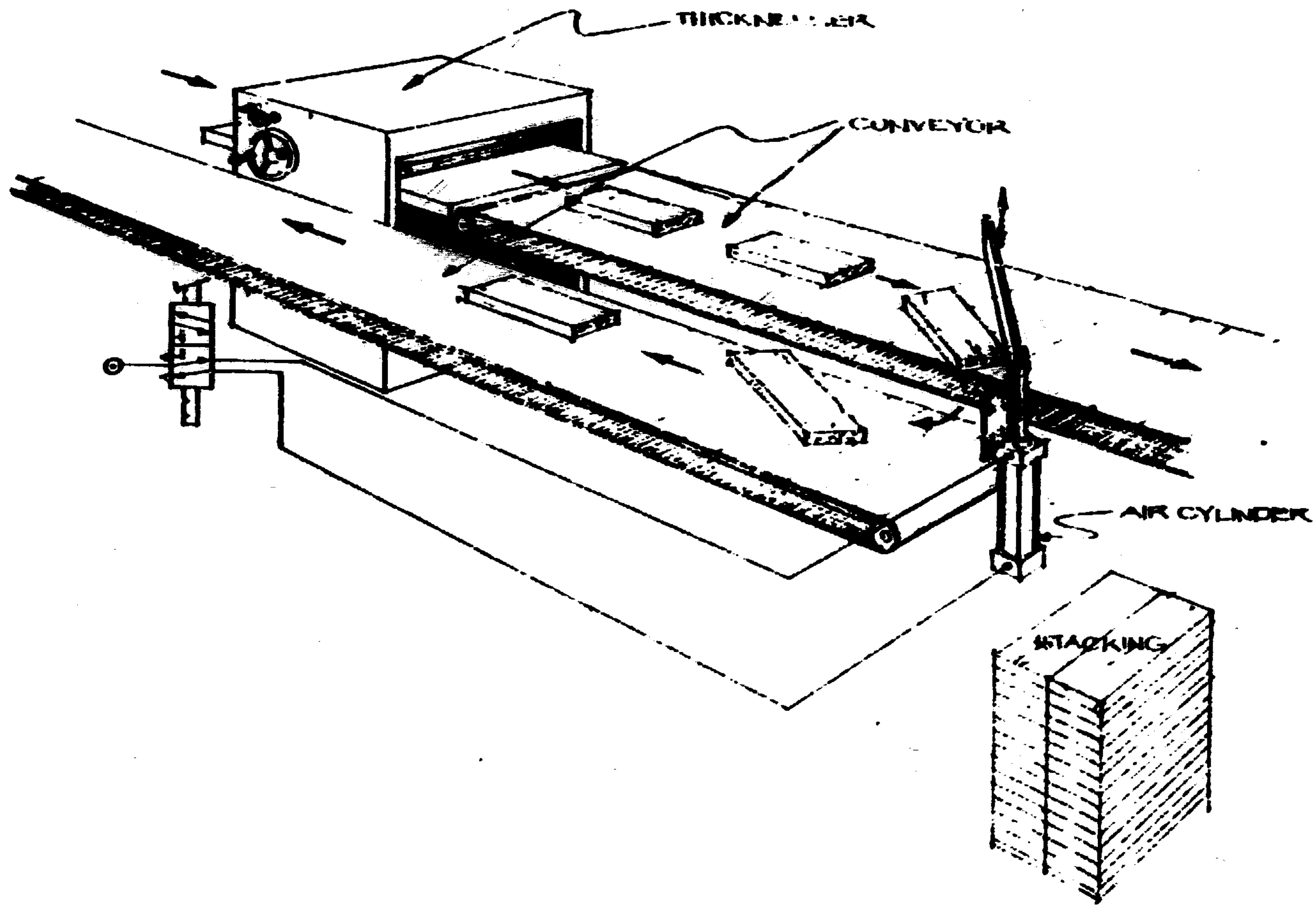


FIGURE 3

RETURN CONVEYOR SYSTEM APPLICABLE TO EDGER AND THICKNESSER OPERATIONS

5. Four - Side Planing

This operation is basically similar to the surface planing operations except that the planing machine in this case is equipped with an additional two vertical cutterblocks to allow surfacing of all the four faces of the work-piece simultaneously.

From the viewpoint of ICA application, improvement on the output from this machine can be attained only by the use of feeding and off-loading devices.

6. Trim Sawing to Final length

This operation is basically the same as the first trimming operation. However, higher cutting precision and more careful work-piece handling are required in this operation. Work-pieces with large cross-sections are trimmed to final length by the radial saw, while those with small cross-sections may be cut on the tilting arbor saw (or table saw) with the aid of a trimming jig to allow cutting of several work-pieces in one pass across the saw.

The forward-and-backward movement of the radial saw may be automated as discussed in paragraph II-B-1 of this paper. The feeding and off-loading system, however, would have to be revised to insure better cutting precision and more careful handling to prevent damage to the planed surfaces of the work-pieces.

In the case where a tilting arbor saw is used, automatic feeding of individual pieces may not be successful because of the small sizes of the work-pieces. However, a significant increase in output may be attained in this operation by the use of trimming jigs, an example of which is shown in Figure 4. Where the work-piece is wide enough, a rubber roller feeding device can be used to improve the output from this operation.

7. Mortising

The basic machines which make mortices on solid wood parts for furniture joints are : slot, chain, hollow-chisel and oscillating mortisers. All of these machines are hand fed and thus, have low outputs. However, ICA may be applied to any one of these machines in order to attain higher output levels, by increasing the feed speed. In case more than one mortise is required on the same work-piece, an automated work advancing device may also be installed. Figures 5 and 6 illustrate the automation system for a chain mortiser suggested by M. Kock and F. Lastuvka. An

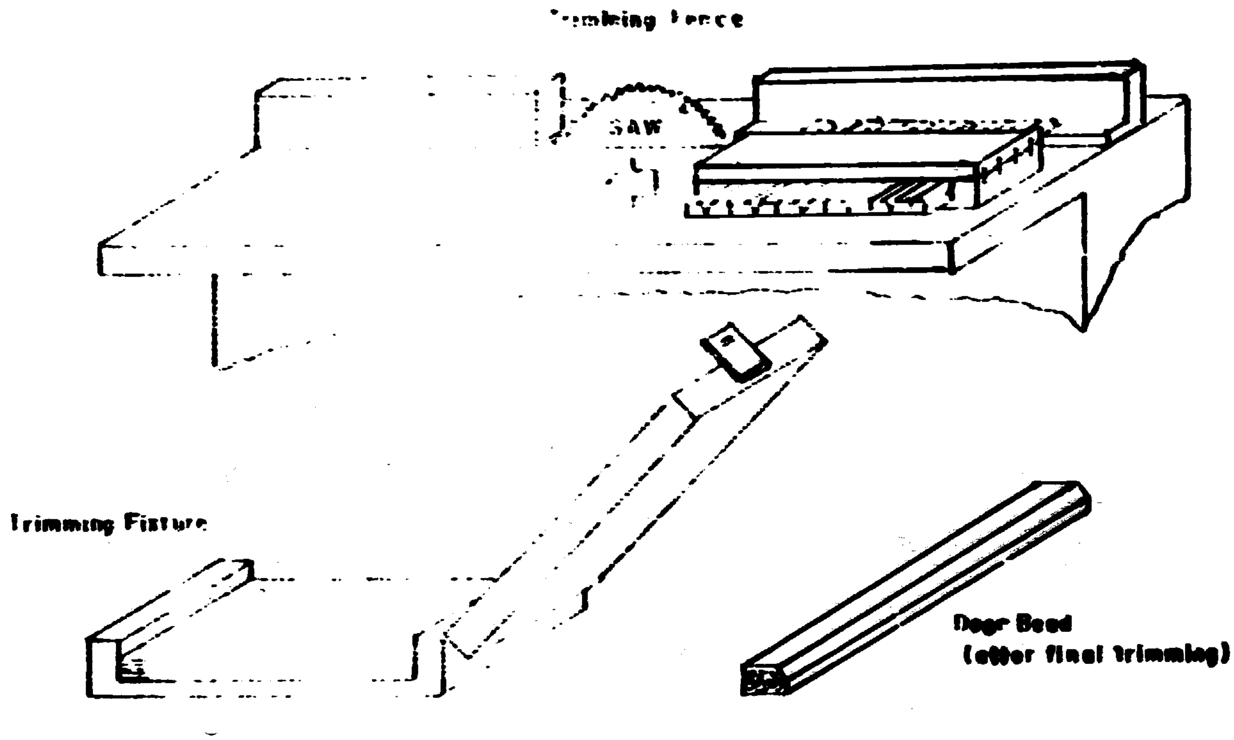


FIGURE 4

TRIMMING FIXTURE FOR WOODEN COMPONENTS
WITH SMALL CROSS SECTIONS

output of 1,000 slots/hour was attained by this system which has the following five essential parts :

a. Machine pedestal mortising guide ;
b. Chain mortising head with pneumatic feed device ;
c. Transport carriage and intermittent feed unit ;
d. Work-piece clamp ;
e. Carriage stop ; and
f. Control console with pneumatic control system for external sensors and cylinders.

Similar arrangements can be designed for the automation of the other types of mortisers, provided of course, that the volume of work justifies such a move.

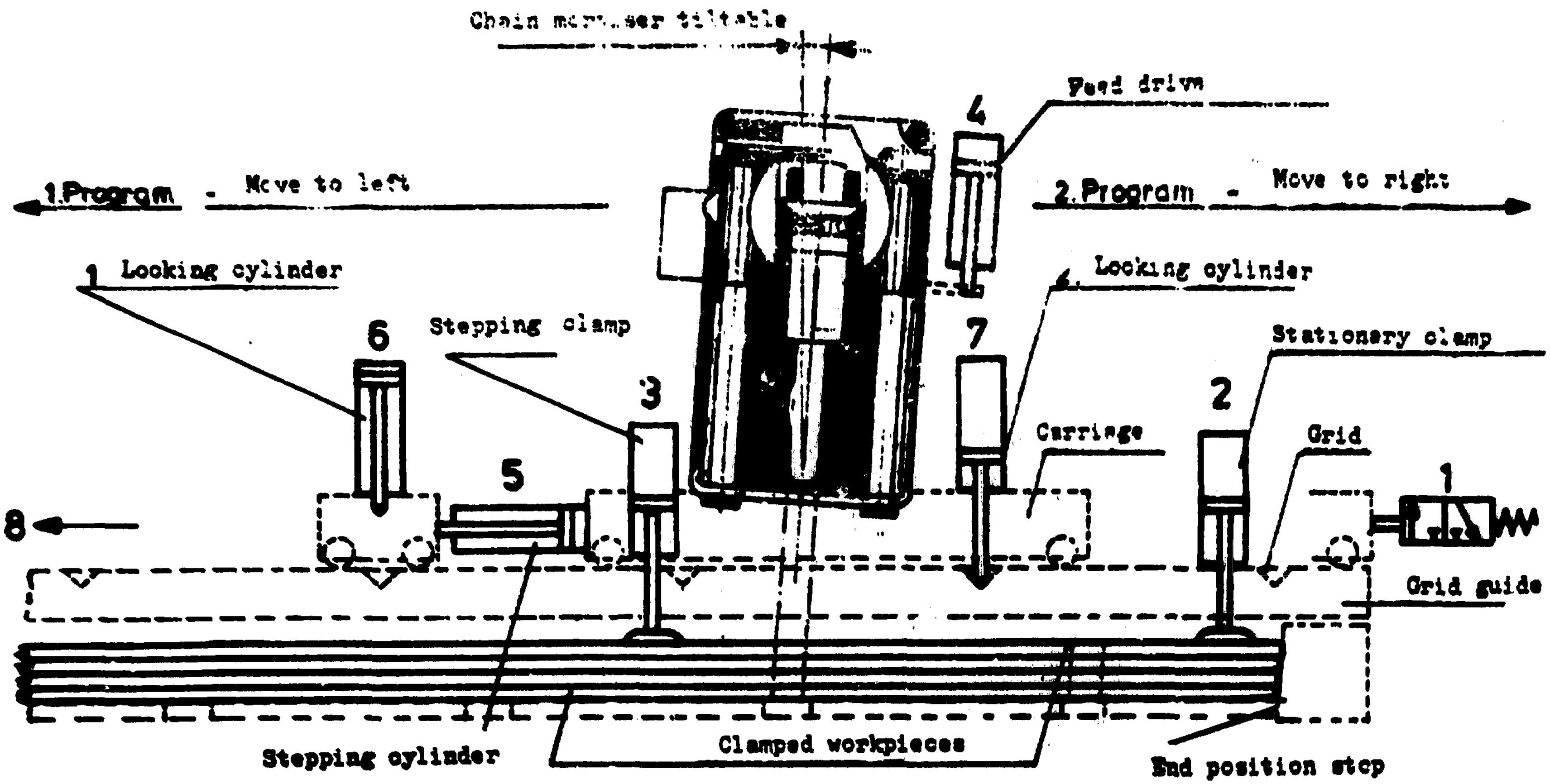


FIGURE 5

ICA DEVICE APPLIED ON A CHAIN MORTISER

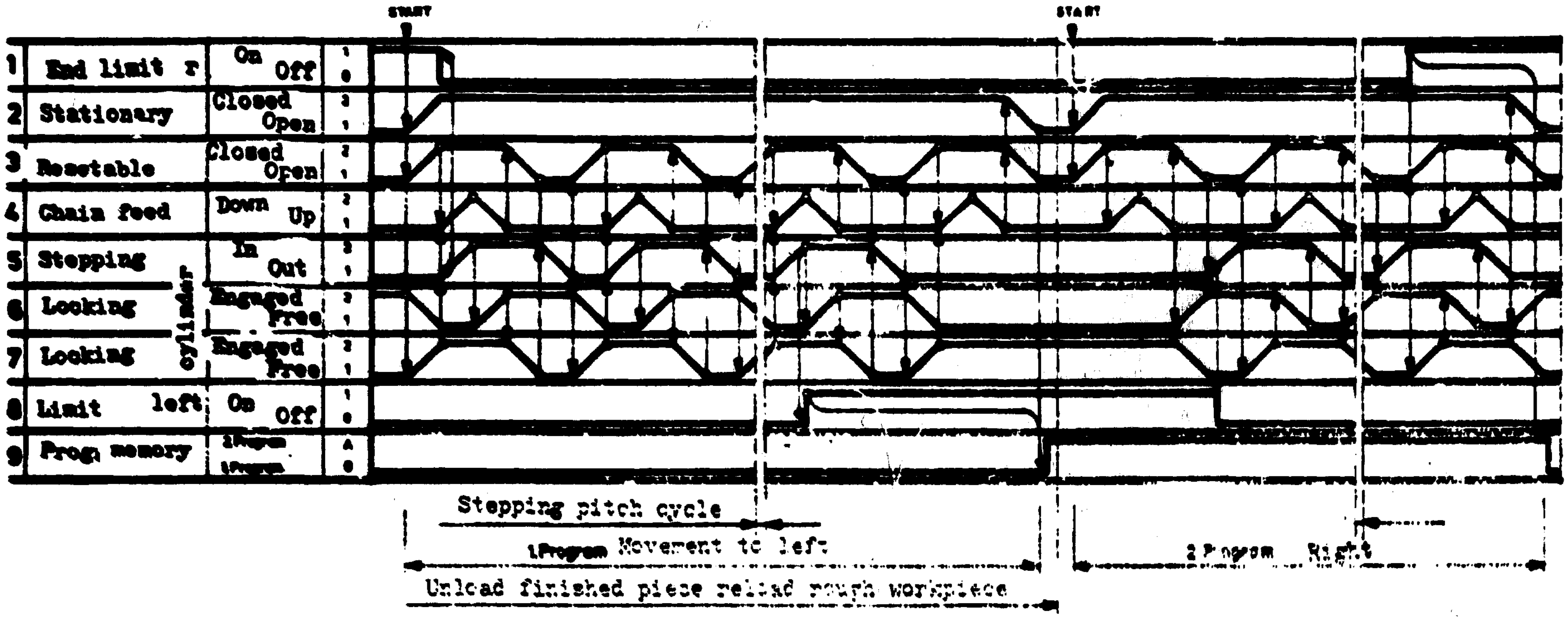


FIGURE 6

TIME – MOTION DIAGRAM FOR CHAIN MORTISER WITH ICA DEVICE

8. Dowel Hole Drilling

The use of dowels in joining components of panel-based furniture has greatly contributed to simplify and facilitate assembly of the panel components. Cost savings are made whenever dowels replace metal fittings in joining one panel to another. For, verily, wooden dowels cost much less than metal fittings.

Dowel holes are usually drilled with precise spacing to achieve perfect fitting between the panel components to be joined. Furthermore, a piece of panel-based furniture usually use many dowels, so that drilling of many dowel holes can hardly be attained with the old hand-fed method. Figures 7 and 8 illustrate the automated dowel hole drilling system suggested by H. P. Brion and W. Santiano.

9. Boring

Boring holes in panel-based furniture production is usually done by a drill press or a router, whichever is better for the required situation. Pilot holes for wood screws on the solid wood components of panel-based furniture can be drilled by the same device used for drilling dowel holes. In this case, however, the depth of the hole is controlled by changing the position of limit switch c_1 in Figure 7.

For drilling holes on small wooden pieces, like drawer fronts, the set-up illustrated in Figures 9 and 10 is recommended.

Where multiple holes of different directions are required on the same piece of solid wood component of the furniture, use of an indexing table becomes more efficient. In this manner, the work-piece is not moved off its clamped position until all the required holes have been drilled. Figures 11, 12 and 13 illustrate such a set-up.

It should be noted in all these set-ups that the drill is usually fixed, while the work-piece is made to move to locate another hole. The reverse situation, moving the drill heads on the fixed work-piece, is hardly conducive to simple implementation in this situation.

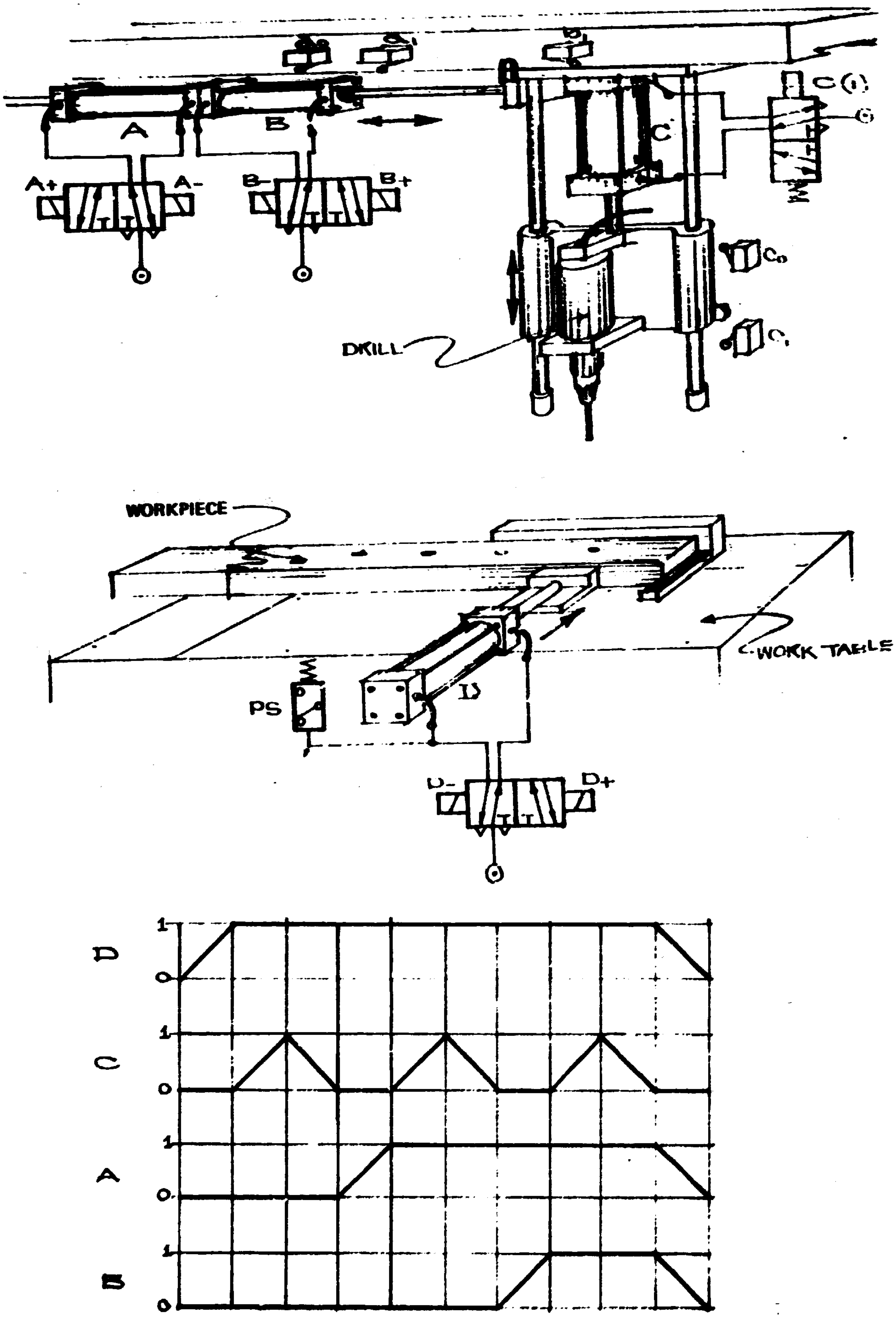


FIGURE 7

DOWEL HOLE DRILLING AIDED BY ICA DEVICE AND CORRESPONDING TIME - MOTION DIAGRAM

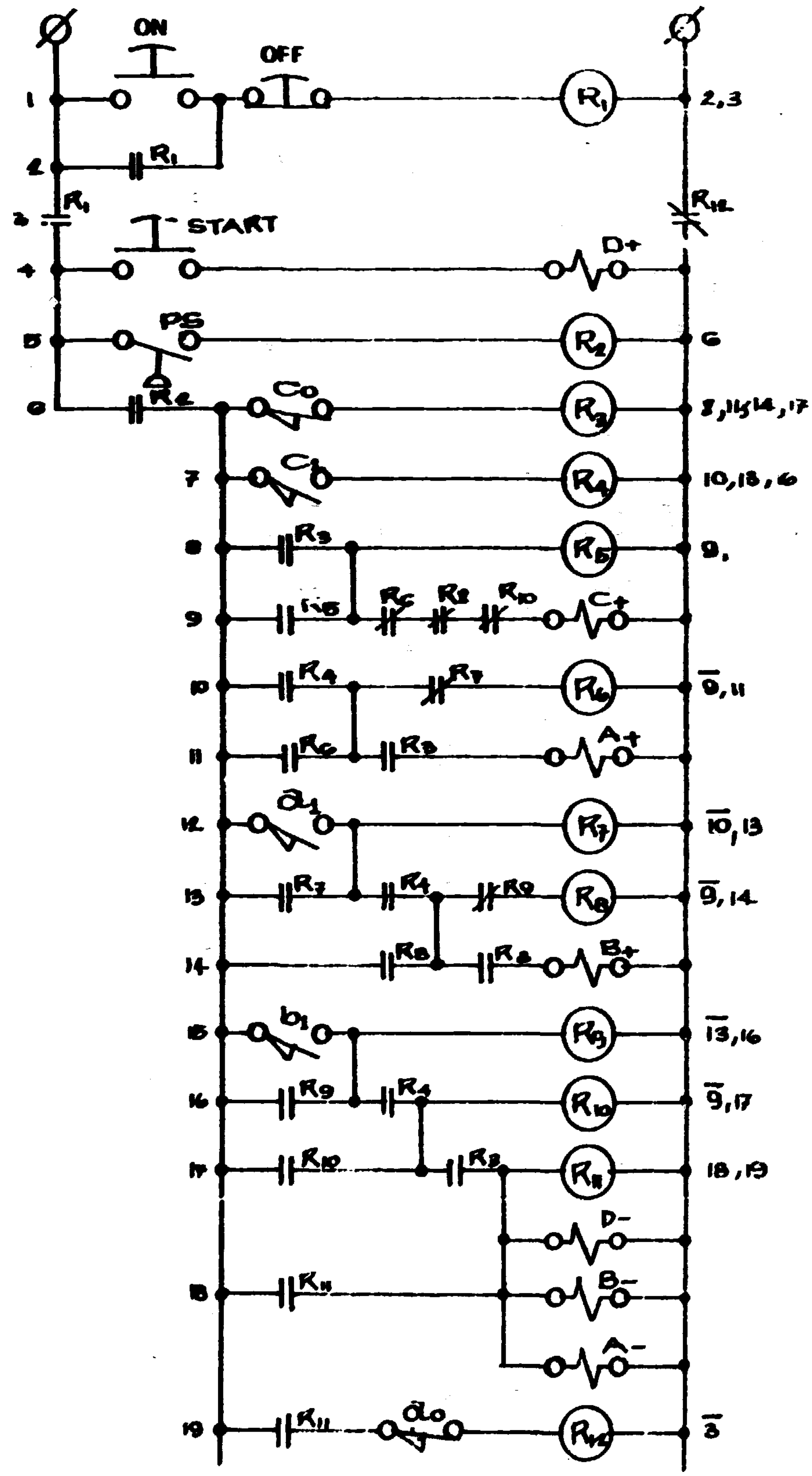


FIGURE 8

ELECTRICAL CIRCUIT DIAGRAM FOR DOWEL DRILLING OPERATIONS WITH ICA DEVICE

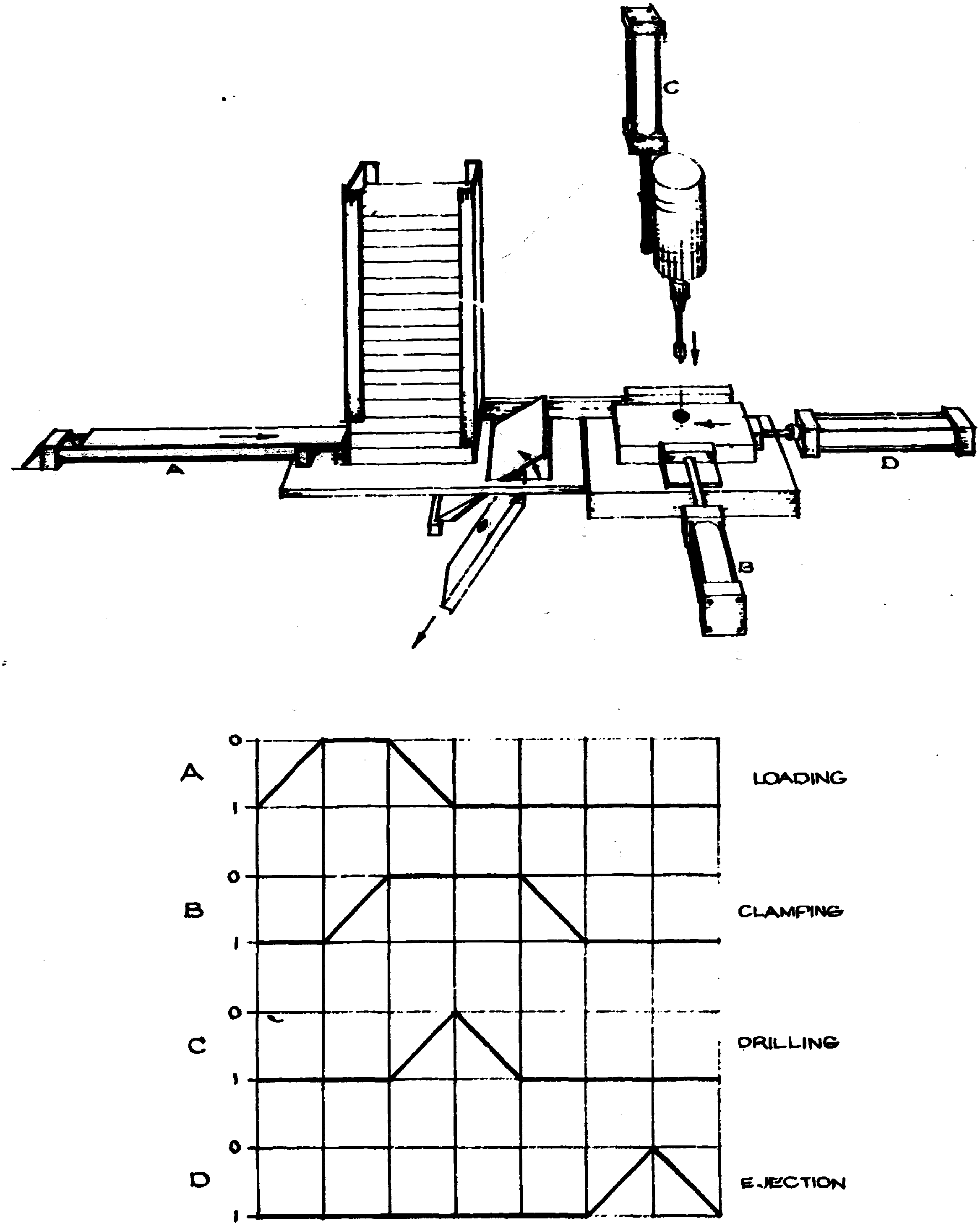


FIGURE 9

AUTOMATIC DRILLING WITH AUTOMATIC FEED AND EJECTION SYSTEM

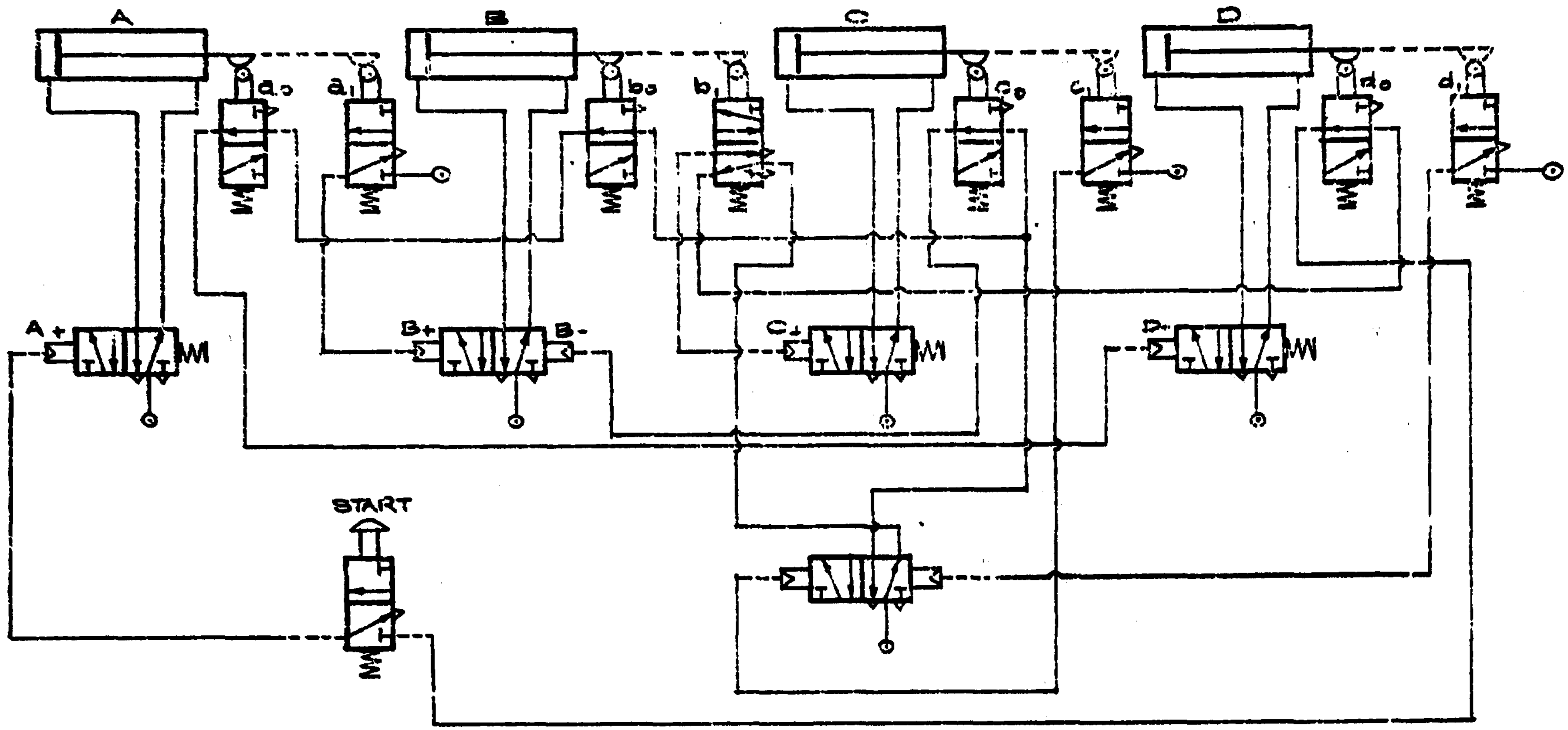


FIGURE 10

PNEUMATIC CIRCUIT DIAGRAM FOR AUTOMATIC DRILLING WITH
FEED AND EJECTION SYSTEM

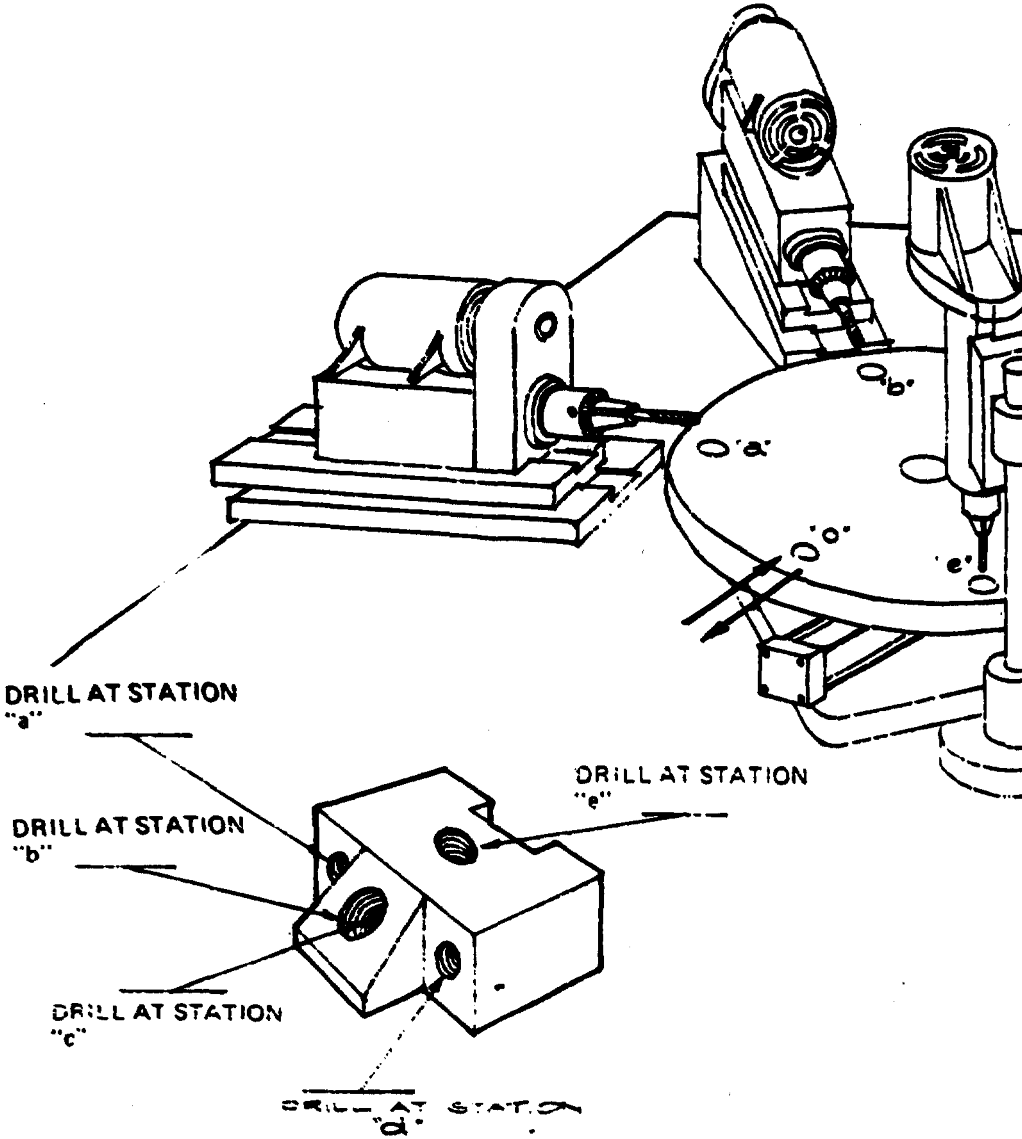
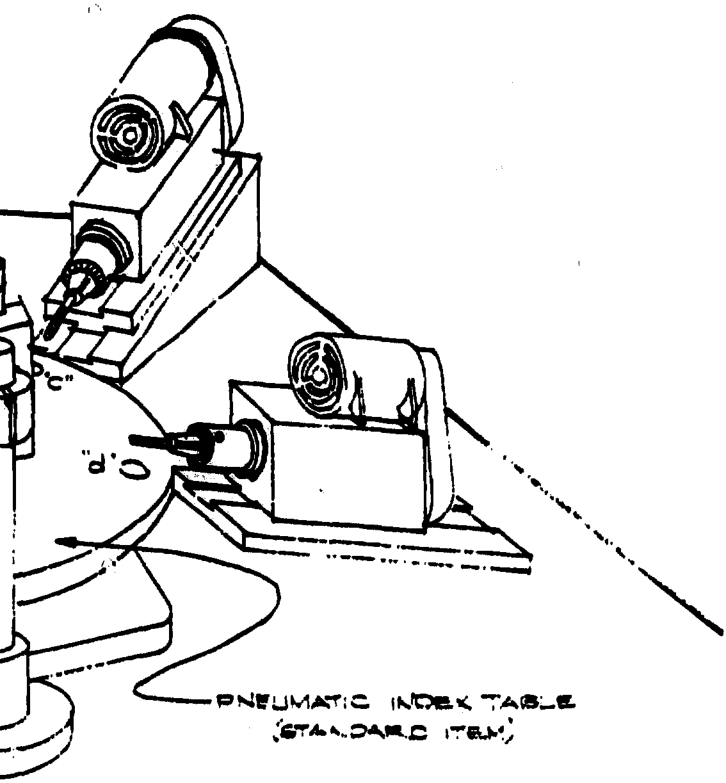


FIGURE 11.

INDEXING TABLE


"C"
"D"
PNEUMATIC INDEX TABLE
(STANDARD ITEM)

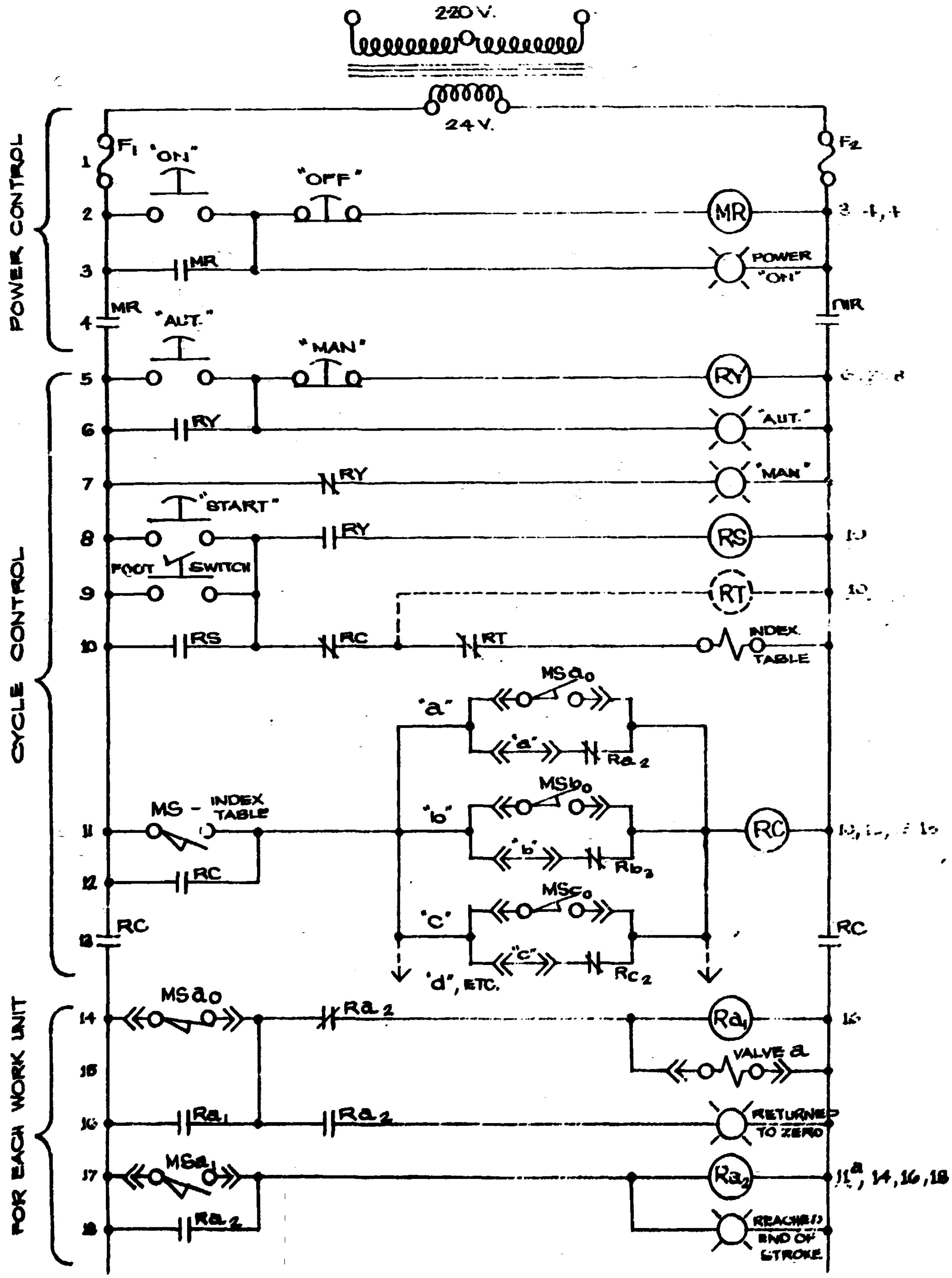


FIGURE 12

ELECTRICAL CIRCUIT DIAGRAM FOR INDEXING TABLE

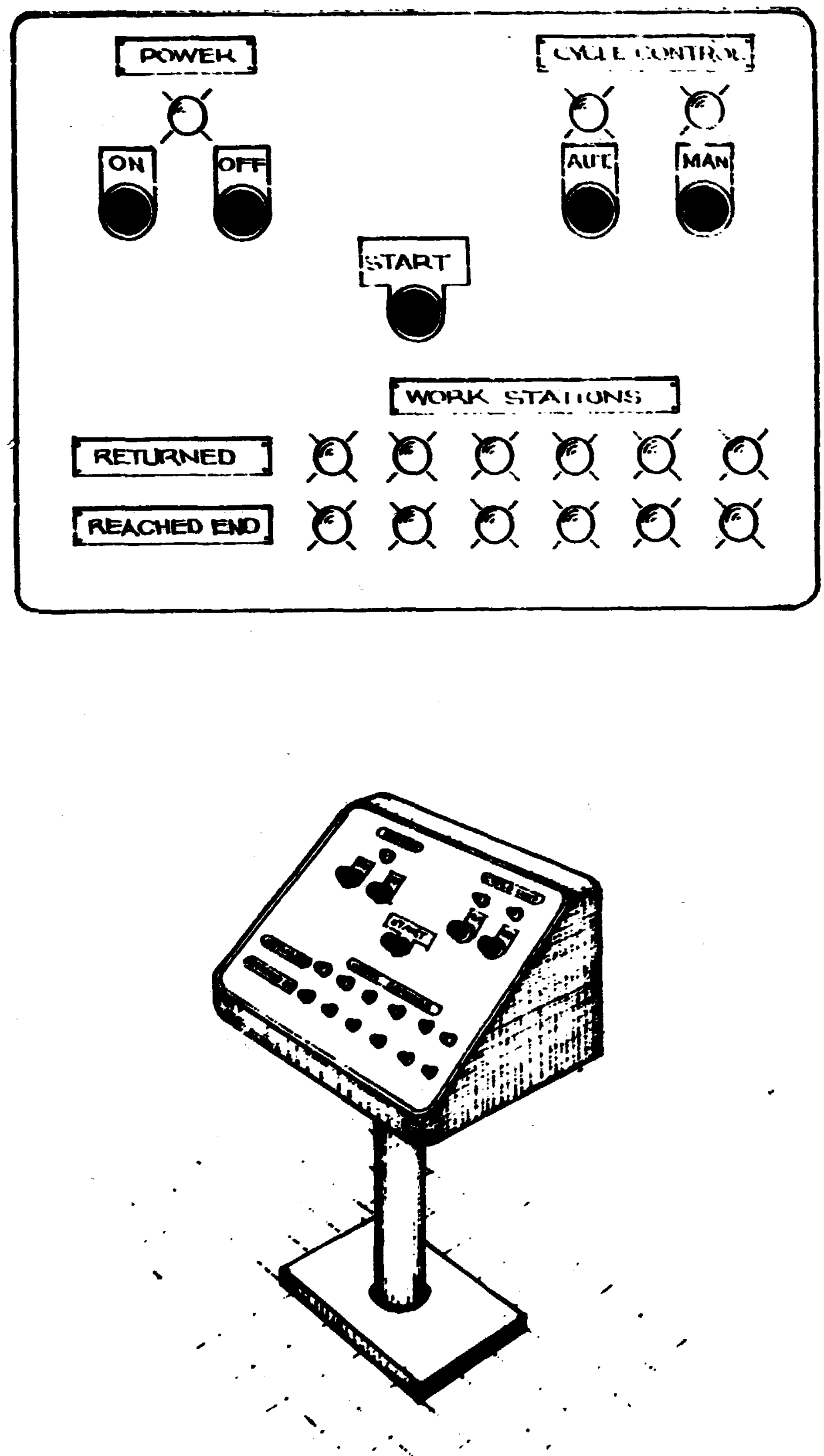


FIGURE 13

CONTROL CONSOLE FOR INDEXING TABLE

10. Tenoning

Tenoning operations on solid wood components are done to make any one or more of the following :

a. Corner - Locks ;
b. Tongue and Groove ; and
c. Stub Tenon Joints.

These operations are usually done on a vertical-spindle moulder (shaper) with special attachments ; a single-end tenoner or a double-end tenoner. Tenoners are preferrable for high volume production as they are equipped with several cutting heads and saws. A double-end tenoner assures better squareness of the work-piece, be it solid wood or panel component. It is also capable of performing other more complicated and precise machining jobs on the work-piece.

ICA application to a vertical spindle moulder (shaper) for processing solid wood components of panel-based furnitures is limited to feeding and off-loading the work-piece. The same situation is true to tenoners. However, additional cutting heads may be installed on the tenoner to obtain less machine set-ups for other milling jobs on the work-piece. Tenoners are also easier to link with other machines by means of transfer conveyors.

11. Moulding

Grooves, rebbets, roundings and other profiles, tenons and slits, and moulding with templates are usually done on a vertical spindle moulder. However, the output of a vertical spindle moulder can be considerably increased, its work quality improved and safer operations better provided, if a feeding device is used on the machine.

12. Routing

Routing work is best done on a high speed heavy duty Router with 15,000 RPM and higher cutting speeds. The higher the cutting speed the better the quality of cut. The basic heavy duty router has a fixed head and a movable table. The table is moved up and down by mechanical linkage controlled by a foot pedal. More advanced router models feature tilting heads and/or tilting tables. However, their outputs do not vary much from the basic fixed-head type of heavy duty router as the routing speed is still controlled by the rate at which the router operator can load, move the work-piece against the router bit, and unload the routing jig/template. Output volume, however, can be increased by the use of good clamping devices and routing templates, moved by pneumatic ICA devices.

Small furniture factories make more use of the portable router. In this case, the router is moved over or around the work-piece to do the routing job. As in any type of purely manual operation, output and quality in this type of work are low. To attain higher outputs and better quality routing jobs with a portable router, a device may be set up to fix the router head in position and move the work-piece against the router bit. Movement of the work-piece is facilitated by the use of a routing jig or template fixture.

Routing set-ups wherein the work-piece is moved around a fixed routing head, lead to possible automation, as discussed in a latter section of this paper.

13. Sanding

Preparation of the solid wood component surfaces for finish coatings is done on a wide range of sanding machine models. In general, we find the following sanding machines being used by small and medium size furniture plants :

a. Narrow belt sanders such as :

1) Single or double belt stroke sanders ;
2) Levelling sanders (horizontal belt sanders) ;
3) Universal oscillating belt sanders ; and
4) Vertical belt sander for sanding the edges and sides of drawers.

b. Profile sanders, which use cloth-backed sanding belts and are specifically effective for sanding surfaces with profiles or contours, and, more recently the

c. Wide-belt sanders with :

1) Single belt,
2) Double belt, and
3) more than two belts.

Except for the wide-belt sander, which has its own mechanism for controlling the pressure of the sanding belt against the surface of the work-piece, all the other sanders mentioned above depend on human judgment and skill to obtain the correct pressure of the sanding belt against the wooden surface being sanded. This, of course, leads to variation in the quality of the sanded surface from one work-piece to another. Furthermore, this common feature of the machines also leads to a highly variable and undependable sanding output.

While it is hardly possible to design devices which will prevent the sanding errors due to human factors, as mentioned in the preceding paragraph, there are certain situations where the configuration of the work-piece and the sanding quality desired permit the use of simple ICA device.

The wide-belt sander, aside from having controls for the sanding belt pressure on the work-piece, also has its own feed mechanism, a belt conveyor. The opening between the feed conveyor belt and the sanding belt surface is adjustable. Thus, the machine is suitable for sanding both solid wood and panel components. The machine is easily linked to other production machines. Obviously, the machine output is greatly dependent on how fast the worker can set the work-pieces on the feed conveyor belt of the machine.

C. POSSIBILITIES OF ICA APPLICATION IN THE PREPARATION OF PANEL COMPONENTS

1. Veneer Preparation

The primary objective of this phase of preparing panel components is to produce veneer sheets (faces, backs, cross veneers and edging strips) with definite sizes, shapes and desirable grain pattern configurations. The three principal operations involved are : clipping, jointing and splicing.

Thus, the principal machinery required are veneer clippers, jointers and splicers. The following considerations will be taken during the discussion of these operations :

1) Face veneers usually come from high-priced timber species and thus require utmost care in processing to keep wastage at a minimum ;

2) Face and back veneers are usually 0.7 mm thick, while cross veneers may vary from 1.5 to 3 mm in thickness ;

3) Cross veneers are normally cut to have their grain patterns perpendicular to the grains of the face and back veneers ;

4) To assure perfect adhesion of the veneers to the core board, the veneer components are cut about 5 mm to 10 mm wider or longer than the core board ;

5) The core boards are cut with up to 15 mm (maximum) excess over the final dimensions whenever the edges are required to have contours or profiles ; and

6) Face veneers usually are sliced veneers ; back veneers are either sliced or peeled veneer, while cross veneers are always peeled veneers. Edge strips usually come from the same veneer sheets as face veneers.

a. <u>Veneer Clipping</u>

Veneer sheets from a set of veneer flitch have very irregular edges and must be cut across and along the grain to obtain rectangular sheets. A hand-fed, pneumatic actuated, foot-operated veneer clipper is the machine most commonly used for the purpose. Clipping accuracy and efficiency on this machine solely depends on the ability of the clipper operator to properly position the veneer sheet under the clipper knife, actuate the knife, withdraw the veneer after clipping an edge and reposition the sheet for successive cuts. Thus, automation of the cutting cycle of this type of machine is hardly possible without interfering with the accuracy of the cut. Mechanization of picking up the uncut veneer sheet from the veneer pile ; and piling the cut veneer sheets on another pallet (or container) is also a hard problem to solve. It has been noted that even in some highly industrialised countries this manual technique of clipping veneers is still used.

However, safety considerations require that the chances of the operator cutting his hands or fingers during the veneer cutting cycle be minimal. A safety device as shown in Figure 14 will help minimise accidents during the clipping operations. The device cuts off the supply of air to the

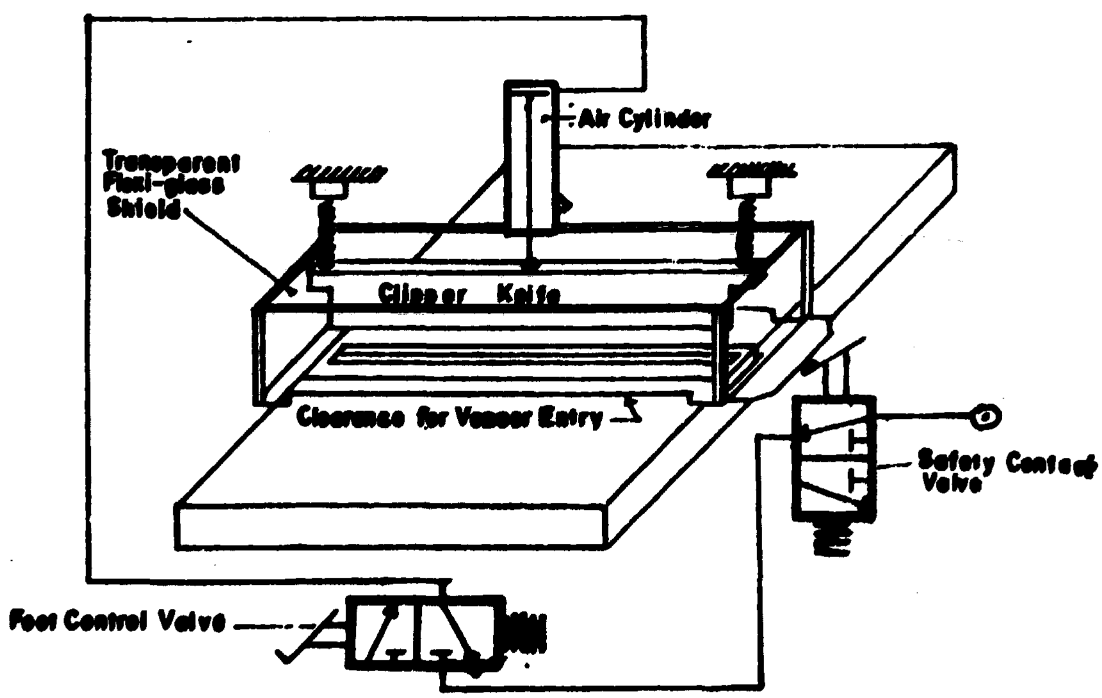


FIGURE 14

VENEER CLIPPER SAFETY DEVICE

foot-operated valve whenever the safety shield is lifted (accidentally or intentionally) off the contact valve, thus making it impossible for the clipper knife to be actuated.

b. Veneer Jointing

In small and medium size plants the veneer clipper is commonly used for veneer jointing operations. Some of these plants use the regular hydraulic-operated "guillotine" for jointing cross veneer and back veneers. The machine makes possible jointing of several sheets simultaneously. Other more advanced plants use a combination cutterblock jointer and splicer. All of these machines are hand-fed. The opportunity for automation of the machines as installed is therefore hardly possible. Safety devices, however, can be installed in the machines to prevent accidents.

c. Veneer Splicing

The basic veneer splicing machines usually found in small and medium size furniture plants are very similar to, if not exactly the same as, those found in the dry veneer processing sections of plywood plants. One splicer model uses belt conveyor to transport the veneer sheets (with glued jointed edges) to be pressed on a metal platen by a heated calender which cures the glue on the veneer splicing joints. The result is a continuous veneer sheet which is then clipped to desired sizes by a standard veneer clipper. Another model lays a thread of adhesive material, in a zig-zag manner, across the joint to be spliced or applies spots of thermo - plastic adhesive material over the jointed edges at pre - determined spacings. Other models use splicing tape, which is sanded off later, after the furniture panel component is completely assembled.

The splicer model using glue thread is highly recommendable for splicing face and bottom veneers. Whereas, the model using a heated calender is preferrable for splicing cross veneers.

Again, the design of the splicers using adhesive thread, tape or laying spots on the splicing joints, require purely manual feeding and off-loading of the machine. The model which produces a continuous sheet provides good opportunity for mechanized feeding and linking to jointing operations.

The combination veneer jointing and splicing machine is considered the best for medium size furniture plants.

However, more recent developments in veneer splicing technology has produced splicing machines with a cutterblock jointer that cuts the veneer edge ahead of the head that lay zig-zag adhesive string to produce a continuous sheet of face or bottom veneer. This type of splicer is recommendable for high volume production. Further automation of the machine by the use of ICA is hardly possible in this case.

2. Preparation of Core Boards From Wood-Based Panels

The basic machine for cutting wood-based panels into smaller size boards to be used as core material for furniture panel components is the "table saw" with a sliding table extension. In some instances the "table saw" is equipped with a tilting arbor to allow beveled cuts on the board's edges. The panel is hand-fed into the sawblade and the sliding table extension facilitates cutting long straight edges.

Among the more advanced models of panel saws are the following :

a. Vertical Frame Panel Saw, where the panel is placed in an upright position on the frame, then held by clamping devices, while the saw is moved across the board to obtain the desired widths (or lengths) by a mobile platform which is moved up and down the length (or width) of the board.

b. Gantry panel saw, where the panel/s are horizontally laid on the machine bed, held by strategically located clamping device. The gantry device holds several sawing units, one of which cuts across the board as the gantry is moved from one end to the other end of the panel/s. Each saw unit is activated at the precise cutting location by means of limit switches that stop movement of the gantry, starts the saw motor, and activates the device that moves the saw unit along the panel's surface.

In some factories, a single-blade edger saw, with chain feed and wide bed, is used to cut wood-based panels into smaller boards. This method requires passing the panel several times through the machine to cut the desired board sizes. This is possible only if the proper type of cross-cutting sawblade is used to cut the panels. Again, the ICE conveying system to return the boards to the saw as shown in Figure 3 is applicable.

3. Panel lamination (Veneering)

The veneer sheets are laid on the core board with urea type adhesive and are hot-pressed (100° to 120° C) on a multi-opening hydraulic press. In small and medium size furniture plants, the hot presses are commonly loaded and unloaded by hand. This results to a low output. In some medium size plants equipped with 15 to 20 daylight hot presses, loading and unloading is done by means of an elevator which carries two workers and the panels. Loading and unloading are both done on the same side of the hot press in the following manner :

a. The elevator is lifted to the highest platen level and unloading starts from the top platen ;

b. The elevator is gradually lowered to the level of each lower platen to unload them ;

c. The pile of hot-pressed panel are unloaded off the elevator at its lowest (normal) position and a pile of laid-up panels is pushed onto the elevator ;

d. Loading starts at the lowest platen, and proceeds upward until the topmost platen is loaded ;

e. The elevator is lowered to its normal position after completion of the loading trip.

However, if the pressing cycle is shorter than the time it takes the elevator to travel from top to bottom platen, the elevator stays at the topmost platen level and waits for the platens to open and the unloading phase proceeds as described above.

In more modern panel-based furniture plants, hot pressing is done on a short cycle single-opening hot-press. Gluing of boards and panel assembly is done on the infeed end of the hot-press. Unloading and loading is done rapidly through a system of conveyors and mechanical linkages. This type of hot-press is easily linked to other machines through conveyorization. Furthermore, this type of press can be used in laminating core boards with sheets of synthetic material (PVC, etc.). In this case, the synthetic material, wound on a reel, is fed into the press by means of rollers and cut to the desired length by a specially designed slither knife which travels across the width of the board at the outfeed end of the hot-press.

It follows from the foregoing discussions of operations of manually loaded hot-presses that application of ICA to the hot-pressing operation itself may involve radical changes in the press design itself, which small and medium furniture plants are not usually equipped to do. However, knowledge of the principles of ICA will help in the proper maintenance of the hot-press inasmuch as the hydraulic system and timing controls of the hot-press are designed under concepts similar to those of ICA.

3. <u>Panel Edge Preparation</u>

This operation is done in preparation for edge veneering or edge shaping. A veneer trim saw is used whenever the edges are to be veneered. In some panel constructions, however, a vertical spindle moulder is used to remove the excess veneer off the panel edges. This technique is specifically done when a solid wood edge-band is glued to the core board, and a profile has to be cut on the edge-bands. This technique is successful only when the panel corners are rounded. Veneer edging allows sharp square corners on panels.

The table saw with sliding table extension is commonly used for veneer trim sawing in small and medium size furniture plants. This type of saw, when equipped with a tilting arbor, will facilitate cutting of canted edges on the boards provided the panels are not too large. Automation of this particular operation may be done as illustrated in Figure 15.

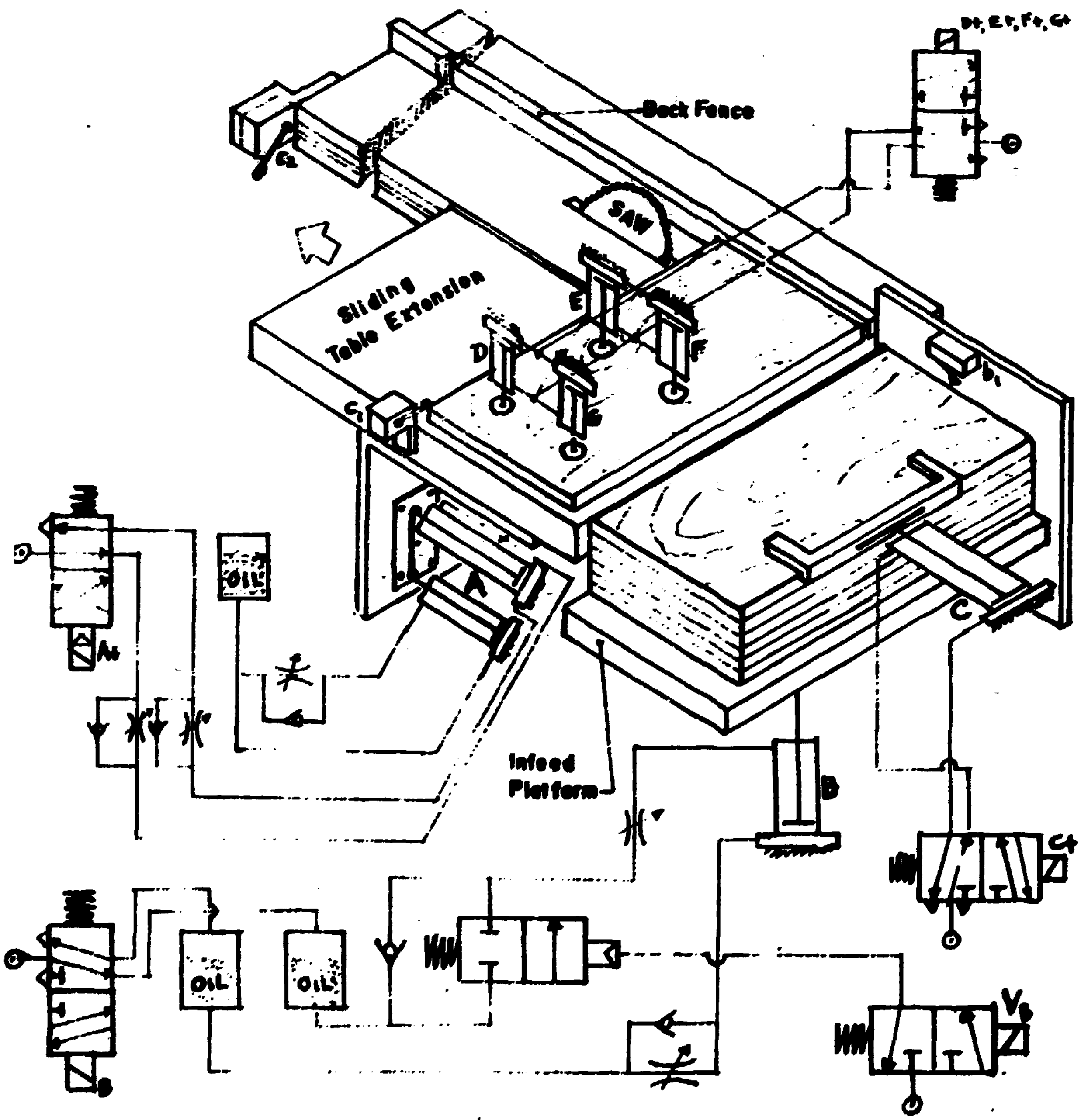


FIGURE 15

ICA APPLIED TO PANEL EDGE TRIM SAWING ON SAW WITH EXTENSION TABLE

In case the edges of the panel will be profiled, an ICA system, as illustrated in Figure 16, will help speed-up the job and improve the quality of work for panels with rounded corners. However, an ICA system similar to the set-up in Figure 15 will be more effective when the panels have square corners.

5. <u>Edge Veneering</u>

Veneer strips are glued to the edges of the panel with the aid of clamps and holding fixtures. In most situations, the glue is allowed to set and cure while the veneer strips are still clamped to the panel edges. This is a very slow process !

Glue setting and curing may be hastened by adequate heating. Figure 17 shows how this can be done with the aid of ICA components, an electric arc-welding machine and a length of

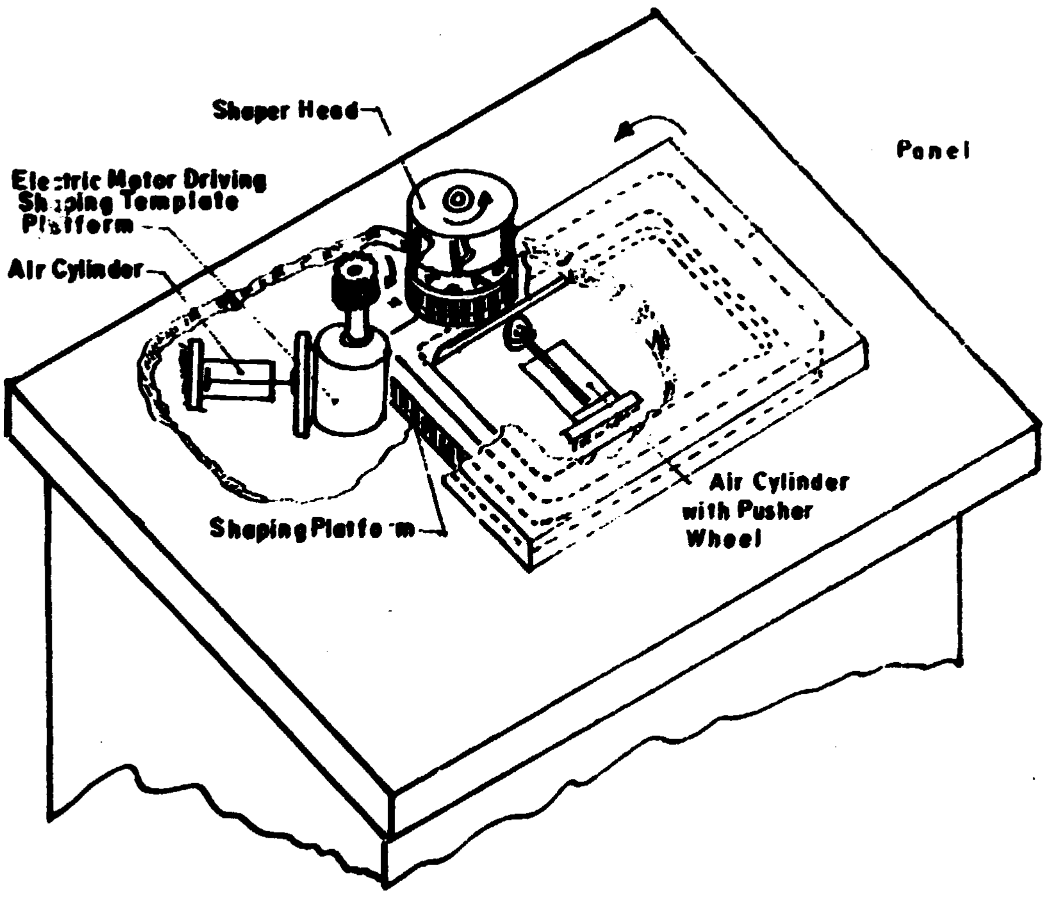
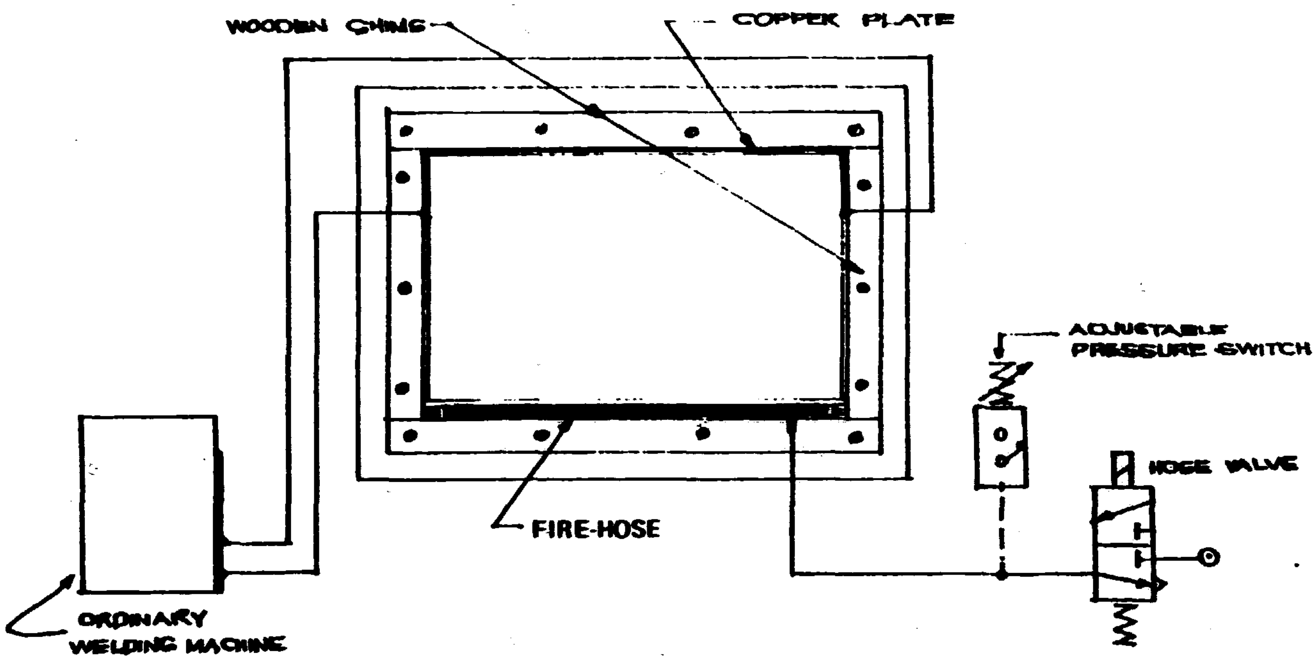


FIGURE 16

EDGE SHAPING ON VERTICAL SPINDLE MOULDER WITH ICA SYSTEM



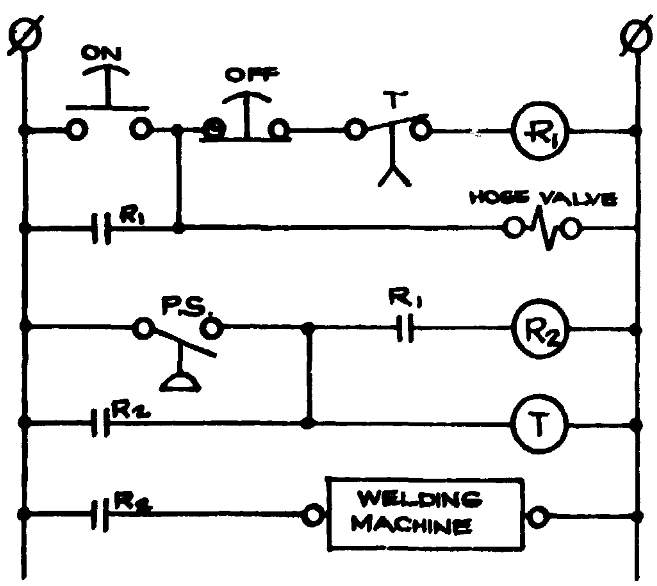


FIGURE 17

EDGE VENEER GLUING WITH LCA DEVICE

ordinary fire-hose. The amount of heat generated on the copper strips is regulated by adjusting the current delivered by the welding machine.

The desired pressure on the veneer strip is attained by controlling the amount of air delivered to the fire hose thru an adjustable pressure switch. Length of pressing time is controlled by the timer connected to the welding machine.

The next step after gluing the veneer strips to the board edges is to level the veneer edge to the surface of the panel and make a slight chamfer on the edge strip to break the sharp edges. In small and medium plants this operation is commonly done with the use of a shaper (vertical spindle moulder).

In more modern plants the edge veneer gluing, levelling and chamfering operations are done successively on one machine, the edge banding machine. There are single-edge and double-edge banding machines currently available in the market.

6. <u>Machining</u>

Machining operations on the panel components are similar to those for the solid wood components, except that the machines required for panel components machining require bigger work-tables or platforms. Hence, the ideas of automation discussed in connection with machining operations for solid wood components are also applicable to machining operations for panel components.

Special reference is made on the matter of making cut-outs on panel components. This operation is usually done by hand on a heavy duty router. It is a slow operation, particularly when the panels are thicker than 19 mm. Moreover, the quality of routing job varies from one panel to another when the worker develops fatigue. This situation calls for improvement thru the use of LCA systems. Figure 18 shows how this may be done, with simple LCA devices. When the router work load for making cut-outs on panels is large, it may be justifiable to automate the router specifically for making cut-outs, as in the case of the second

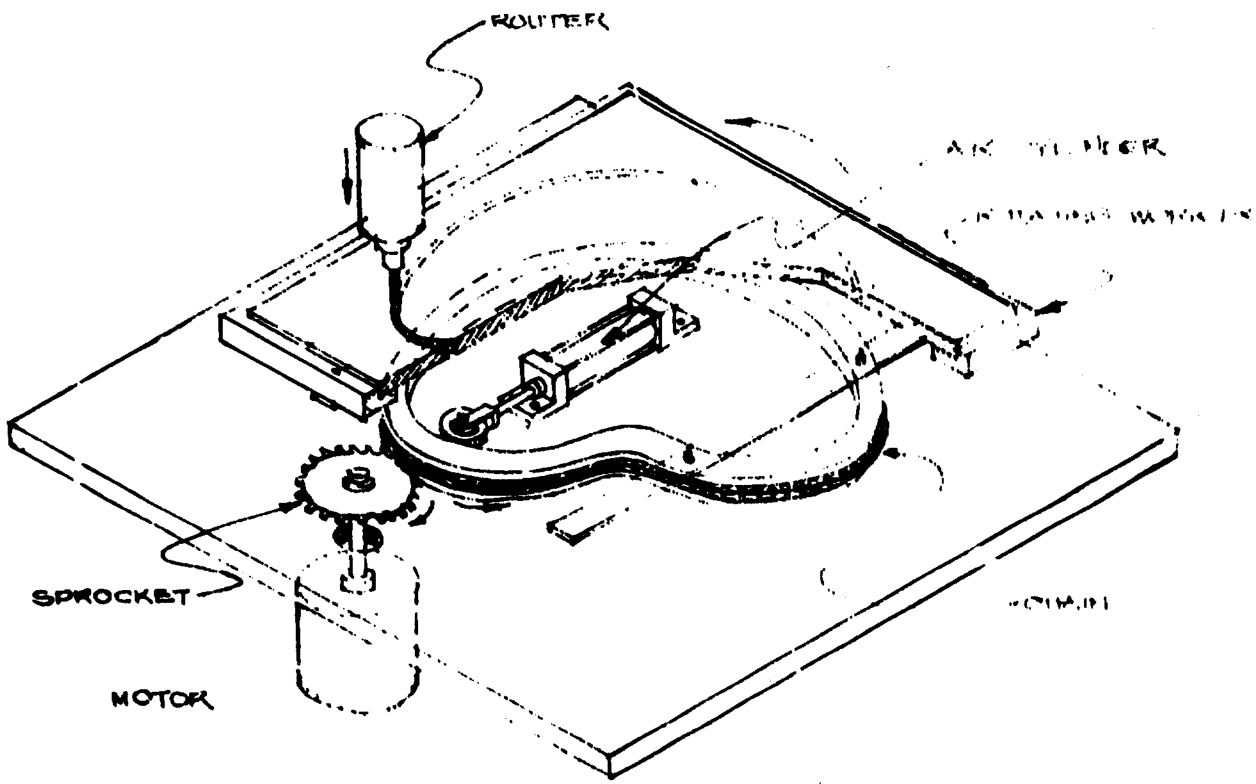


FIGURE 18

ROUTING CUT - OUTS ON PANELS, AIDED BY LCA DEVICE

illustrative example in this paper. The original steel-bed work-table of the heavy duty router is replaced by a steel frame which holds the pneumatic cylinders, valves and limit switches that control the movement of the panel under the router bit. The basic panel movements are left-to-right and forward-and-backward of the router bit. Other cut-out shapes can be routed by adjusting the design of the ICA system to fit the desired shape.

Caution : This type of cut-out routing will always give rounded corners on the cut-out. The acuteness of the rounded corners depends on the size of the router bit used.

7. Sanding

Small and medium panel-based furniture plants commonly use narrow belt sanders (single or double stroke sanders) for sanding panel components. As discussed in a previous section of this paper, this operation is rather slow, and requires a high degree of skill on the worker. Incidence of veneer sand-thru on the panel edges is high.

More modern plants use wide belt sanders, usually double belt models. While other plants use drum sanders with drum oscillating mechanisms. These modern sanding machines have their own feed mechanism and can be easily linked to other operations in the plant.

Edge sanding panel components in small and medium size plants is usually done on a universal sanding machine with oscillating mechanism for the sanding belt. Some models of this type of sander have tables which can be inclined to allow sanding of panels with canted (sloping) edges. The panel surface to be sanded is pushed by hand against the moving sanding belt. Again, a certain degree of skill is required of the worker in order to reduce sanding rejects to a minimum. Automation of this operation is hardly possible without interfering with the working mechanism and design of the machine.

Panels with profiled edges are edge-sanded on a "contour sander" using a narrow cloth-backed sanding belt. The key to success in this sanding operation is the proper shape of the pad at the back of the sanding belt, which should mate properly with the profile of the panel edge.

D. POSSIBILITIES OF ICA APPLICATION TO ASSEMBLING OPERATIONS OF PANEL - BASED FURNITURE MANUFACTURING

The basic tools and implements, among others, in assembling panel-based furniture are :

1) Screw drivers ;
2) C-clamps and bar clamps ;
3) Toggle clamps ;
4) Stapling tools ;
5) Glue applicators ;
6) Assembly jigs and fixtures ; and
7) Frame and carcass clamps.

The key to efficient and rapid assembling operations is the use of adequate jigs and fixtures equipped with clamps or other forms of work-piece holding devices. Separate jigs and fixtures are needed for the sub-assembly of drawers, special shelvings and cabinet partitions; appliques on doors and drawer fronts, automatic drawers-locking-mechanisms, etc. Modular assembly jigs and fixtures can be designed and fabricated for the assembly of the panel-based furniture carcass, sidings, top, back and bottom. This method leaves the front open for easy access to the inside areas of the cabinet. In some cases, the top panel is last to be assembled, particularly in furniture items where the top panel edges protrude over the sides and front of the furniture, such as in night tables, dressers, and the like. There are other instances, however, where the back panel will be the last to be assembled, like in stereo speaker units, console type of radio - phono cabinets, etc.

1. Drawer Assembly

Whether the panel-based furniture item is shipped in the assembled or "knock-down" state, drawers are always assembled before finishing. Modern furniture design calls for drawer fronts flush with the cabinet front surface, unlike the old cabinet designs where drawer fronts are provided with lips which overlap the front face of the drawer frames, covering the clearances between the drawer and the drawer frame. Thus, the drawers should be assembled as squarely as possible in order to attain the desired fit with the drawer frame. This constraint imposes strict adherence to machining tolerances of drawer and drawer frame components, so that perfect squareness is attained when assembling drawers. Perfect squareness in assembling drawers is better attained through the use of metal assembling jigs and pneumatic actuated clamps which will hold the components firmly in place until the adhesive applied to the joints has set, or until fasteners have been put in place to fix the drawer components in a squarely assembled form. Figure 19 illustrates such an assembly jig.

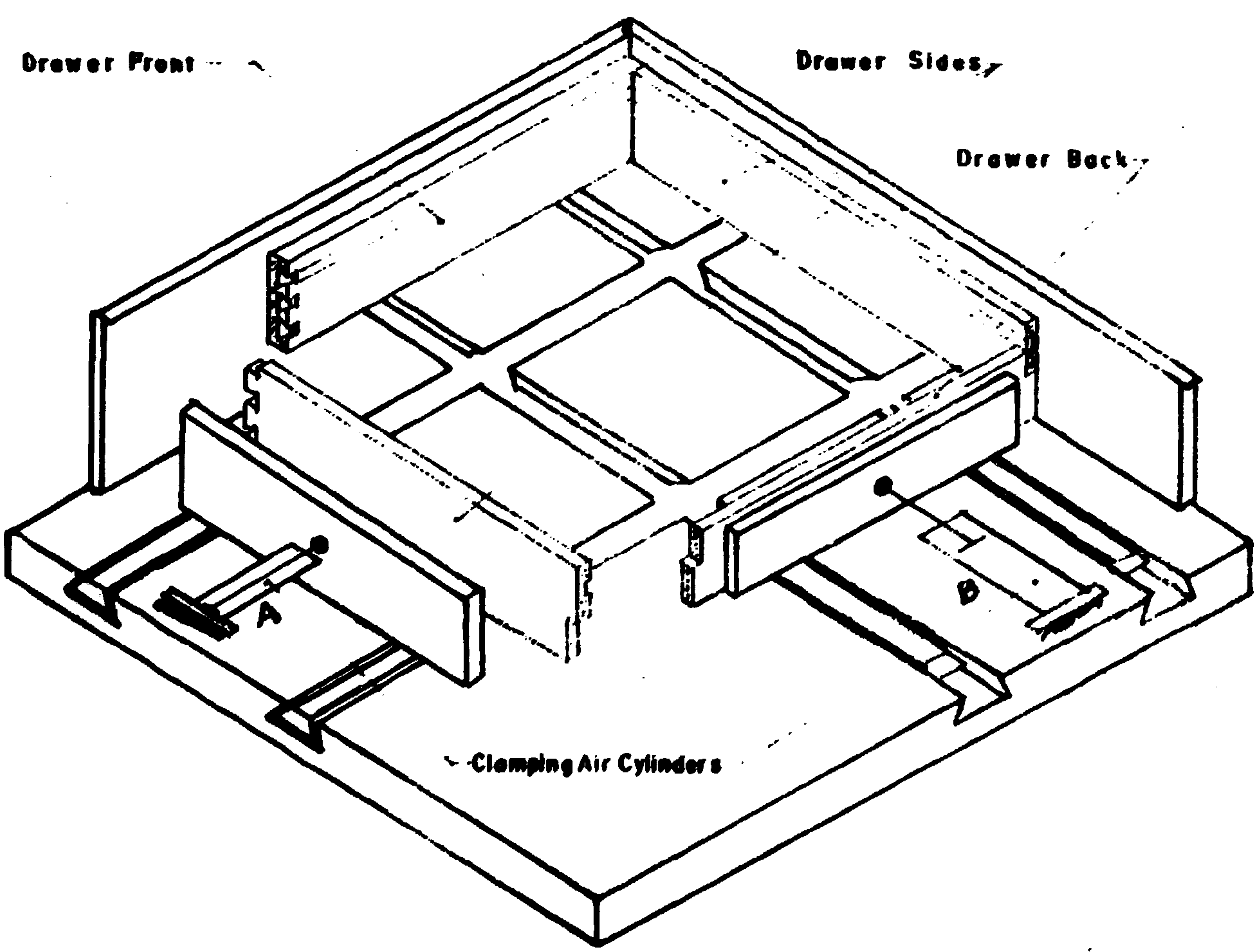


FIGURE 19
DRAWER ASSEMBLY JIG

2. <u>Glue Application</u>

Too much glue or too little glue does not give good assembling results. Excess glue leads to glue squeeze-outs and messy gluing job. Glue-starved joints are weak as there is less adhesion to make the joint strong enough. Hence, for precise glue application requirements, a device operated by LCA components similar to the system illustrated in Figure 20 may help attain a satisfactory gluing job. The amount of glue deposited on the wooden piece is controlled by the size of the nozzles and the speed by which the wooden piece is pushed under the glue nozzles.

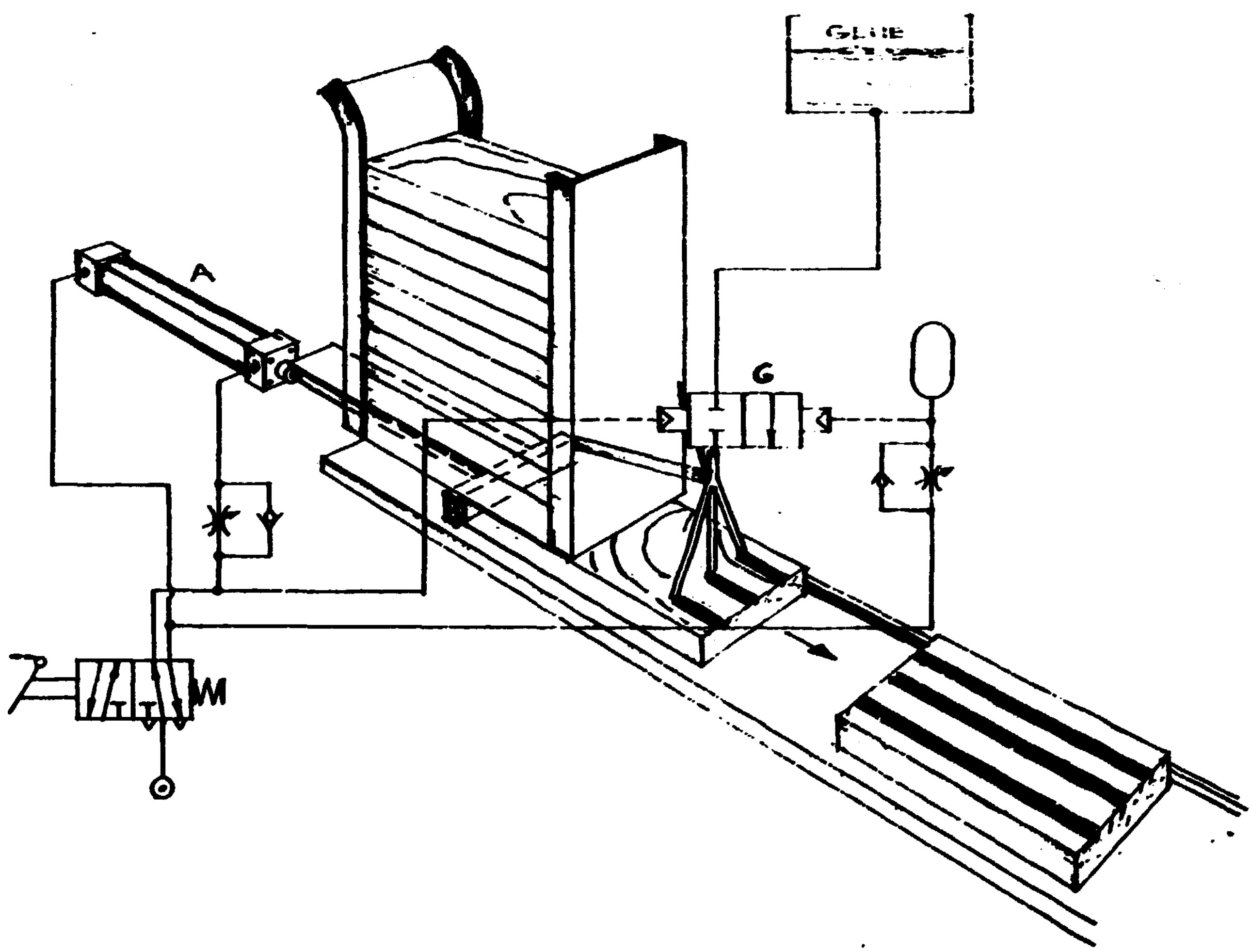


FIGURE 20
GLUE APPLICATION WITH LCA CONTROLS

3. <u>Screw Driving Tools</u>

With proper size pilot holes, wood screws can be used to attach hardware and other fittings to panel-based components of the furniture. The danger, though, arises from turning the screw more than what the wood substrate can take, thus destroying the holding power of the screw threads to the wood-based panel. Such screw "over-driving" frequently occur with the use of mechanical screw-drivers. The use of pneumatic screw-drivers equipped with adjustable clutch device will help reduce rejects due to "over-driving" woodscrews. The clutch device can be set to match the screw-driving limits determined for each type of panel-substrate and screw size.

4. Modular Assembling Jigs and Fixtures

Modern designs of panel-based furniture items are basically rectangular or square in shape. This feature makes it possible to devise modular assembly jigs for joining the carcass of the panel-based component and also for joining the panel to the carcass. Figure 21 shows P. Pavola's suggestions of such an assembling jig which allows assembly of two cabinets at a time. The jig uses a fire-hose with air pumped into it to clamp the components in place while the assembling activities go on.

For assembling cabinet doors, a device suggested by H. Brion and W. Santiano, Figure 22, also makes use of a fire-hose and a pneumatic cylinder with appropriate control valves to attain the desired pressure on the parts being put together.

E. POSSIBILITIES OF ICA APPLICATION TO FINISHING OPERATIONS ON PANEL - BASED FURNITURE

The basic operations involved in clear finishes for wooden furniture may be summarised as follows :

a. Sap staining or full surface staining ;
b. Filling ;
c. Seal coating ;
d. Scuff sanding (if necessary)
e. Top coat application ; and
f. Polishing (buffing), if necessary.

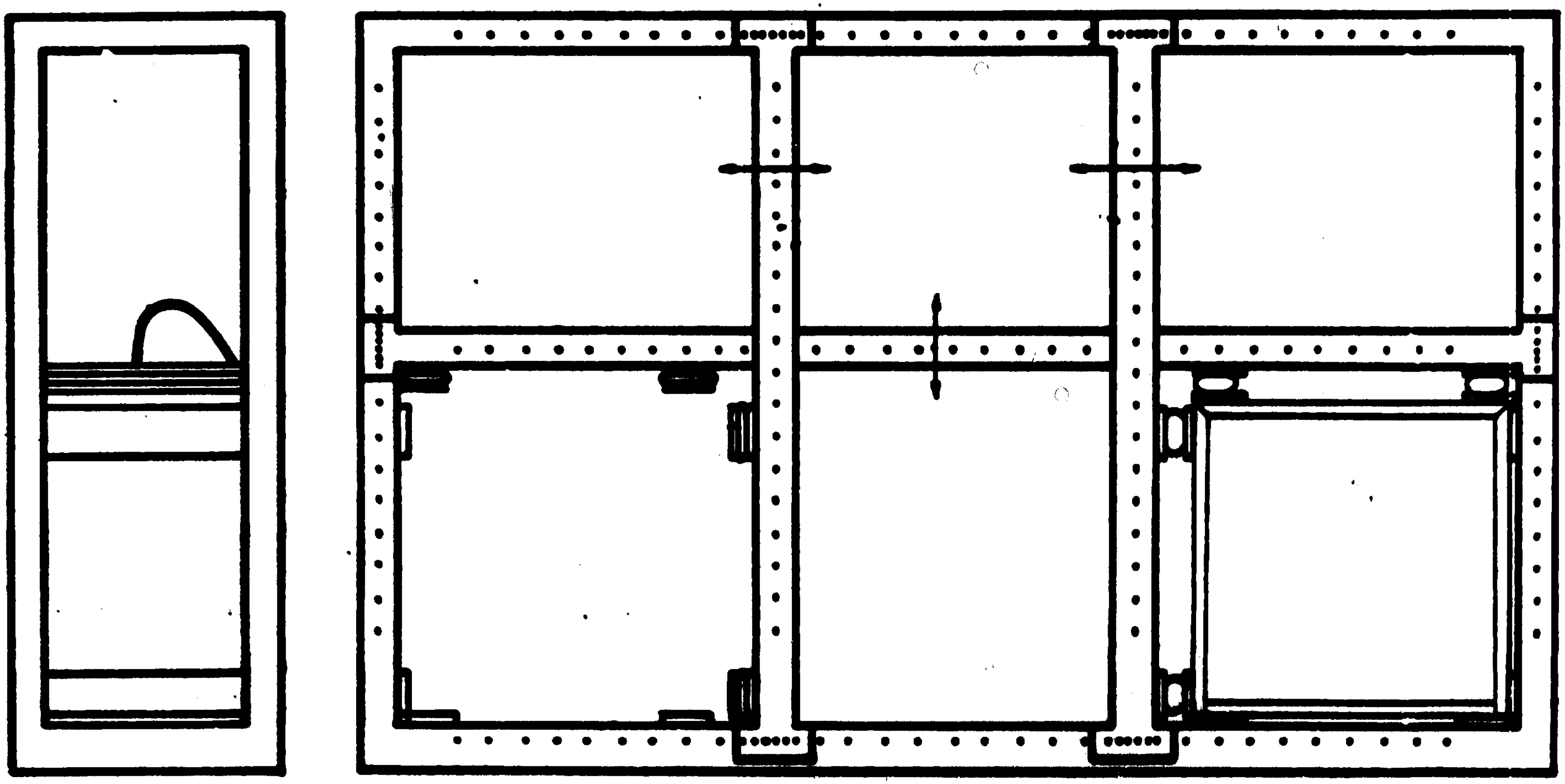
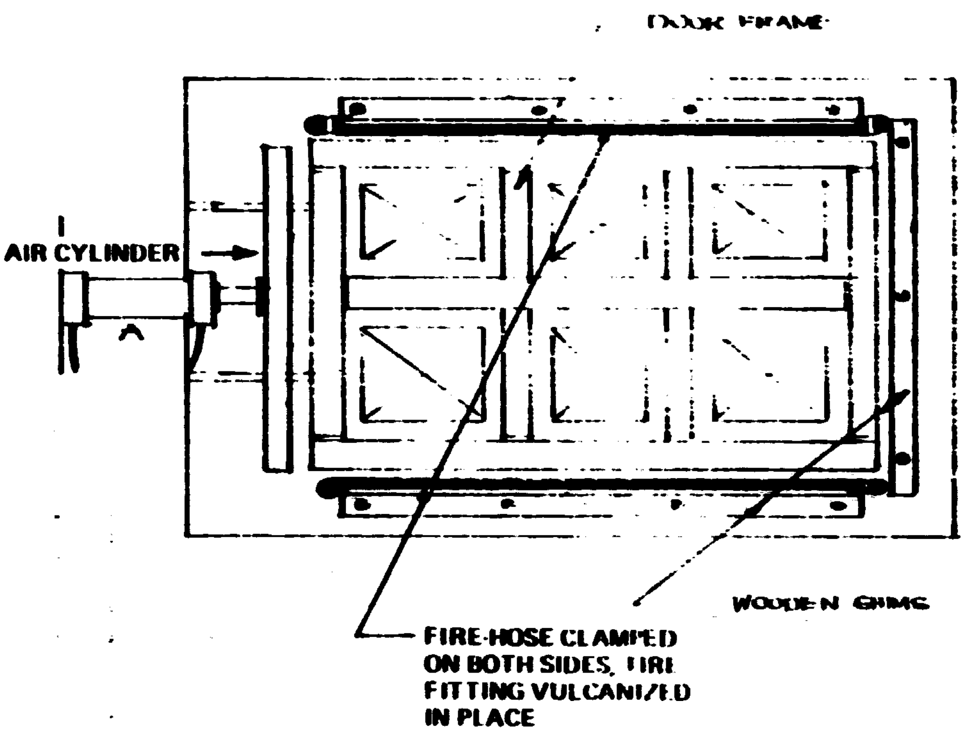


FIGURE 21

PANEL - BASED CABINET ASSEMBLING FIXTURE



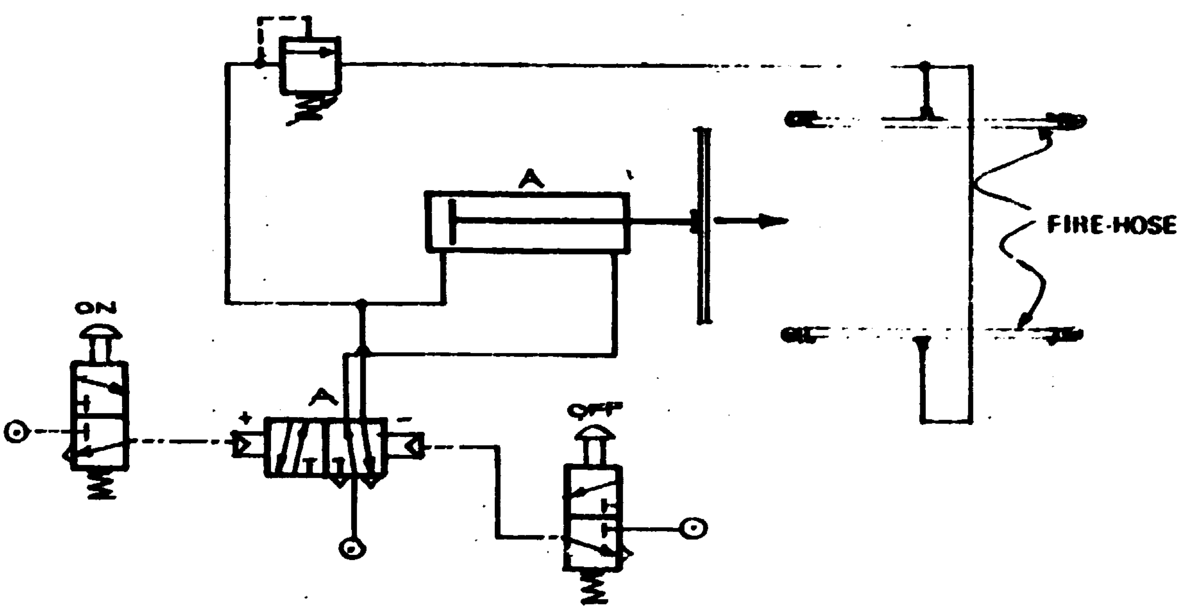


FIGURE 22

CABINET DOOR ASSEMBLING JIG

1. Staining Operations

This operation is normally done by spraying, using conventional air-spray guns. The primary objective in sap staining is to deepen the shade of sapwood areas on the face veneer and make it match the other areas of the panel face. Full surface staining aims to even out the depth of colour tone on the panel surface, particularly in veneer cut from wood species which exhibits "metamerism" (some degree of difference in the absorption and reflection of light) between the tight and loose sides of the veneer sheet. In other cases, full staining is used to deepen the shade or give the panel surface another color. It is thus obvious that the success of this operation is principally dependent on the ability of the human eye to detect the areas which need more stain or to determine the amount of stain to be sprayed on the panel surface. The operation therefore is hardly possible to automate.

2. Filling Operations

The common prime material in this operation is the wood-filler with a quick-drying oil. The objective is to pack the pores of the veneer surface with filling material in order to get a smooth surface after the top coat is applied. The key to success in this operation involves the use of devices which can effectively push the filler particles into the wood pores. Air-operated reciprocating machines with felt padded-shoes are commonly used in this operation. The machine is hand-operated and has its advantage and disadvantages. A rotary-type filler-padding machine has shown better results than a reciprocating type of padding machine. This operation is discussed in detail under Illustrative Example "C".

3. Sealer Coat Application

This operation is normally done by hand spraying. However, in some medium-size furniture plants, sealer coats are applied with the use of the pressure curtain coater. With a sealer material properly formulated for the machine, a tremendous amount of savings is attained in the form of reduction of materials consumption and labour usage. Since only two edges of the panel, in addition to the top surface, can be coated in one pass thru the machine, a device which will return the coated panel to the feed-end of the machine will greatly help speed-up production. Figure 23 shows such a system with automated panel turning device.

Sealer coat application on assembled furniture items is done by spraying. Should the volume of spraying job justify automation of this operation, it is possible to design an automatic spraying system with the use of ICA devices. See Figure 24.

4. Scuff Sanding

Some sealer material formulation raises the nibs on the wood surface, thus requiring light sanding operations to cut off the nibs. This is best done manually. Automation of the operation is not recommended!

5. Top Coat Application

This operation is also normally done by spraying. The methods and devices recommended in the paragraph on sealer coat operation are also applicable in this operation.

6. Finished Surface Polishing

This operation helps to heighten the gloss of finished surfaces. A portable air-operated or electric motor driven buffing machine with a rotating disc padded with a bonnet made of lamb's wool is best used for assembled furniture. However, in systems where the panels are finished prior to assembling, a heavy duty buffing machine is usually used to polish panel surfaces. This machine is equipped with a cylindrical head which rotates on its axis at a pre-determined speed. The rotating head is padded with fine woolen material which polishes the panel surface. In other models, the rotating head is equipped with closely-packed strips of fine woolen material instead of one sheet wrapped around the buffing cylinder. The panel surface is brought in contact with the buffing material by means of a platform which is raised or lowered manually. In some models, a limit switch device is installed to prevent the platform from moving beyond a certain distance nearer to the buffing head. This feature helps prevent burning

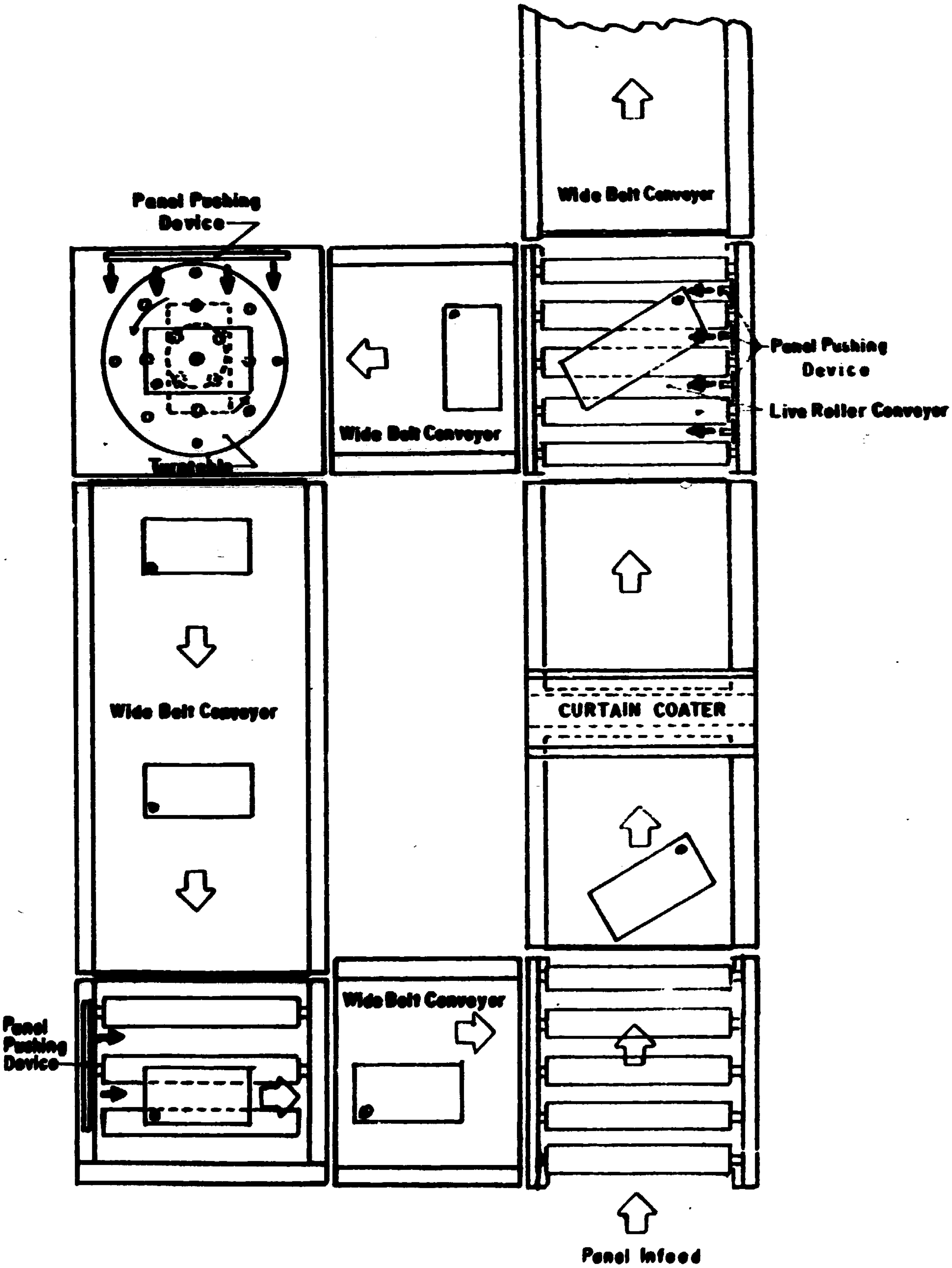


FIGURE 29

PANEL RETURN CONVEYOR, CURTAIN COATING OPERATIONS

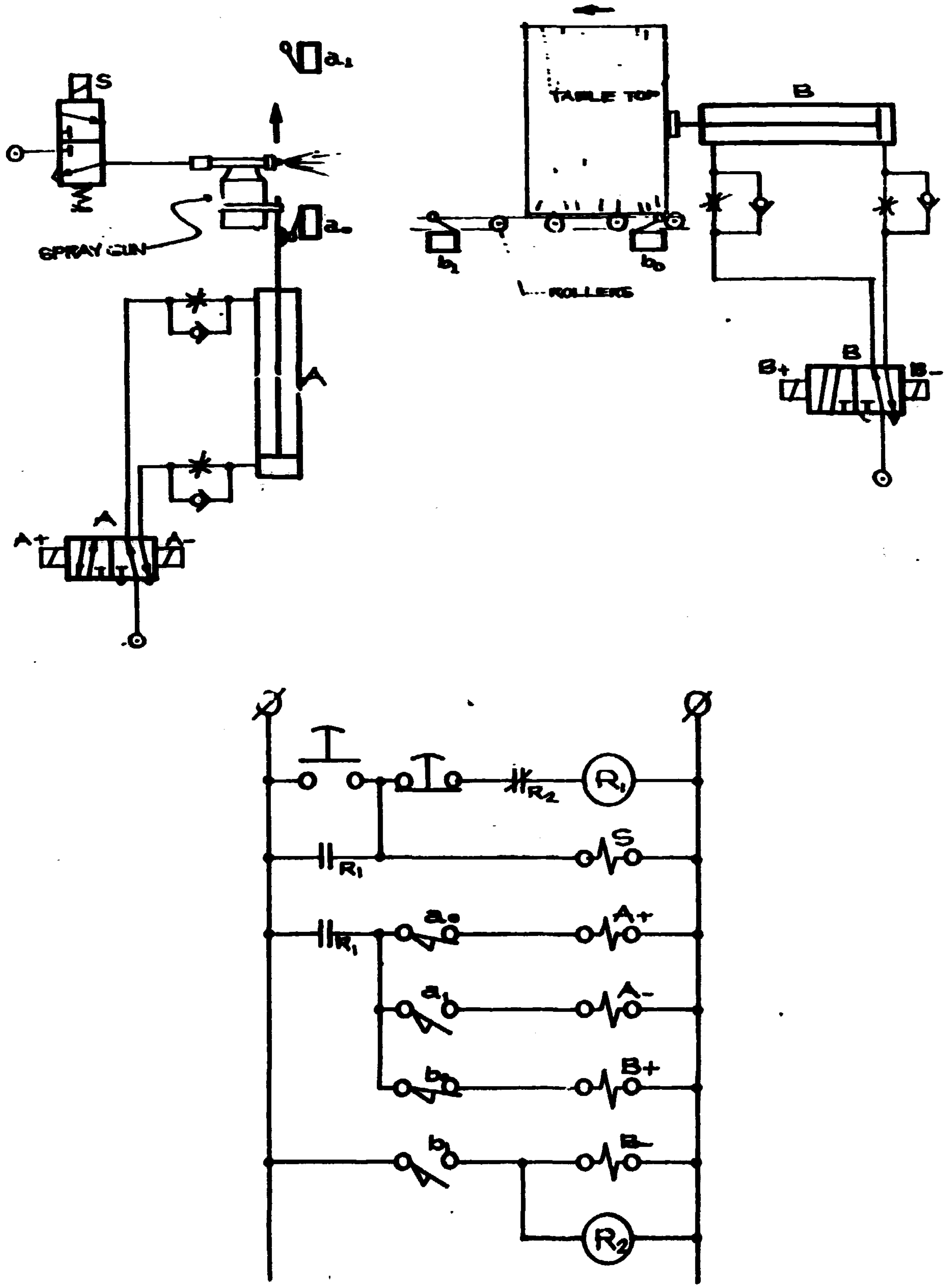


FIGURE 24

AUTOMATED SPRAYING SYSTEMS

of the finished surface as a result of over-heating.

Application of ICA to this operation is possible in the case of the heavy duty buffing machines. A device can be installed which will automatically raise the buffing platform up to a desired level, move the panel forward until the rear edge is polished, and maintain contact between the rotating buffing head and panel surface for a pre-determined length of time, and lower the buffing platforms thereafter. Loading and unloading the platform can also be automated. See Figure 25.

F. POSSIBILITIES OF ICA APPLICATION TO MATERIALS-IN-PROCESS HANDLING AND TRANSPORT

It will be recalled that the foregoing discussions often indicated success of automating operations in the manufacture of panel-based furniture if this is aided by an adequate handling and transport system for the materials-in-process. Time and space do not allow a detailed discussion of the handling and transport system devices which can be set-up for each of the operations covered in this paper. However, illustrative examples of such devices are presented in the following paragraphs in the hope that the reader will be motivated to apply such devices, wherever possible, in his own manufacturing operations.

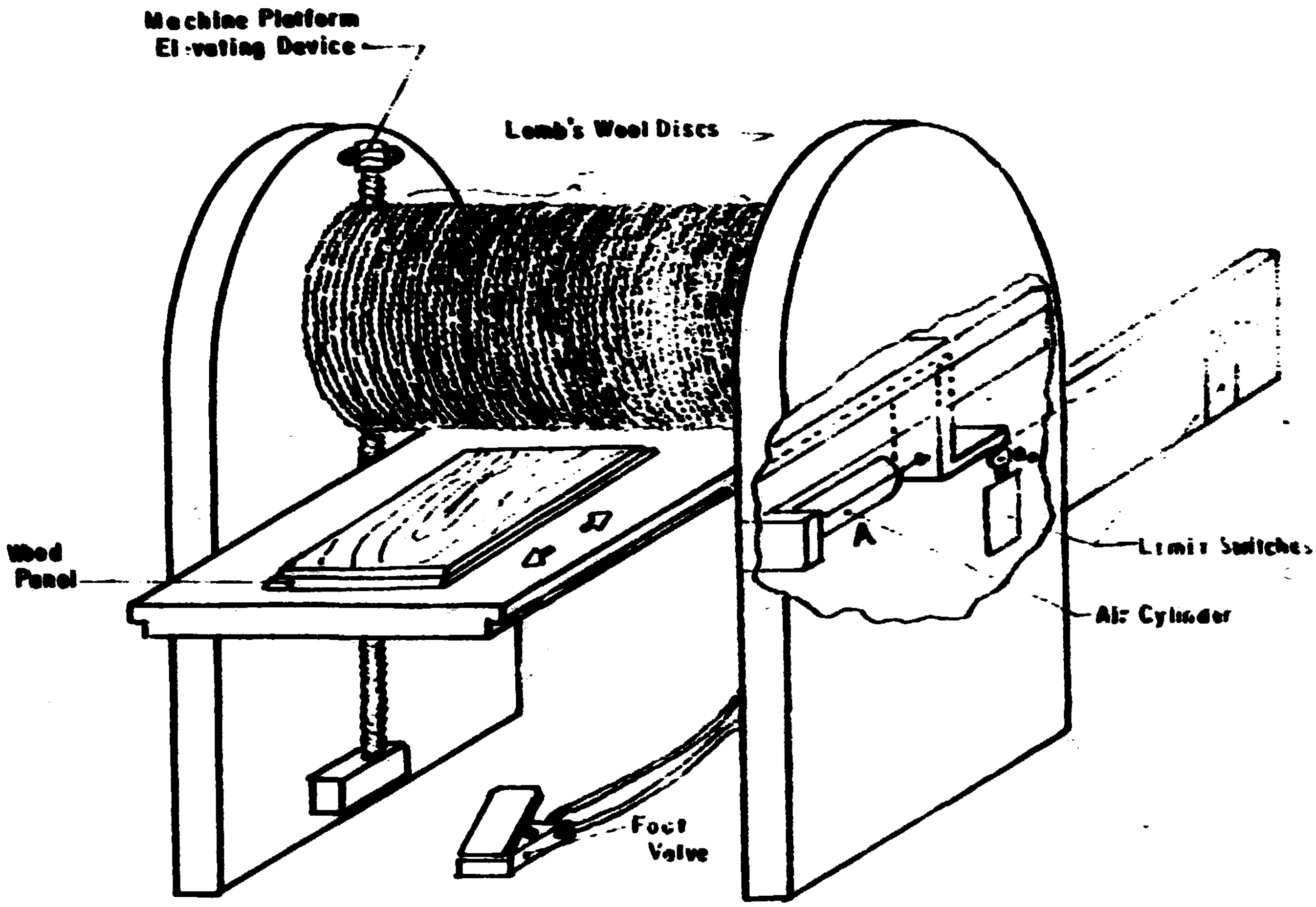
The design of materials-in-process handling and transport system should be guided by the following considerations :

a. Safe transport of the material or product component from one operating station to another ;

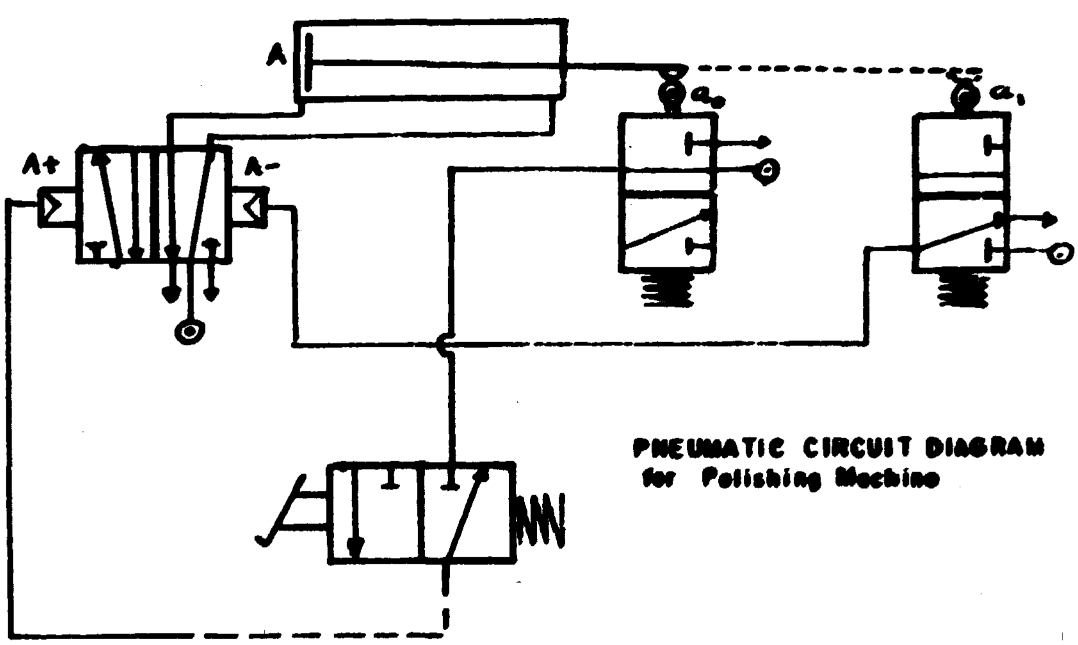
b. Speed in transporting the materials or furniture components ;

c. Adequate quantity to be transported so that continuous operations is assured in the succeeding operating station ; and

d. Cost of fabricating, installing and operating the handling and transport devices is justified by the benefits to be derived from their use.



HEAVY DUTY PANEL POLISHING MACHINE



PNEUMATIC CIRCUIT DIAGRAM
for Polishing Machine

FIGURE 25

AUTOMATED BUFFING MACHINE

1. Machine Feeding Techniques and Devices

M. Koch and F. Lestouvka presented a number of machine feeding techniques and devices, aided by hopper feeds operated by ICA systems, applicable to solid wood or panel components. Figures 26 to 29 are schematic diagrams of such hopper-feed devices.

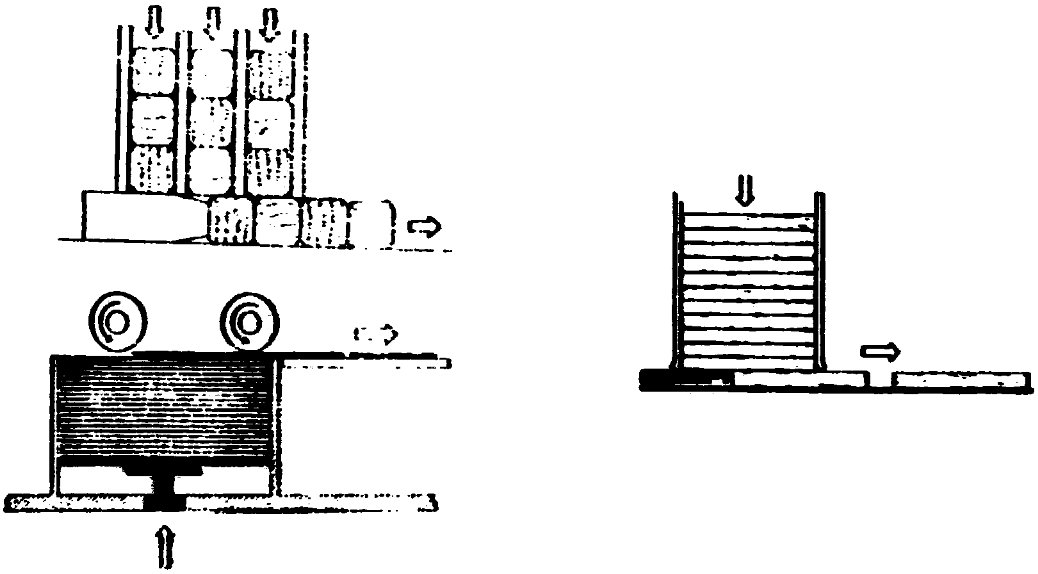


FIGURE 26

HOPPER FEED SYSTEMS

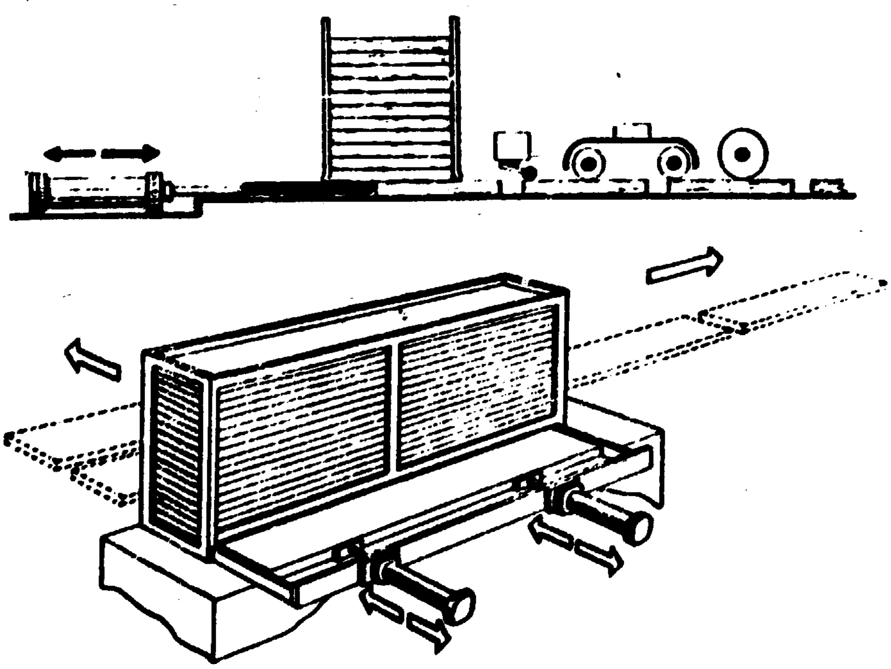


FIGURE 27

STACKED HOPPER WITH PNEUMATIC EJECTOR

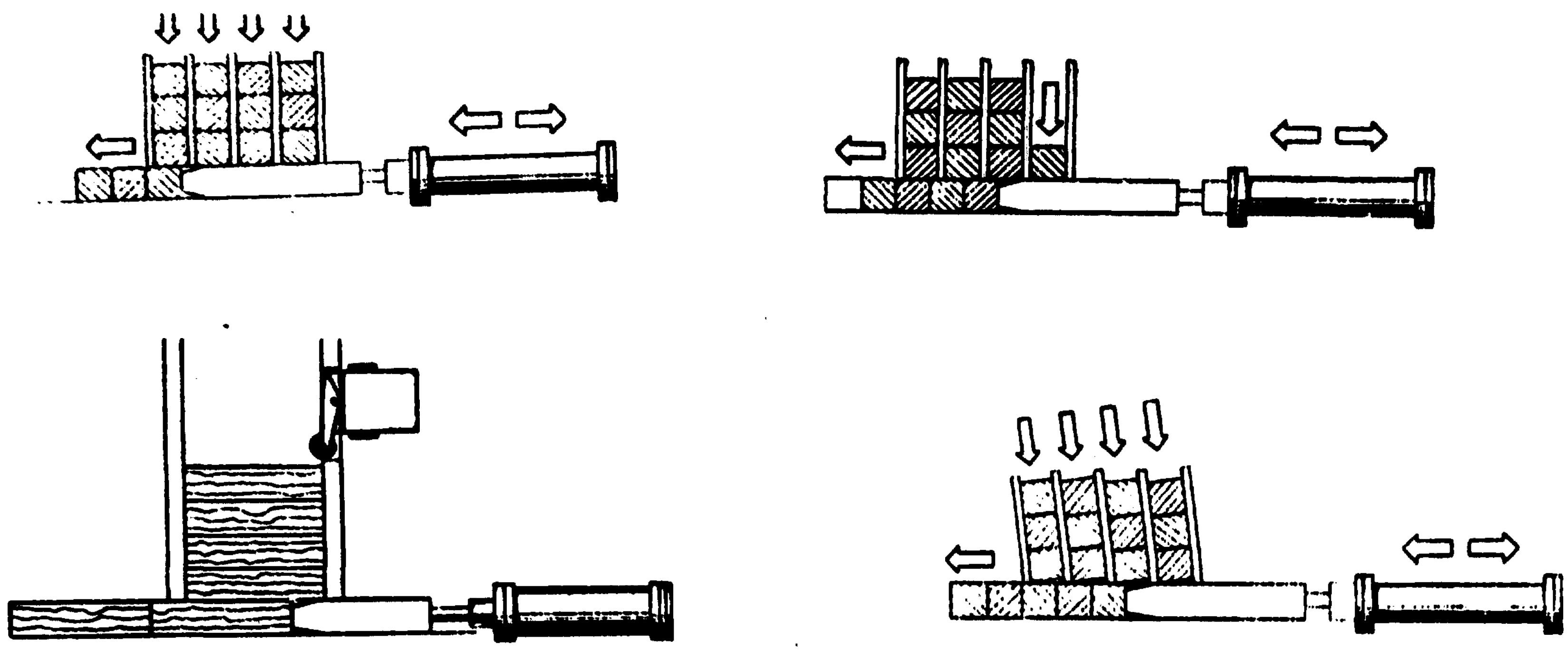


FIGURE 28

MULTI - STACKED HOPPER DEVICES

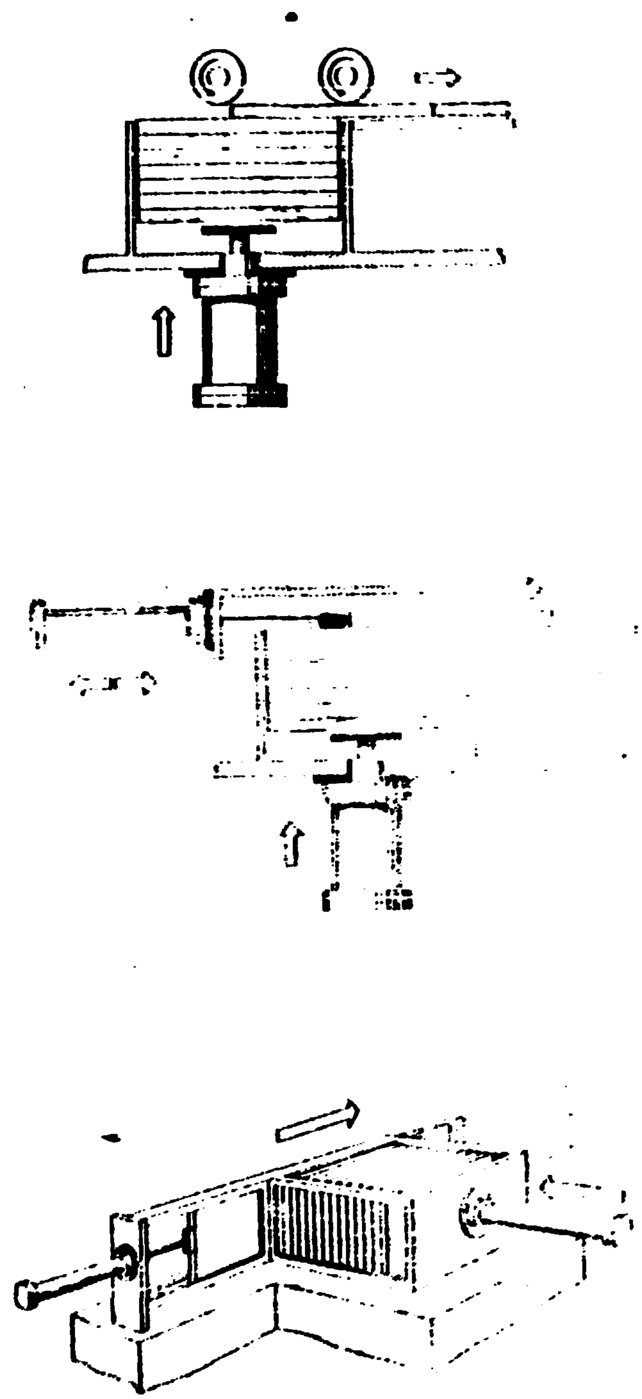


FIGURE 29

PANEL FEEDING DEVICES

2. Transport of Panels

Certain situations require that panels transported on a live conveyor be turned 90° or 180° to facilitate feeding of the next machine. Figure 30 illustrates how such a device can be installed in live conveyor systems.

3. Other Devices

Work-piece holding and clamping systems often produce better results if toggle-clamps, air cylinder operated clamps, eccentric clamps ,etc. are used. This is particularly so in operations where vibration of the work-piece leads to poor machining quality. Some of these clamping accessories are shown in Figure 31. It will be noted that each type of clamp has its own specific mode of use.

III. ILLUSTRATIVE SAMPLE PROBLEMS AND ICA SOLUTIONS

The following illustrative examples of some problems encountered in medium-size panel-based furniture manufacturing plants are given in the hope that the reader will gain some idea on how ICA helps in the solution of manufacturing problems, and, also serve as a guide in situations where a decision has to be made as to whether to automate or not.

A. THE CASE OF ROUTING CUT - OUTS ON PANELS

1. Situation

A panel-based cabinet factory currently producing 400 units per week intends to double its production within the next 24 months, with the following conditions :

a. The factory floor area under the expanded operations program will be reduced to 2/3 of the present area, to provide space for another line of product to be produced under the expansion program ; and

b. Production operations will still be restricted to one 8-hour shift per working day, but only 5 working days/week will be allowed, instead of the current

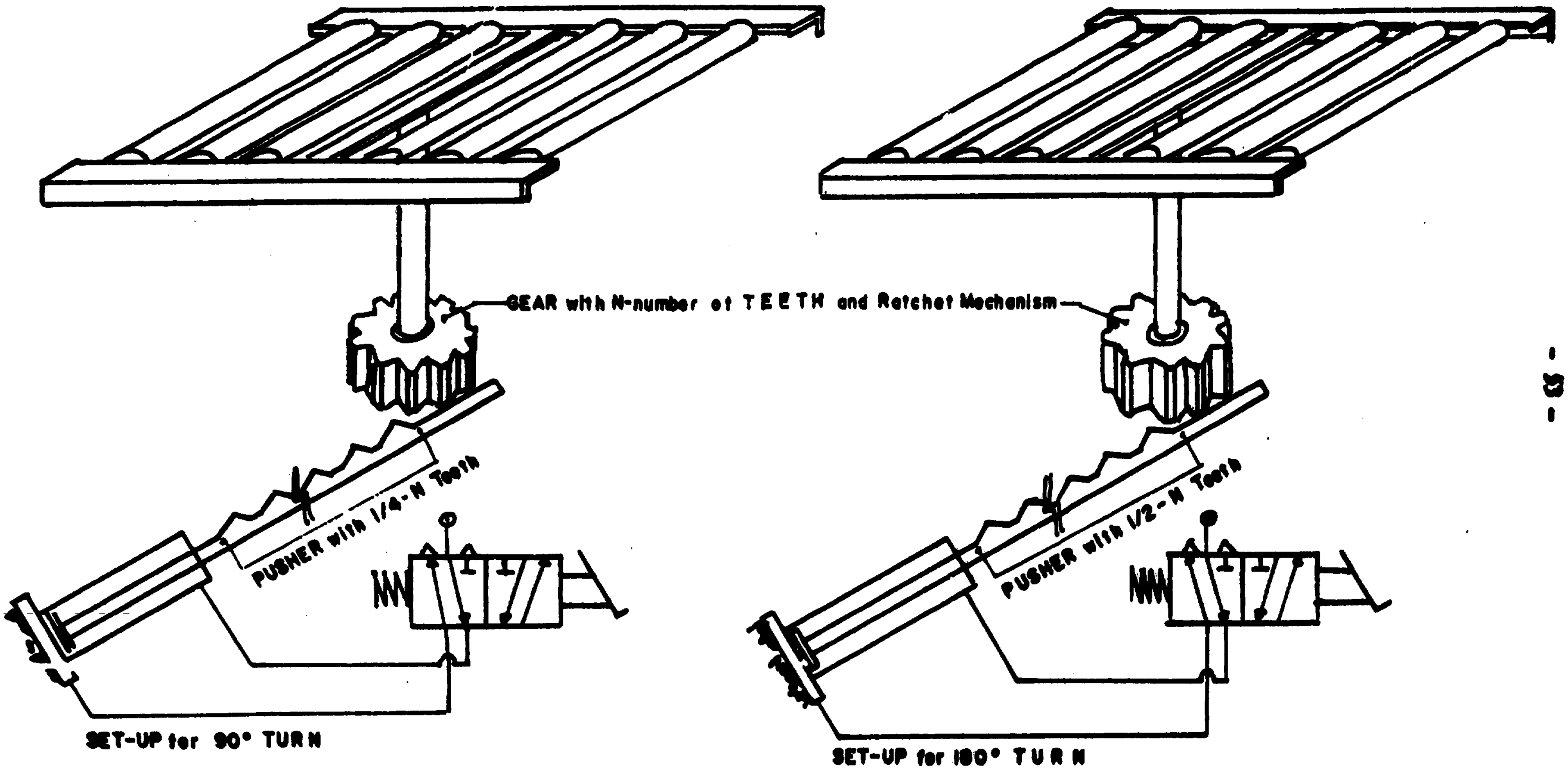
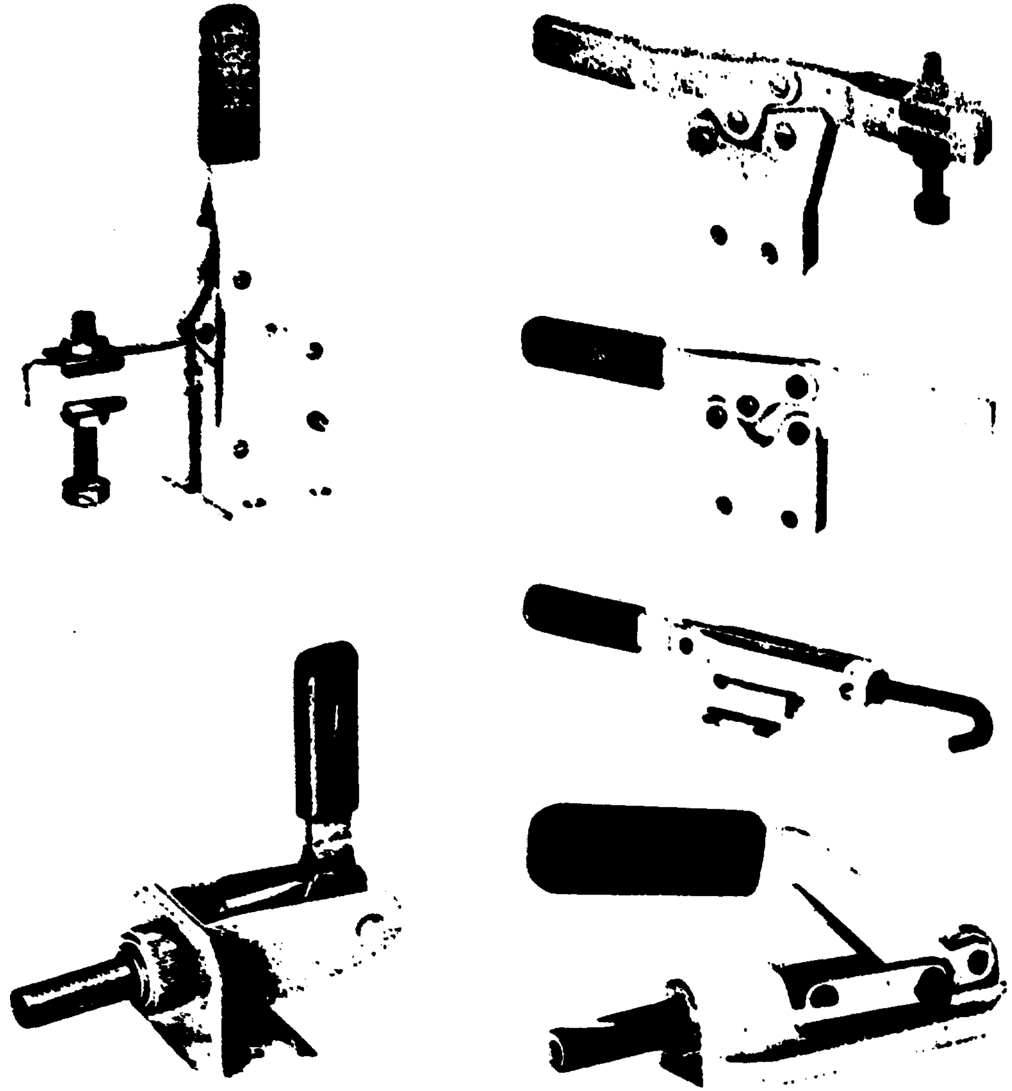
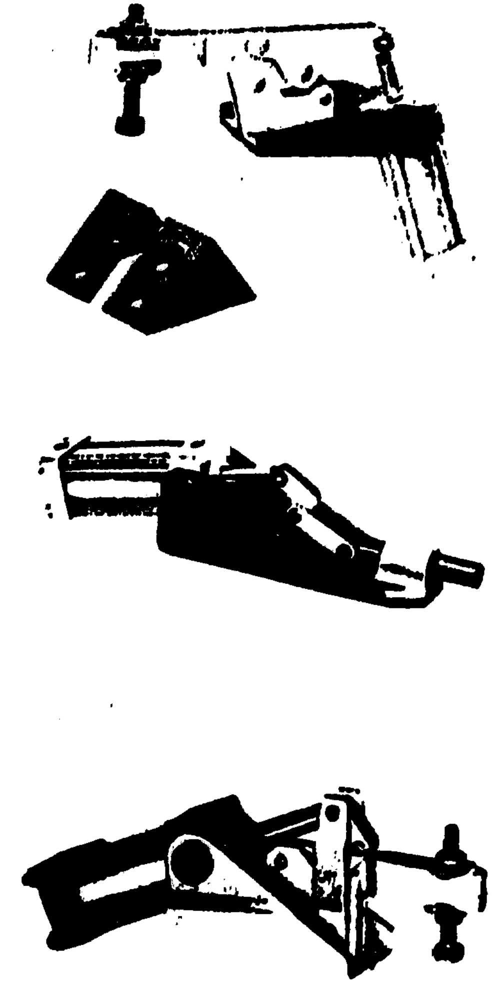


FIGURE 30

DEVICES FOR TURNING PANELS 90° OR 180°



MECHANICAL (TOGGLE) CLAMPS



PNEUMATIC CLAMPS

FIGURE 31

SAMPLES OF CLAMPING DEVICES

6 working days per week.

In short, production output will have to be increased 240% the present capacity. Among the potential bottleneck operations studied was the routing operations in the panel machining section. There were two heavy duty routers available, both manually-fed and of the fixed-head and elevating-table type. Current routing work load on the two machines is about 80% of available machine time, excluding machine set-up time. Further investigation showed that 90% of the routing time is taken up in routing cut-outs on two of the panal components of the cabinet.

2. <u>Problem</u>

How to attain the 240% increase in production output and still comply with the two major constraints on floor space allocation and working hours per week.

3. <u>Options Available</u>

a. Replace the two routers with specially designed, more advanced models featuring automatic-moving routing fixtures. It will take about 6 months to put in running condition from date of order for the machine. This option will increase routing capacity to 300% of the present capacity and cost US$18,000.00, installed and operating.

b. Keep the present routers and run them 3-shifts. This option will require an additional 4 router operators, 4 more maintenance technicians (2 electricians and 2 mechanics) and 2 foremen. Furthermore, the diesel-electric generating set will be run 24-hours per day.

c. Replace the present steel table of the existing routers with routing fixtures equipped with an appropriate LCA system that will move the work-piece to make the desired cut-outs on the panels and allow performance of other routing jobs, and simplify loading and unloading the routing fixtures with the use of pneumatic clamps actuated automatically and position the work-piece correctly with respect to the router bit. This option is expected to increase routing capacity to 275% of current capacity ; require the same number of workers as used at present and cost approximately US$10,000.00, fabricated, installed and operational.

5. Value Analysis of Options

Option 3 (b) was set aside out-right because it did not conform to working-hours constraint set by Management. The following comparative analysis between Options 3 (a) and 3 (c) was evaluated.

a. Both Options will require the same number of workers and same skill level of workers.

b. Some modifications are needed to be done on the routers under Option 3 (a) in order to enable the machines to perform other routing jobs, aside from making cut-outs on panels.

c. Power and air consumption of the machines in both Options are about the same.

d. The conversion job under Option 3 (a) requires materials which are available locally. Only a few of the ICA components may have to be imported by the local representative of the manufacturing firm.

e. Maintenance requirements of the machines in both Options are about the same.

f. The present routers can be sold at US$2,750.00 each, including the frequency changing units.

g. Both Options meet the expanded capacity requirements.

6. The quantitative cost comparison between the two Options are as follows :

	OPTION 3 (a)	OPTION 3 (b)
Book Value of Present Machine	———	US$4,500.00
Machine Acquisition and Installation Cost —	US$18,000.00	———
Machine Modification Cost ———	750.00	US$ 9,000.00
Total Costs ———	US$18,750.00	US$13,500.00
Less : Re-sale Value of Present Machines ———	5,500.00	———
Net Cost ———	US$13,250.00	US$13,500.00

Pure economic considerations indicate that Option 3 (a) will be more advantageous. The fact that the capacities of the machines under Option 3 (a) exceed the expansion requirements by 60%, while those under Option 3 (c) give a lower excess capacity of 35% did not matter significantly inasmuch as both excess capacities were well above the required machine capacity.

Management then made an inquiry as to whether the capabilities of the shop personnel and the available machine shop facilities are adequate enough to do the conversion job on the routers without in any way adversely affecting current production outputs. Their findings, together with the schedule of conversion work for the two routers, proved that the job can be done satisfactorily in the company's machine shop.

7. Management's Decision

Considering all the available data and findings submitted by the evaluation committee, Management decided to adopt Option 3 (c), to convert the present routers to more automatic operations. The slight (S$250.00) advantage of Option 3 (a) was considered too small as compared to the knowledge to be gained by the company's personnel in automating their old machines.

It will be noted that Management did not even bother to determine whether the Project Cost is within maximum allowable investment levels for the single reason that the factory space required by the routers will be the same as that of the present space. And, that any other option can be considered only if the factory space required by the Option will be less than the present space occupied by the two machines, aside from being economically justifiable.

8. The ICA system adapted for the conversion of the present routers is illustrated in Figures 32, 33 and 33 (a).

B. THE CASE OF THE SPECIAL PANEL SANDER

1. Situation

A factory producing panel-based cabinets was having problems with the top panels final sanding operations. Daily panel rejects rate due to veneer sand-thru was averaging 6% since the start of operations. However, these rejects at times would go as high as 12%. Six workers have already been successively trained and assigned to the sanding job, yet Management feels that the 6% average reject is becoming to be unbearable as a result of the increasing costs of materials and labour. The final sanding operation is done on a double-belt stroke sander, using first a 180-grit belt, then finally, a 240-grit sanding belt.

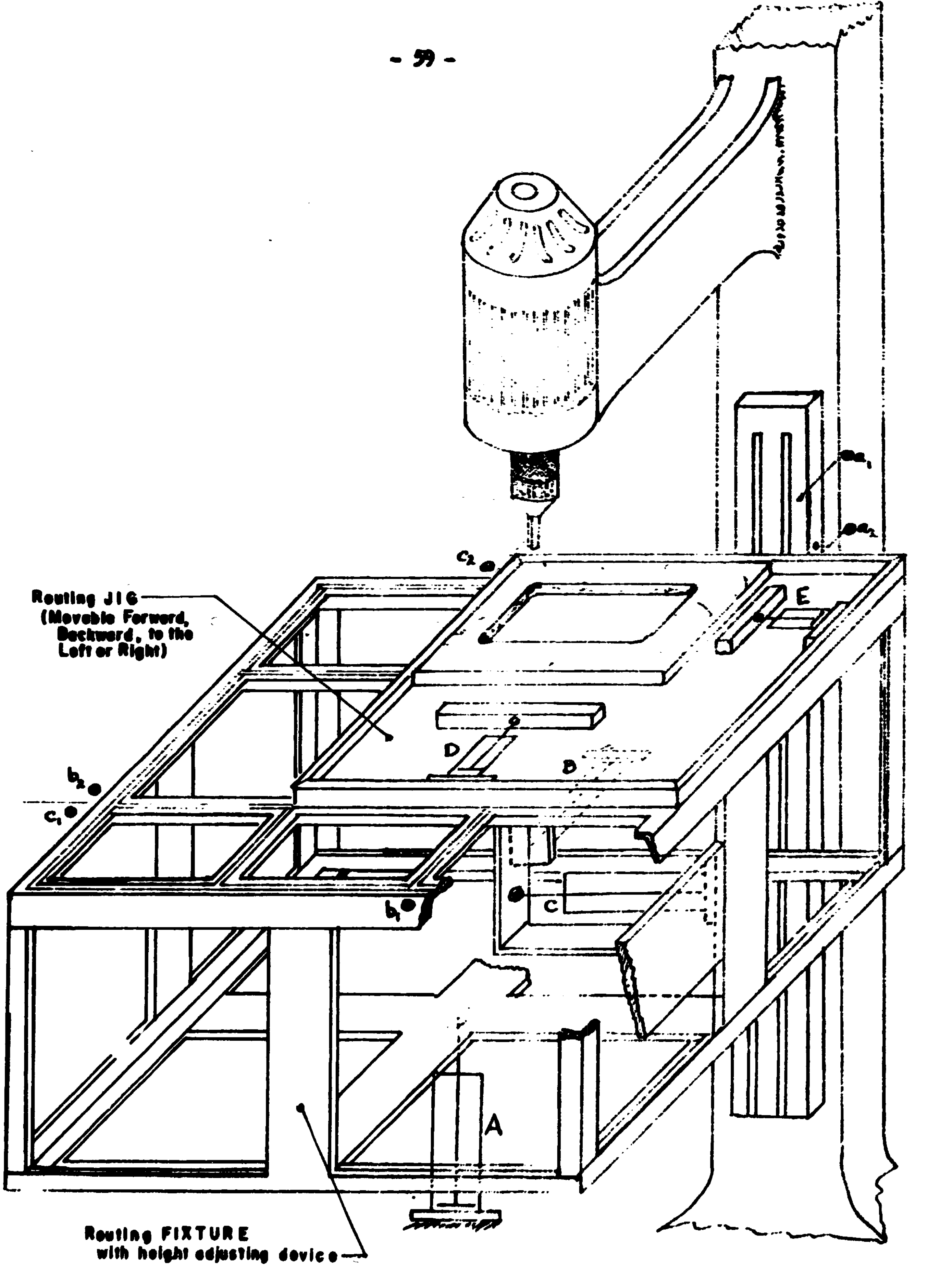
2. Problem

How to improve the final sanding operations by significantly reducing the reject rate, or possible totally eliminating rejects at this operation.

3. Analysis of the Problem

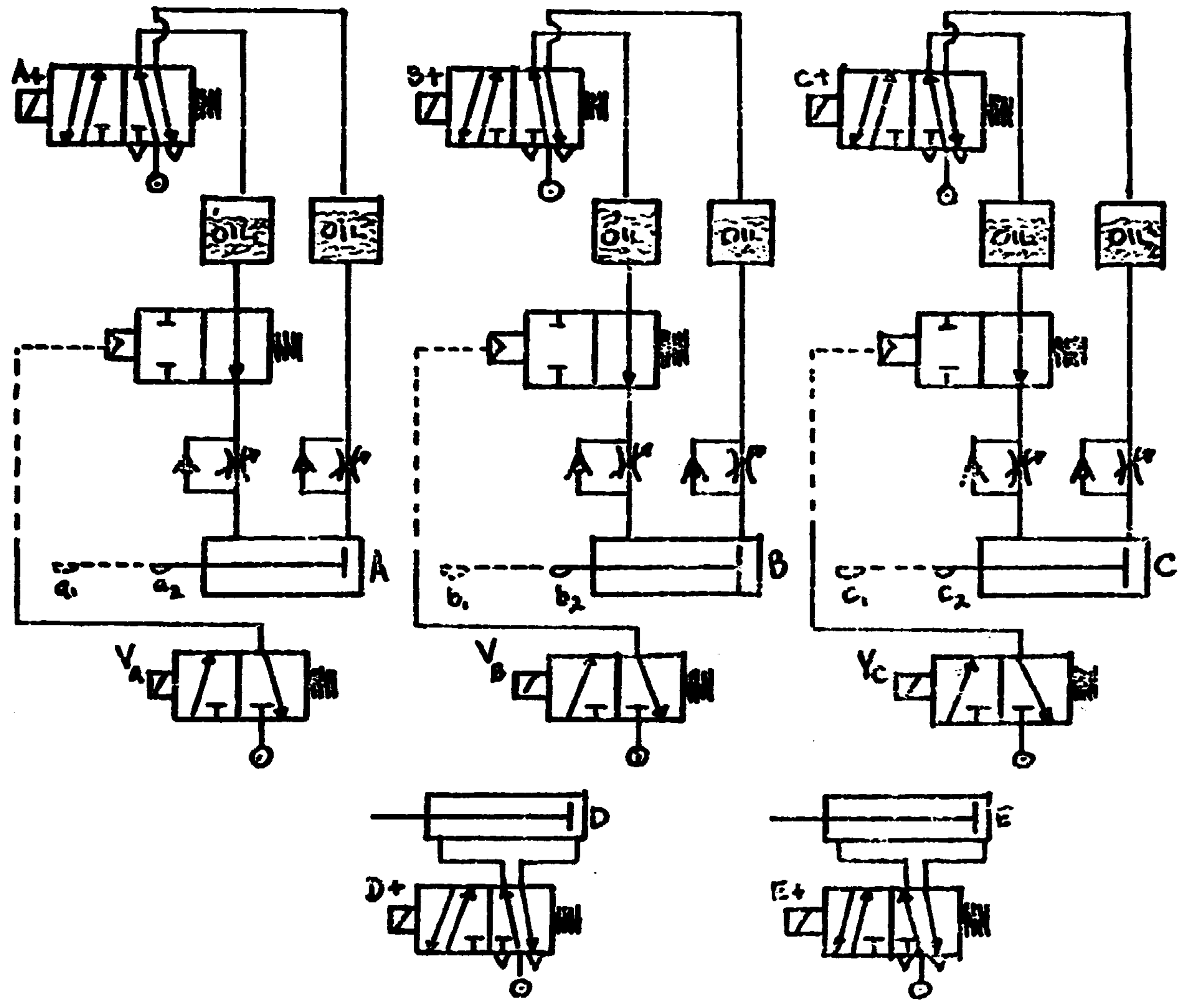
a. The company loss as a result of the veneer sand-thru rejects was calculated at US$6,093.00/year.

b. A performance check on the six workers who were assigned to the stroke sander showed no appreciable



Note: ⊕ marks approximate locations of Limit Switches

FIGURE 32: AUTOMATED HEAVY DUTY ROUTER



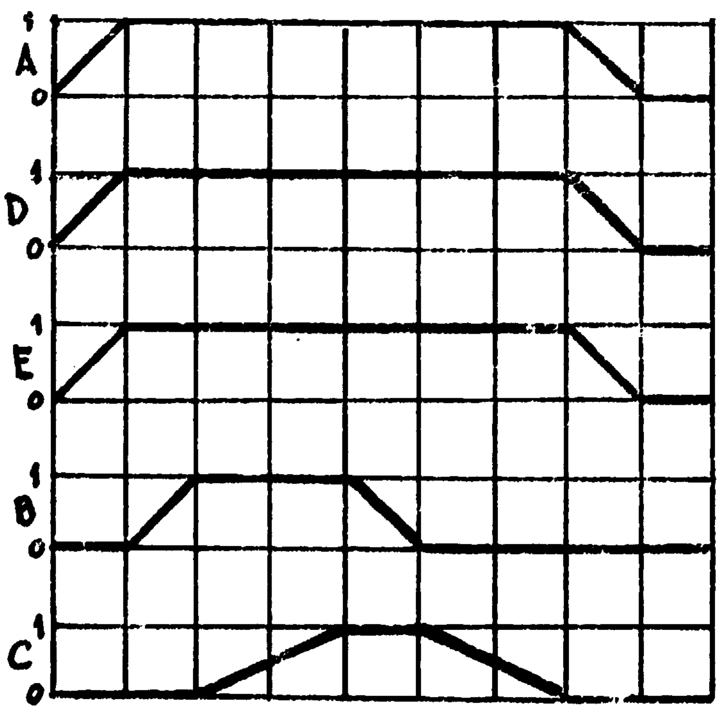


FIGURE 33: PNEUMATIC AND TIME-MOTION DIAGRAMMES FOR AUTOMATED ROUTER

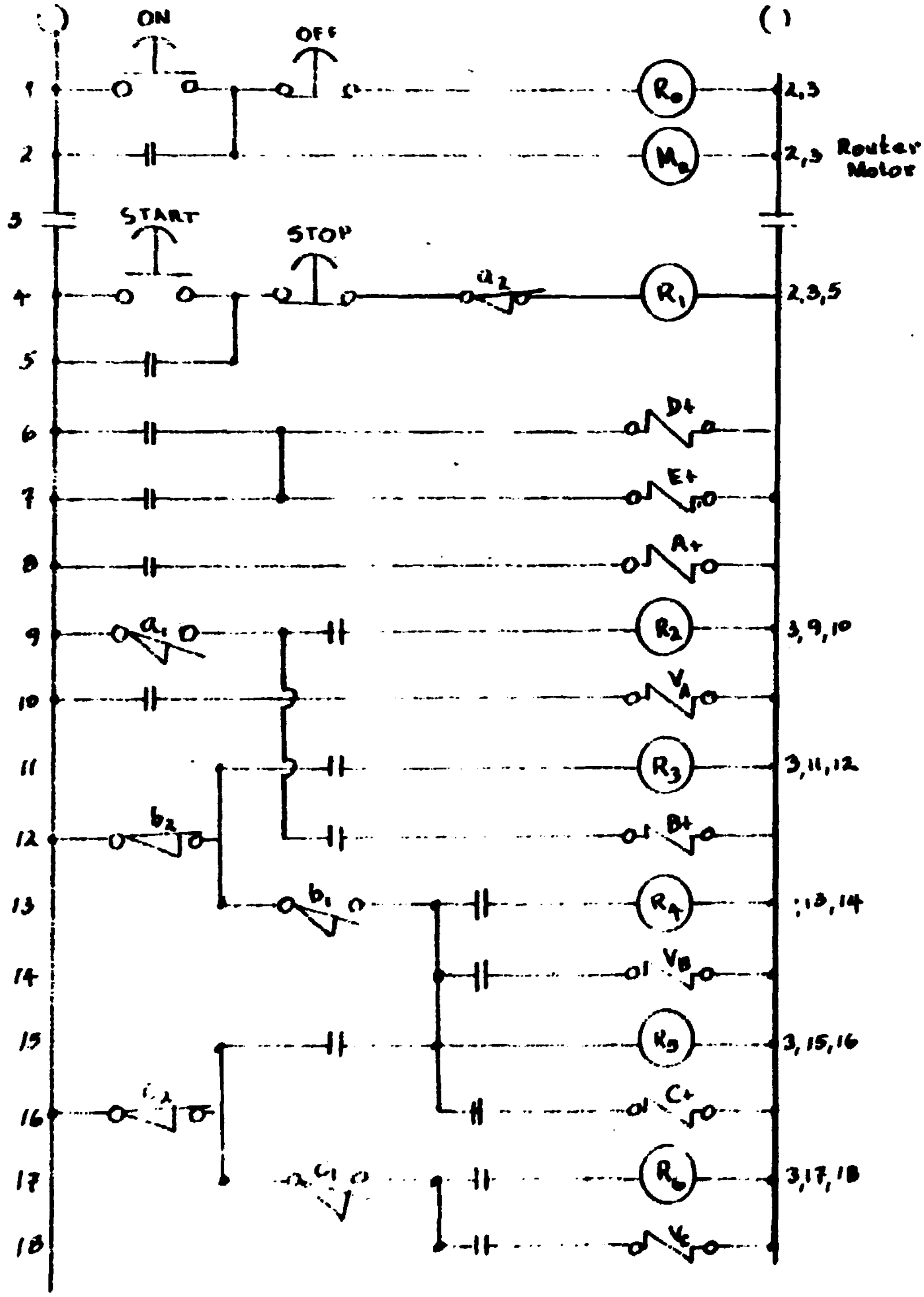


FIGURE 33 (a): ELECTRICAL CIRCUIT DIAGRAMME FOR AUTOMATED ROUTER

variation in their individual rejects rate.

c. 100% of the rejects were veneer "sand-thru" on the edges of the panels.

d. The first sanding pass was tried with a 200-grit sanding belt ; the second belt with 280-grit sanding belt. Production output dropped to 75% of the standard for the operation, while the reject rate dropped to 4%. This result was still unacceptable to Management.

e. A thorough analysis of the stroke sanding operations indicated that 90% of the rejects occur during the following periods of the daily work cycle of the machine operators :

   1) The 1/2-hour period following the start of each working day ;

   2) The 1/2-hour period after each break period ; and

   3) The 1/2-hour period at the end of the work shift.

   These findings indicated the following :

   1) It takes about 1/2-hour for the worker to regain his skill to apply the correct pressure on the stroking pad after any rest period ; and

   2) Work fatigue at the last half hour of the work-shift makes the worker lose his "touch" of the machine.

f. The Industrial Engineering Department recommended the acquisition or fabrication of a panel sanding machine which can apply uniform pressure of the sanding belt on the panel surface regardless of the condition to work of the machine operator, both physically and mentally.

4. Options Available

The following options were found available :

a. Import, install and operate a double wide-belt sander, with feed mechanism and the necessary sanding belt pressure control at a total cost of US$9,500.00.

b. Design and fabricate the special sanding machine in the company's machine shop at a total cost of US$9,750.00, operational.

c. Design the machine at the company's Engineering Department and have it fabricated by a local machine shop and then installed by company personnel, at a total cost of US$9,500.00, operational.

5. Value Analysis

a. Option 4 (a) will take 6 months from date of placing an order for the wide-belt sander to put it in operation, or an additional loss of US$3,046.50, before the veneer "sand-thru" problem is solved. The machine will also require an additional worker at the panel discharge end of the machine. However, the skill required of the working feeding the machine will be less. The machine is expected to completely solve the "sand-thru" problem. The sanding capacity will be increased 400% of the current output.

b. Both Options 4 (b) and 4 (c) will take 60 days to put in operation and are expected to reduce the reject rate at levels below 1%, all minor repair rejects. Only one worker is required by the machine in the two Options. Sanding capacity is expected to increase 150% of current capacity. The skill level required of the machine operator is two levels below the present operator.

The economic aspects of the proposed solutions are reflected in the following comparative tabulations :

Item	Option 4 (a)	Option 4 (b)	Option 4(c)
Costs : (Based on 5 Years Depreciation Period			
Machine Acquisition and Installation Costs ————	US$ 9,500.00	US$ 9,750.00	US$ 9,300.00
Production Labour Cost ————	6,200.00	3,100.00	3,100.00
Sanding Belt Cost, 5 Yrs. ———	9,500.00	6,500.00	6,500.00
Power and Air Cost, 5 Yrs. ———	4,500.00	2,700.00	2,700.00
Other Maintenance Supplies Cost, 5 Years ————	3,200.00	2,850.00	2,850.00
Total 5 Years Cost ————	US$32,900.00	US$24,900.00	US$24,900.00
Benefits :			
Savings in Repair and "Dead Cull" Losses due to Rejects ————	US$ 6,093.00/yr.	US$ 5,077.00/yr.	US$ 5,077.00/yr.
Total Value of Materials Savings in 5 Years ————	US$30,465.00	US$25,385.00	US$25,385.00

6. **Pay-back Period**

To check if the proposals comply with company policies requiring a maximum of two years pay-back period for such projects, the following pay-back periods were obtained :

	Option 4 (a)	Option 4 (b)	Option 4 (c)
Pay-back Period	1 year - 7 months	23 months	23 months

7. Maximum Allowable Investment for the Project

$$I_{max} = \left[\frac{nN}{1 + \frac{i}{200}\ (n + 1)} \right] \left[\left(\frac{Q_2}{Q_1} - 1 \right) \left(m + w\ \left(1 + \frac{P}{100}\right) + V_1 \right) + \left(V_1 - V_2 \right) \right]$$

where:

I_{max}	=	maximum allowable investment
i	=	current interest rate on money (percent per annum)
n	=	depreciation period (years)
N	=	number of operating hours per year
Q_1	=	current hourly output
Q_2	=	projected hourly output to be produced through the installation of LCA
m	=	fixed hourly machine cost including overhead.
w	=	direct hourly wages
P	=	proportion of indirect labout cost (percentage of w)
V_1	=	variable hourly machine cost at output Q_1

The maximum allowable Investment for the project is computed as follows based on current interest rate of 14% per annum and a depreciation period of 5 years, 310 working days/year.

		Present Sanding Operations	Proposed Sanding Operations
Q =	hourly output	23 panels	25 panels
m =	fixed hourly machine cost including overhead	US$0.295	US$0.30
w =	direct hourly wages	US$0.30	US$0.23
p =	proportion of indirect labour cost to direct labour	35 %	35 %
V =	variable hourly machine cost	US$0.97	US$0.83

$$I_{max} = \left[\frac{5 \times 8 \times 310}{1 + \frac{14}{200}(5 + 1)} \right] \left[\left(\frac{25}{23} - 1 \right) \left(0.30 + 0.3\ (1 + 0.35) + 0.97 \right) + (0.97 - 0.83) \right]$$

$$= \underline{\text{US\$17,034.72}}$$

The actual net investment is the Project Cost less the re-sale value of the stroke sander which is :

For Option 4 (a)	US$9,500.00 -	US$4,800.00 =	US$3,700.00
" " 4 (b)	US$9,750.00 -	US$4,800.00 =	US$4,950.00
" " 4 (c)	US$9,300.00 -	US$4,800.00 =	US$4,500.00

Hence, all three Options were well within the limits for Maximum Amount of Investment allowable for the Project.

8. Management's Decision

An inquiry from the Central Bank on current regulations covering opening letters of credit for the importation of machinery brought out a recently enforced circular requiring a deposit of 50% of the face value of letters of credit. The value of money to the company is about 20% per annum. Hence, inspite of the apparent economic advantage of Option 4 (a), as illustrated in the preceding sections, the actual Project Cost for Option 4 (a) will be increased by the money the Company could make on the amount deposited for opening the letter of credit, if the amount deposited were available for the company's disposal for the sixmonth period, which would be about US$475.00. Hence, the actual investment in Option 4 (e) would be US$9,975.00. Thus, management narrowed down the choice between Options 4 (b) and 4 (c). The difference in Project Cost is US$450.00 in favor of Option 4 (c). However, Management felt that this is a small amount if weighed against the opportunity of his engineering personnel to learn how to automate machines in the factory. Thus, Management decided to implement Option 4 (b).

Figures 34 and 35 illustrate the LCA solution under Option 4 (b).

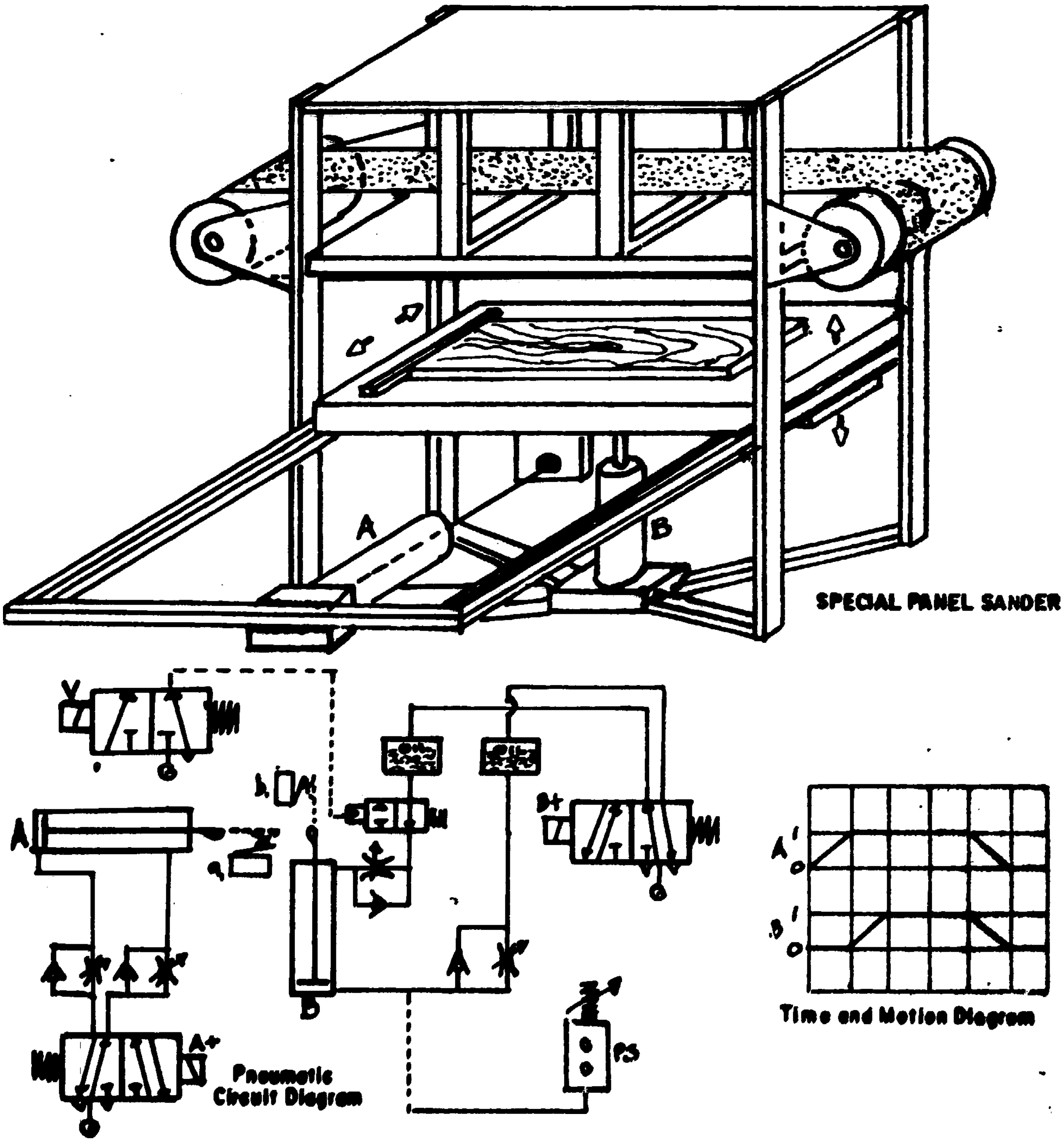


FIGURE 34

LCA SOLUTION TO SANDING PROBLEM AND CORRESPONDING TIME – MOTION DIAGRAM

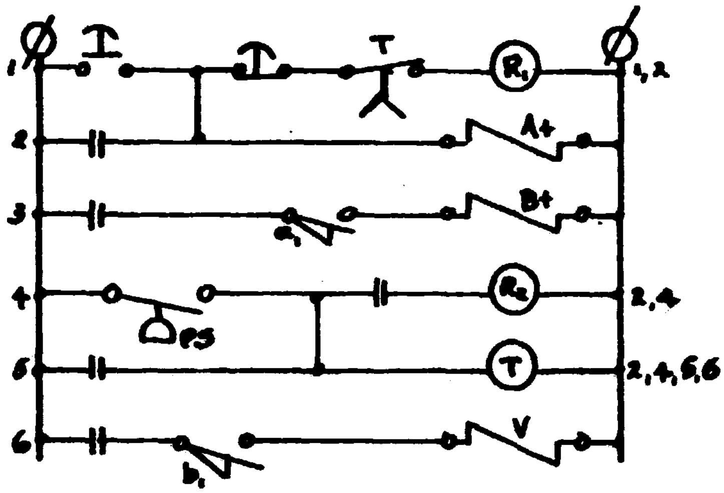


FIGURE 35

ELECTRONIC CIRCUIT DIAGRAM OF
SPECIAL PANEL SANDER

C. THE CASE OF THE FILLING LINE CREW

1. Situation

The filling line of the Finishing Department of a panel-based furniture factory was manned by 8 men, including the filler sprayer. Current output was 120 panels per 8-hour with acceptable filling job. Management insists that the filling line can be manned by at most 5 workers including the filler sprayer, if some method can be developed to speed-up the filler padding phase of the operations. The Engineering Department was directed to solve the problem immediately.

Note : The filling operations is summarised as follows :

a. Spray filler mixture on panel surfaces and edges, 1 man needed ;

b. Allow filler to flash-off, no men needed ;

c. Massage or pad filler by hand, three men ;

d. Wipe excess filler off the filled panel, 2 men ;

and

e. Inspect filled panels and repair/touch-up when necessary, 2 men.

2. Problem

Determine the bottleneck in the filling line and formulate a solution to erase the bottleneck.

3. Technical Analysis of the Problem

The Industrial Engineering Section conducted a ime and otion Study of the line operations and found the following areas of low output :

a. The filler massaging/padding operation ; and

b. The excess filler wiping operations.

Experiments showed that the most effective pore-filling action was given by the combined padding and shearing motion of a medium-hard felt pad material over the wooden surface to be filled. The shearing action generated by passing the workers' palms in a circular motion across the panel surface was not enough to push the filler pigments deeper into the pores of the panel surface. Consequently, the panel surface was loaded with excess filler which became hard to wipe off the surface once the filler started to set. In their efforts to clean the panel surface properly, the filler wipers unintentionally dislodged some of the filler particles out of the filled pores. Thus, about 40% of the panels were sent back to the filler sprayer to be done all over again.

4. Options Available

a. Import a filler rotary padding machine at a total cost of

US$450.00, installed and operational. This option was expected to reduce the filling line crew to 5 men and increase the filling output by 30%.

b. Fabricate a portable, air-operated rotary filler padding device at a total cost of US$480.00, installed and operational. This option is expected to reduce the filling line crew also to 5 men and increase the filling output by 25%.

5. Value Analysis

The imported rotary filler padding machine could be put operational six months from date of order, while the locally made machine could be put in operation within 60 days. The difference in cost was only US$30.00. Management could not wait for 6 months to save US$30.00. Instructions were given to the Engineering Department to proceed with the design and fabrication of the rotary filler padding machine.

6. Maximum Allowable Investment for the Project

For record purposes, the Engineering Department went ahead with the calculations for the economic justification of the proposed machine. The maximum allowable investment for the project was calculated as follows :

i = 14% per annum
n = 3 years
N = 310 days x hours/day = 2,480 hours/year
Q_1 = 120 panels/day = 15 panels/hour
Q_2 = 150 panels/day = 18.5 panels/hour
m = 0, since no machine is currently being used
w = US$0.30/hour, the average direct hourly wages of the filling line crew
p = 35%
V_1 = US$0.18/hour
V_2 = US$0.26/hour

$$I_{max} = \left[\frac{3 \times 2,480}{1 + \frac{14}{200}(3 + 1)} \right] \left[\left(\frac{150}{120} - 1 \right) \left(0 + 0.30 \left(1 + \frac{35}{100}\right) + 0.18 \right) + (0.18 - 0.26) \right]$$

$$= \underline{\underline{US\$4,126.88}}$$

The estimated project cost of US$480.00 is well below the maximum allowable investment for the Project.

7. Pay-back Period

Again, for record purposes, the pay-back period was determined as follows :

Costs (3 Years)	Present	Proposed
Machine cost, as installed and operational ----------------	-----	US$ 480.00
Direct labour cost ----------------	US$2,332.00	US$1,395.00
Power and air cost ----------------	840.00	970.00
Supplies and spare parts cost -----	-----	220.00
Administrative cost ----------------	1,166.00	698.00
Total cost ----------------	US$4,338.00	US$3,763.00

Net savings : US$4,338.00 - US$3,763.00 = US$575.00/ 3 years or

US$191.67/year

Pay-back period : $\frac{US\$480.00}{US\$191.67} = \underline{\underline{2.5 \text{ years}}}$

8. Management's Decision

Management gave more weight to the small value of investment involved and waived the company policy setting 2 years as pay-back period, for this particular project. It further confirmed its initial decision to go ahead with the fabrication of the rotary filler padding machine.

Figure 36 shows the design of the padding machine and the pneumatic circuit involved.

IV. S U M M A R Y

This paper attempted to present situations in a panel-based furniture manufacturing plant which could be possibly automated to advantage. It has also made suggestions on some accessories which may prove useful in the design of automated system. Time and space did not permit the discussion of more examples. However, it is felt that the three illustrative examples given in Section III of this paper, together with pointers on automation given during the analysis of some of the stages of the manufacturing operations will help the reader realise that there are benefits to be gained from LCA, provided the decision to automate is based on factual analysis of the problem at hand.

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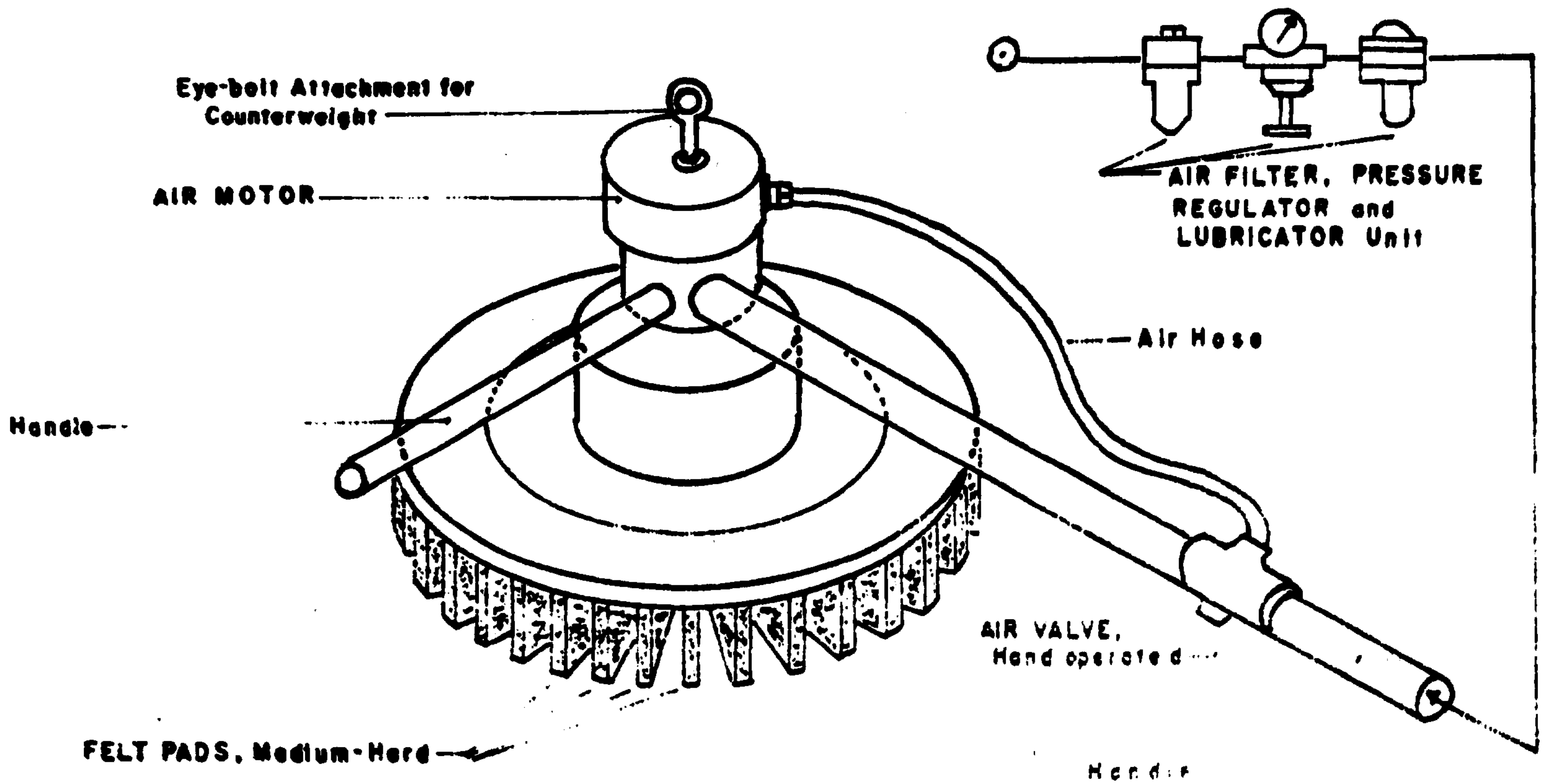

FIGURE 36

ROTARY FILLER PADDING MACHINE

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