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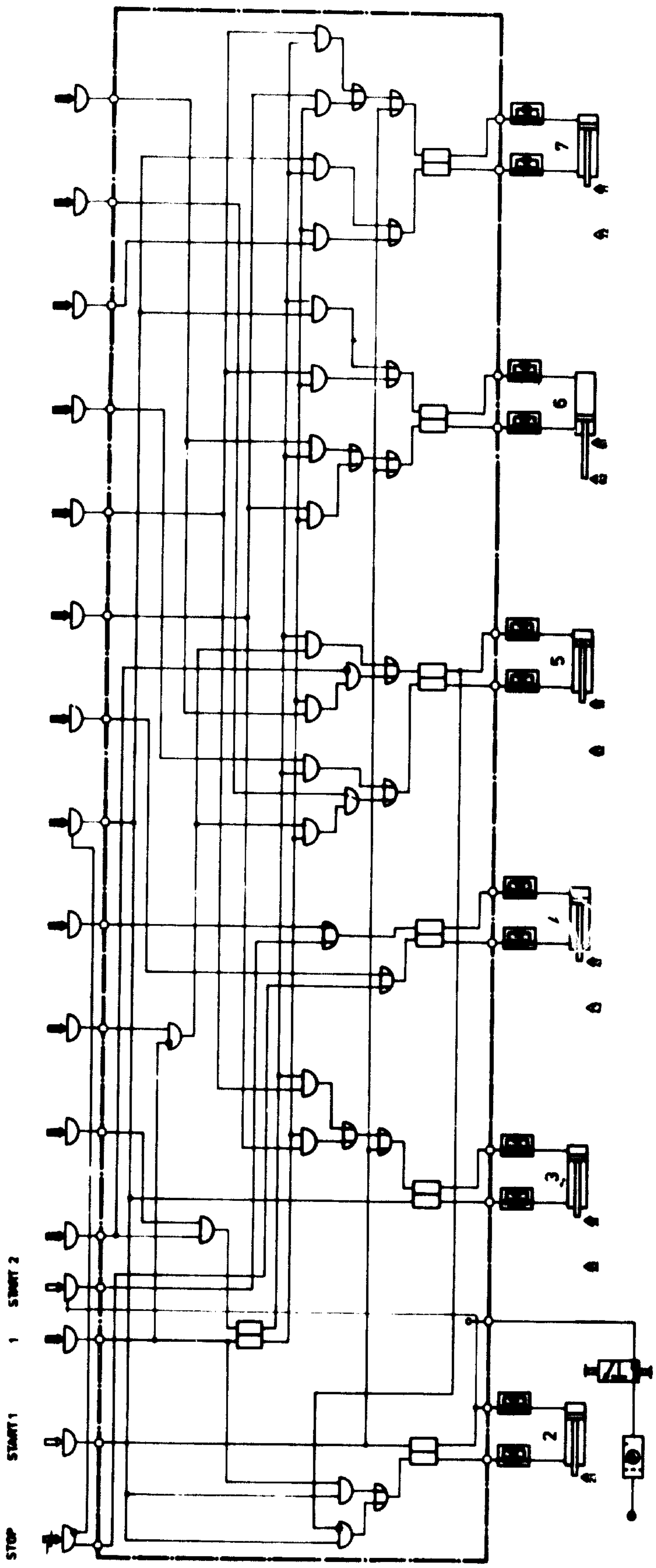

Pulsator Testor Schematic

Fig. 3.1

2.1.1 Costing

			DM
a)	1 old (6 years old) mortising machine (≈ 5000,- DM new value)	Current value	2.500
b)	Designing time for modified machine	121 hours	
c)	Preparation of machine		6.650
d)	Pneumatic fitting		3.740
e)	Assembly time for the pneumatic control system	78 hours	
2.1.2	Purchase price of new special machine	estimated	27.000
2.1.3	Prior production work time	12 sec. per slot	
	Current production time	3 sec. per slot	

2.2 Another example shows application of pneumatics to a belt sanding machine

Object of exercise is to extend the working life of the sanding belt and to produce a "super finish effect" on the work piece. By imparting an oscillatory movement to the sanding belt loose sand particles are more readily removed. Continuously variable adjustment of the oscillatory movement is desirable and is dependent upon grade of sanding belts in use.

Sanding belts of up to 2000 mm wide are used in the furniture industry and the oscillatory movement must be applied in a direction at right angles to the motion of the belt.

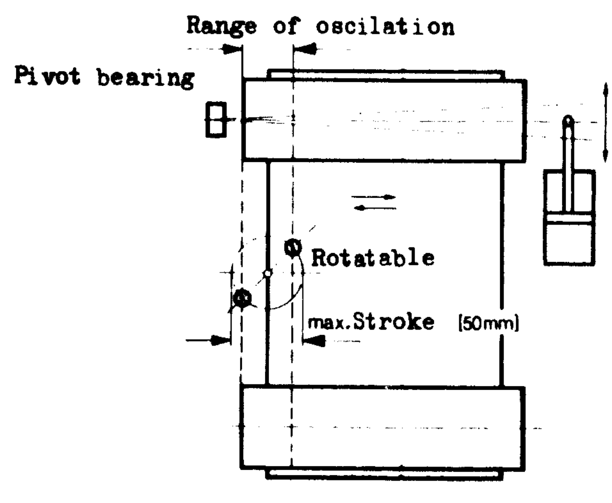

Fig. 4

Various manufacturers of wide belt sanding machines have adopted differing techniques and methods for the oscillatory movement. Pneumatic systems are in general widely used for this purpose, whereby a pneumatic cylinder is used to move the axis of a belt sander roller at one end, about a pivot center at the opposite bearing, thus forcing the belt to move over to the left or right on the roller.

When the cylinder pushes the roller upwards, the sanding belt moves to the left and when the cylinder pulls the roller axis downwards, it moves to the right. Continuous to and fro operation of the cylinder thus causes an oscillatory sanding action in conjunction with the spead of sanding belt.

In one example of such a machine the pneumatic control system used a high pressure air nozzle for sensing the position of the belt. The nozzle with a 2 mm opening being mounted under the belt, movement of the belt covers and uncovers the jet from the nozzle thus producing a control signal to move the roller axis setting. The jet of air from the nozzle was sensed in a spoon shaped collecter and directly operated a four way pneumatic spring return type valve which in turn controlled the cylinders acting upon the roller axis.

The oscillatory movement of the belt then covered the nozzle again, the spring return four-way valve returned to its original position, till the nozzle was once again uncovered. Oscillations are in this way dependent upon the whole inter-play of belt movement and speed, roller position (alignement) and nozzle. With an air supply of six bars as required for satisfactory operation of the four-way valve 360 l of air was required per minute. This high rate of air consumption was the reason for wanting to change the control system to a low pressure operating system.

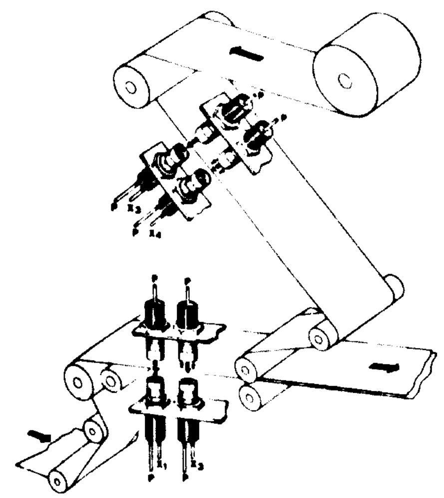

Fig. 5

Sensing of belt edge position with low-pressure air barrier and nozzle sensors.

A double belt system is shown here with two low-pressure air nozzles and sensors for each belt. One sensor is set such that the low-pressure air jet reaches its sensor beyond the edge of the belt and produces a signal. The second one is set further in the distance between the two positions provides a deviation for the belt edge position and could be some tenths of a milimeter to say a couple of milimeters. Air flow to the second sensor is interrupted by the belt. Therefore, no signal is present from the second sensor. When the belt moves too far to the right then the air jet from nozzle 2 will reach sensor 2 and a signal will also be given from sensor 2.

We will now have two signals which through an "and" gate and control system alter the roller setting so as to move the belt back towards the first nozzle. Similarly should the belt move too far to the left then the air path to the first sensor is interrupted and both reset in the oposite direction to move the belt back to the right.

We, therefore, have the following signal sequence:

Sensor 1	Sensor 2	Roller axis movement
1	0	0
1	1	+ 1
0	0	- 1

The distance between the two sensors near the edge of the belt determines the range or amount of the oscillatory motion of the sanding belt. By altering the distance between the two sets of nozzles and sensors it is possible to alter the amount of the oscillation. By mounting both sets of nozzles and sensors on a rotatable plate, one can easily adjust the amount of oscillation by simply rotating the plate thus achieving a continuously variable facility. A 0 - 50 mm max continuously variable oscillation range was achieved on the machine here described.

The newly installed pneumatic control system allows the precise presetting of required amount of oscillatory motion. Low-pressure nozzle and sensor elements in addition drastically reduce the compressed air requirements and energy consumption. They require a working air pressure of only 0.2 bar normally, in this application, however, a working pressure of 0,5 bar was chosen to ensure immunity from any influence from the strong suction currents of the built-in suction cleaner.

With a nozzle width of 1,5 mm and pressure of 0,5 bar some 50 l/min of air is required. This is only 14 per cent of earlier consumption i.e. a saving of some 86 per cent of compressed air requirements. Sensors and nozzles are mounted on the main machine frame. Other pneumatic control system elements are mounted on a panel and fixed to the machine, on this panel are mounted all elements including the low-pressure regulator filter and gate valves etc. Energetic moving parts of the control system are mounted in the machine frame. Two sanding belts of different grades are controlled on the machine. The cylinder strokes required are quite short as only a slight alteration of the roller axis is necessary.

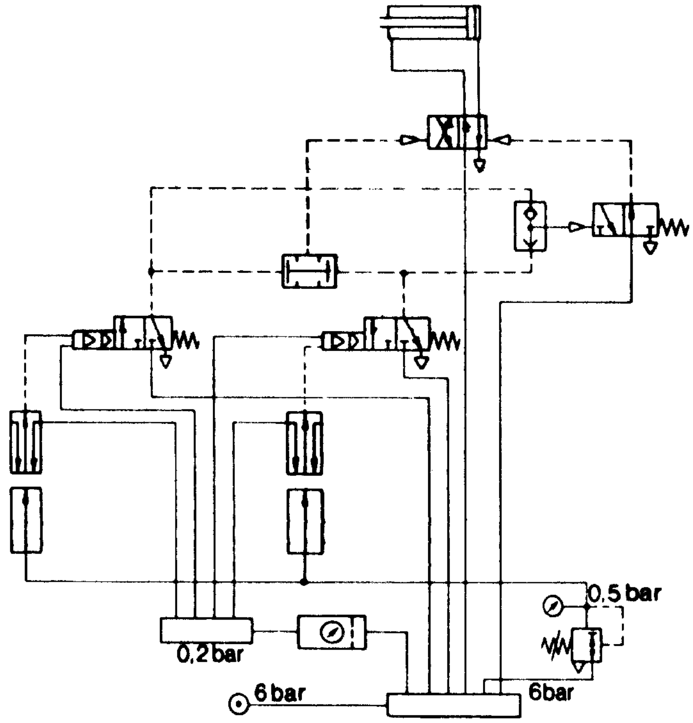

Fig. 6 - Circuit diagram of the pneumatic control system

The basic control elements are duplicated for each controlled roller. In the works where this modification was carried out eight such complete systems were installed and since 1974 have been operating trouble free at a rate of some 30.000 operations per working day. The extent of saving of compressed air:

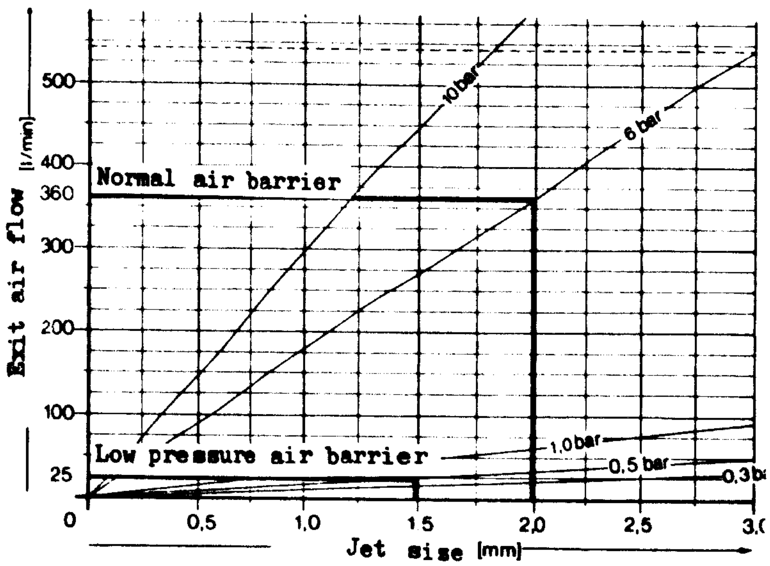

Fig. 7 - Air consumption versus pressure for various jet sizes.

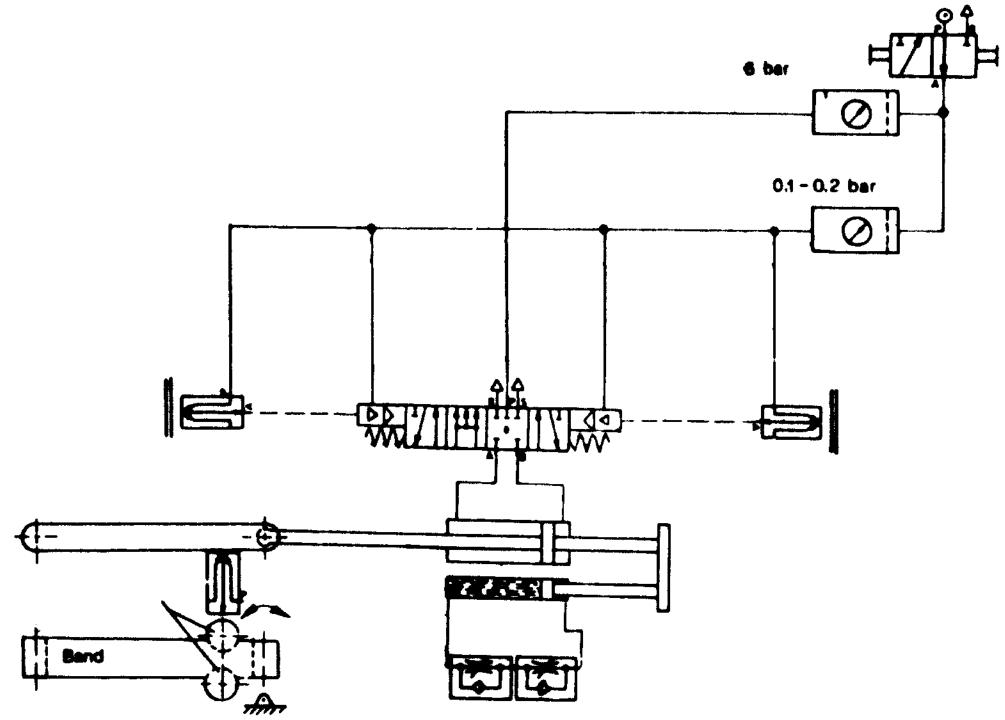

Fig. 8 - Another variant for belt sander oscillation control.

2.3 Further examples will illustrate the range of possible simple ideas that can be applied in low-cost automation

Automatic press clamp and drilling jig

This special purpose machine was designed for glueing together the parts of drawers and at the same time for boring the holes required for the lock. Various clamping programms can be selected by the hand operated program selector knob. Program start signal is initiated by means of a foot operated pedal valve.

Five electro pneumatic drilling plus feed attachments are provided and controlled pneumatically. The drilling attachments can be adjusted and preset in any position and can also be fitted out with multi-splindle heads.

Glueing and clamping of the drawers is done in a frame clamp. Five pneumatic cylinders are provided for holding and clamping together with two cylinders providing a positioning function.

The special machine is used for rationalised production in small series manufacture but could also be used to advantage for larger scale mass production runs. Assembly times are short and presetting or programming of the machine is easy and quickly achieved.

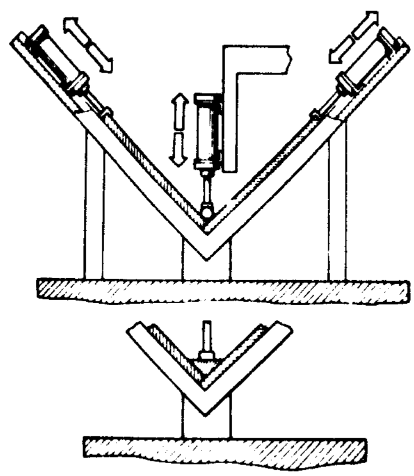

Fig. 9 - Jig used for corner jointing

In woodworking the tool heads, milling, mortising, boring, sanding etc. are normally electrically driven whilst other functions such as clamping, drive-feed, positioning, transport etc. in pneumatically operated equipment are achieved by means of pneumatically operated cylinders. This is the case here for all given examples of milling machines.

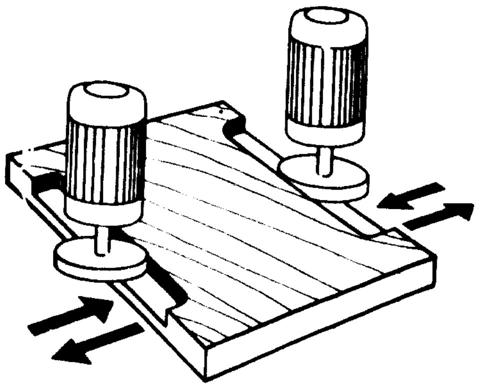

Fig. 10 - Double-sided profiling.

In this machine the work piece is carried forward to the work positions on an in-feed bed and both sides can be profiled simultaneously. Double acting pneumatic cylinders are used to position the profiling cutters to bring them into position and withdraw them. Fig. 10 indicates with arrows the directions in which the pneumatic cylinders move the profiling cutters.

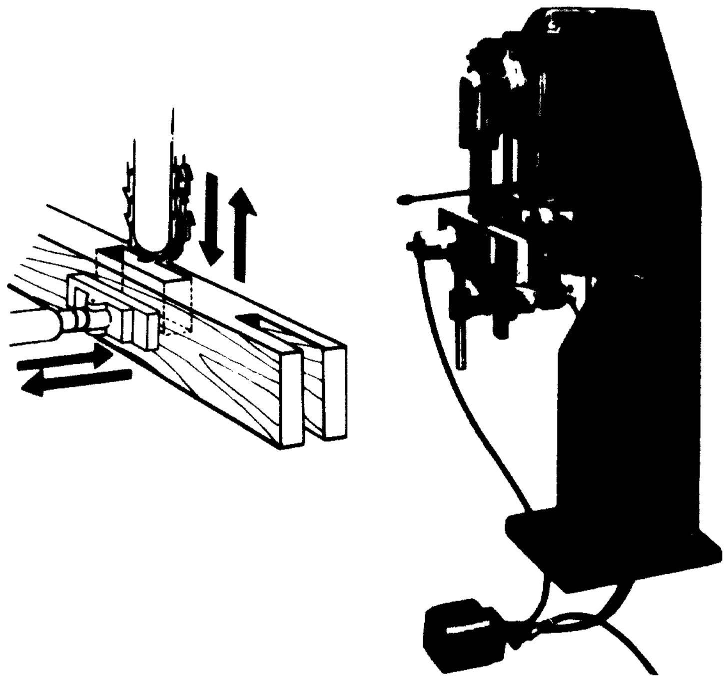

Fig. 11 - Chain mortiser.

The chain mortising machine is controlled by a pneumatic foot pedal allowing the operator both hands free for locating the work piece. The foot pedal initiates operation of the spring return single acting clamp cylinder as well as the double-acting feed drive cylinder controlling the chain milling head. Feed-rate is readily adjustable by means of a speed regulating valve.

Pneumatic control system of the corner locking and finger jointing machine is functionally similar to that of the chain mortiser. A fixed mounted rotating cutting head is employed and the work pieces together with the work table to which they are clamped rise and fall. The work table automatically returns to its rest position after each work cycle and the clamp cylinder releases. The next work cycle is again restarted by the foot pedal.

The usually flat and cubic shapes of work pieces in woodworking lend themselves readily to gravity hopper feed. Stocked boards or blocks lend themselves readily to hopper feed.

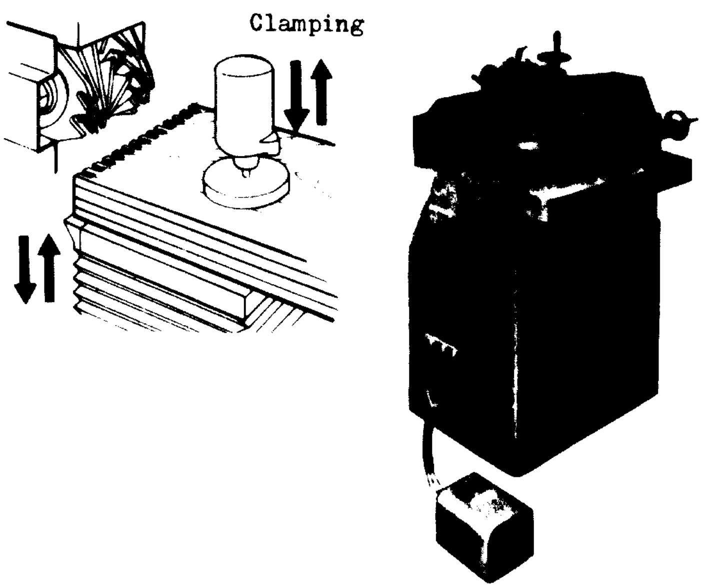

Fig. 12 - Corner locking and finger jointing machine.

Work pieces loaded into a chanel frame can very easily be fed one by one automatically to a machine and fed in for machining.

In a vertically loaded hopper workpieces can be added as required from above where gravity alone will hold them down in position and the ejector mechanism (air cylinder usually) can automatically feed them individually to the machine position Fig. 13. Single stack vertically loaded hoppers are more general as dictated by the larger work piece sizes. Hopper size (number or work pieces held) depends upon machining speed (parts per unit of time). For smaller work pieces multi-stack hoppers can be constructed allowing for higher rates of production with reasonable time intervals for restocking the hopper (Fig. 14). Multi-stack vertical stores also allow a larger number of pieces to be stored in a given height of the hopper. Some machines may require a hopper which is capable of feeding work pieces from the top of the stack (Fig. 15). This will require some means of moving the pieces upwards. Such a construction does not readily lend itself to refilling during operation of the machine. A number of hoppers are then necessary which can be filled separately and then brought to the machine to replace empty hoppers.

Movements and positional changes

All fixtures or attachments for the feeding or positioning of workpieces imply movement and change in position. These include such items as conveyors, feeder units, drive units and embrace a large number of diverse individual mechanisms and devices. Conveyor belts, conveyor chain - roller beds or slideways will not be discussed here as these are normally purchased complete.

Some idea of the range of pneumatic fixtures and facilities that can be provided or built on to machines can be obtained by looking at existing products and state of the art. Sketches will show some pneumatically operated equipment grouped together according to three functions.

The operations of feeding-in and distribution generally also implies the further function of separation.

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Distr.
LIMITED

ID/WG.296/2
26 March 1979

ENGLISH

United Nations Industrial Development Organization

Seminar on wood processing industries

Cologne and Hannover, 16 - 30 May 1979

CALCULATION OF PNEUMATIC SYSTEMS FOR FURNITURE AND JOINERY INDUSTRIES *

by

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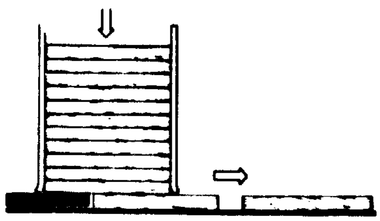


Fig. 13

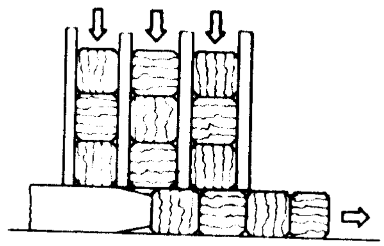


Fig. 14

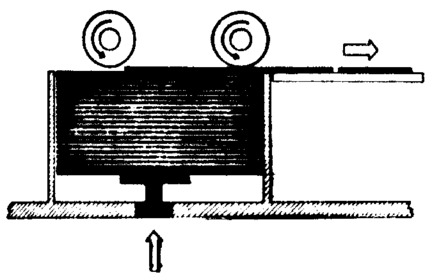


Fig. 15

Hopper feed systems

Seperation or selection is usually combined with the feed-in function and often the same device simultaneously performs both operations. Machining of separate piece parts (as against continuously fed long stock) are fed-in one at a time as the machine generally can only machine individual pieoes or in some special cases a group of pieces when held together. Selection and feeder action is combined in stack hoppers where the principle of operation is the same irrespective of general construotion. Pieces are stacked one on top of another and the lowest or upper most pieoe as may be required is selected and pushed out when called for. The pneumatic cylinder to which is attached an appropriately shaped and length of ejeotor arm operates in rythm with the machine cyole pushing out and feeding in a work pieoe as required. The operation cycle is usually set and originates from the machine that follows the hopper. A start signal can simultaneously be given to start other related operations.

Command signals can also be initiated by a chain link in a chain driven oonveyor whioh carries the work pieoes to the machine. Cycle sequenoe oan thereby also be a funotion of time.

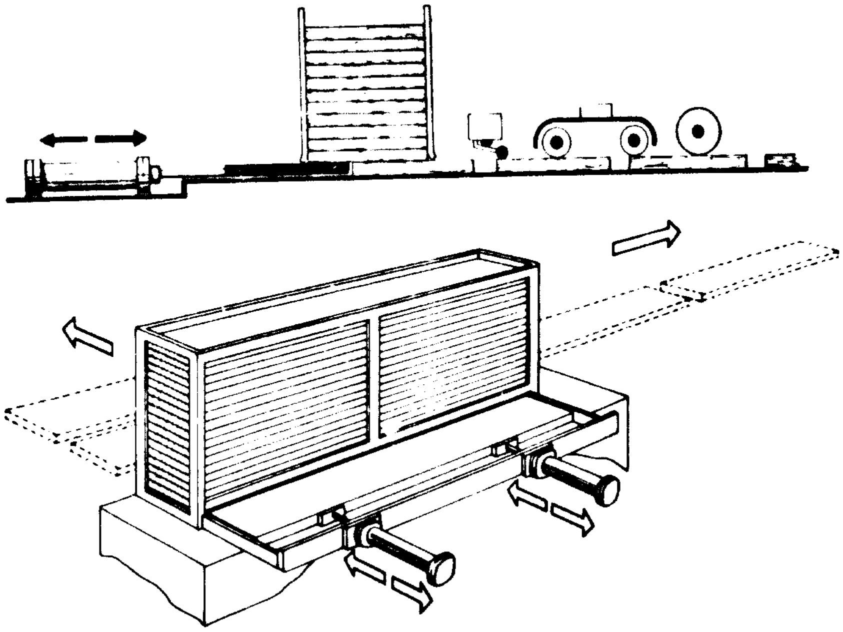


Fig. 16 - Stacked hopper with pneumatic ejector along shortest axis. Additional optional feed-in motion could also be provided along length axis.

For work pieces with a side relationship ration greater than 1 : 3 it may be better to arrange for the work pieces to be ejected along their shorter axis. Where the work piece surface is smooth, it may still be possible to push it along its longer axis particularly when not too many pieces are stacked on top. When ejection of the lower workpiece against the friction and weight of others stacked on top may be problematical then ejection along the shortest axis may be better even when a further direction ohange by means of a further fixture is necessary.

Two or more pneumatic cylinders can also be used together, instead of 1 large one, for extra large or heavy pieces. The choice of one or more cylinders depends upon various factors and a detailed study of a given application and the corresponding selector mechanism is often necessary to decide upon the most apt configuration. Other details to consider are tolerances and range of movement required, various mounts swivel joints fork ended couplers are available for cylinders to suit mechanical construction adopted and to allow suitable flexibility in the coupling.

Longitudinal ejectors naturally require a longer stroke pneumatic oylinder and more space. The cylinder can be mounted so as to eject from the right hand side or left as preferred or if necessary to pull instead of push.

In the latter case, the pulling arm and the cylinder will need to be mounted under or above the stack.

Feeder units of this sort with a single stroke length of up to 2 m for various functions are well established.

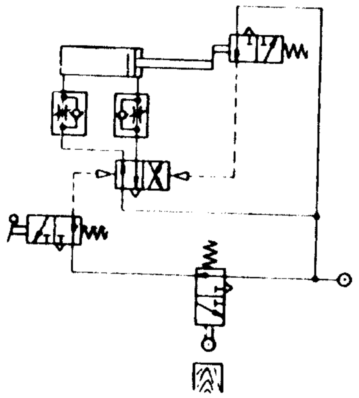


Fig. 17 - Cylinder feeder control

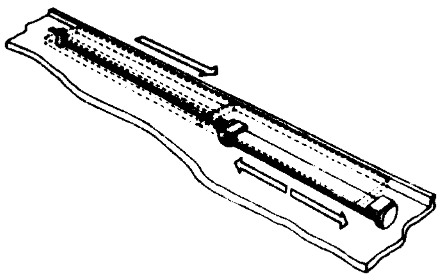


Fig. 18 - Selection and ejection lengthwise

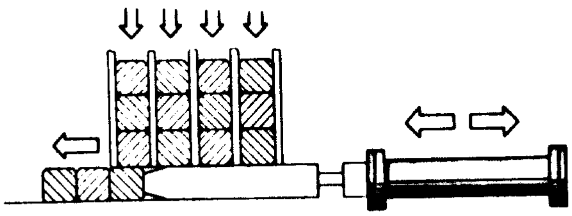


Fig. 19 - Multi-stack hopper with pneumatic cylinder pusher. Ejector construction and operation similar to standard stack or gravity feed store hopper but with multiple work piece delivery.

Multi-stack storage hopper: Pneumatic cylinders can also be used for selecting and feeding workpieces from these but the construction and principle of operation, number of cylinders will vary, dependent upon whether work pieces are called for individually or in batches.

Cyliner stroke is selected to match the total length of the stack hopper (Fig. 19) in this construction normally as many pieces as chanels provided are fed out each stroke, in Fig. 19, 4 are shown unless some chanels are empty. Additional external means of control can, however, be provided to limit the number of blocks (work pieces) pushed out to one or more as may be required. A simple way of achieving this when workpieces are led on to the machine at right angles to the stack hopper ejector feed axis is by means of a guide rail stop set as required to one or more blocks wide.

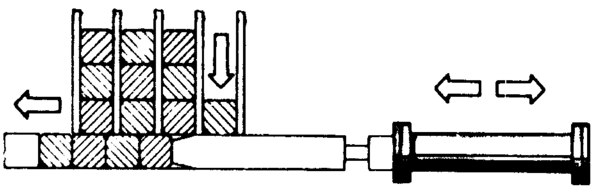


Fig. 20

The cylinder always starting from its fully withdrawn position pushes out one block to the stop rail per cycle down to the last block irrespective of the stack order.

A multi-stack-hopper has certain advantages where the time interval between refills is irregular due to its relatively larger reserve capacity.

Provision can also be made for a pneumatic signal to be given to stop operation or give a warning signal etc. when the number of pieces in the hopper falls below a pre-set number. This can be designed and set to suit individual machine requirements.

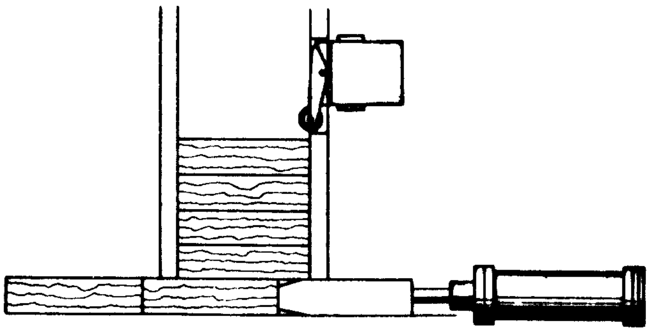


Fig. 21 - Built-in limit switch to indicate when level "pre-set number" in stack falls below a given point.

In the multi-stack hopper of figures 19 - 20, the workpieces are shown with rounded corners, hoppers of this sort should provide a loose fit and the workpieces need to have slightly rounded corners otherwise blocking and jamming can occur.

Where workpieces have sharper corners practical experience has shown that a canted construction as in Fig. 22 is desirable. An angle of just 1 - 3° is usually sufficient to avoid jamming.

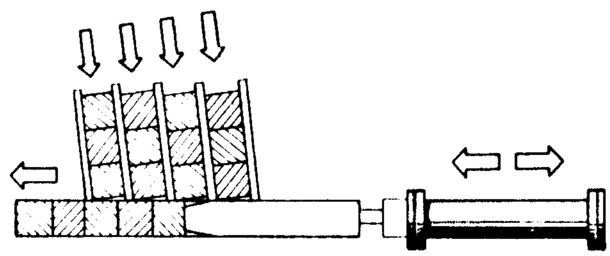


Fig. 22 - Multi-stack hopper construction for sharpercornered workpieces. The stack guides are canted towards the direction of push from the cylinder by some 3° degrees. Thus reducing the danger of jamming.

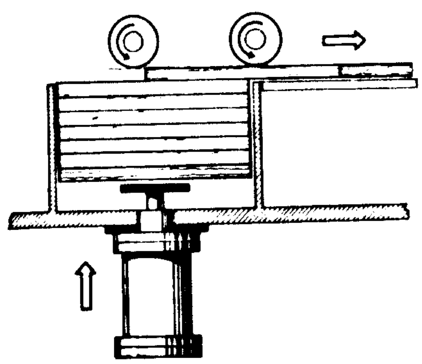


Fig. 23 - Stack-hopper feed-out at top. The pneumatic cylinder holds the stack against the feed mechanism above, air pressure can be pre-set over a wide range to suit requirements refilling from top in-situ not possible.

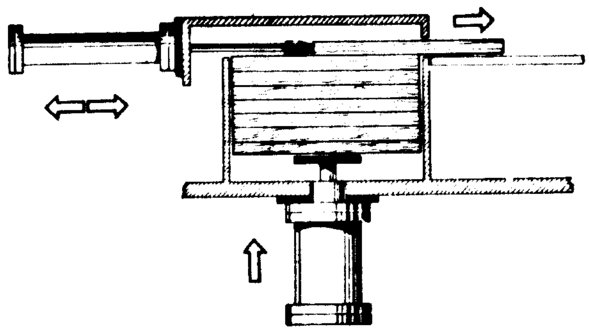


Fig. 24 - Channel/stack hopper feed out at top or side tensioning and push-out by means of pneumatic cylinders.

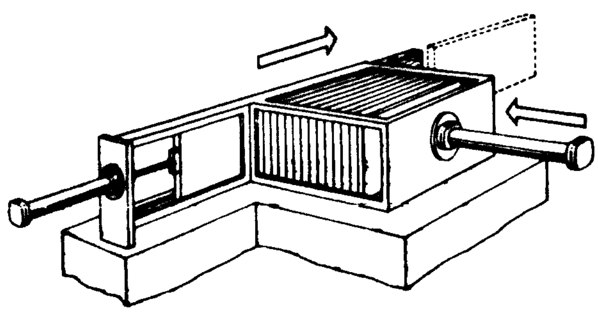


Fig. 25 - Adjustable hopper side feed onto machining bed and end-feed into machining position. Two pneumatic cyliders are used.

Frame clamps are particularly popular in the construction of window and door frames or similar items. The general principle of operation can, however, be adapted to various other production items. The difference only being one of the number of workpieces to be clamped together and of shape. However, one of the most important points is to ensure that various pieces are firmly held together in the frame for the duration of the machine drilling, boring, glueing operation. Fixed form or adjustable frames can be built according to requirements or output quantity. Clamping action is performed by single acting pneumatic cylinders from two sides simultaneously against opposing fixed supports Fig. 26. This is in fact a classic example of a simple frame clamp and can be used vertically or horizontally as required. Horizontal clamps are usually only used for smaller products such as windows, picture frames, furniture parts, door frames, furniture etc. Larger sizes are usually easier to handle in up-right clamps.

3. Applications in the machine building industry

3.1 Pneumatic controls were first used to solve the simplest operations

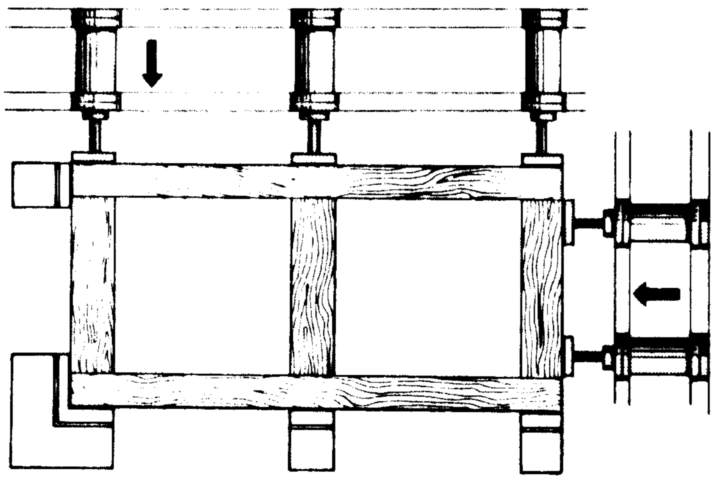


Fig. 26 - Frame clamp which may be arranged standing, inclined or horizontal. The clamping cylinders are adjustable.

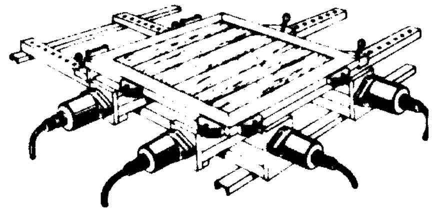


Fig. 27 - Clamping jig with adjustable frame size.

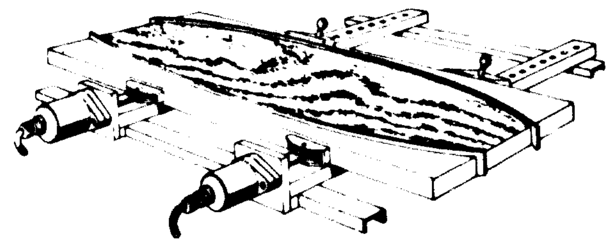


Fig. 28 - Edge lipping press. The width and the shape is roughly fixed by two adjustable fixed stops, clamping is by the two pneumatic cylinders which can be slid freely over the whole length of the press.

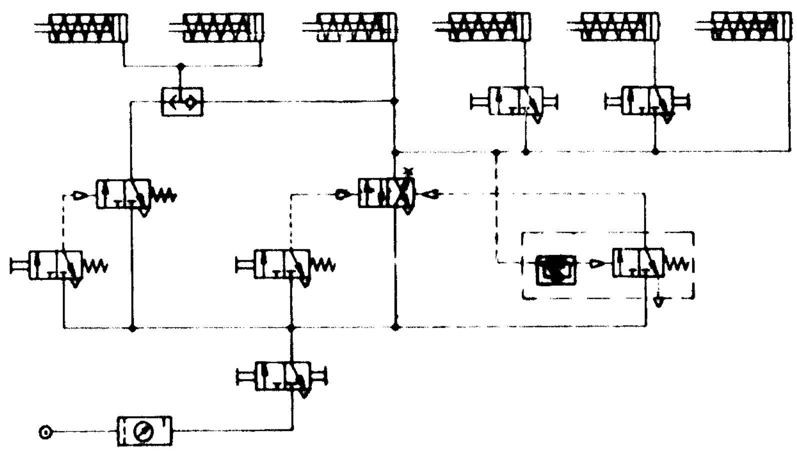


Fig. 29 - Control diagram of the edge lipping press. The two groups of cylinders can be controlled individually or jointly.

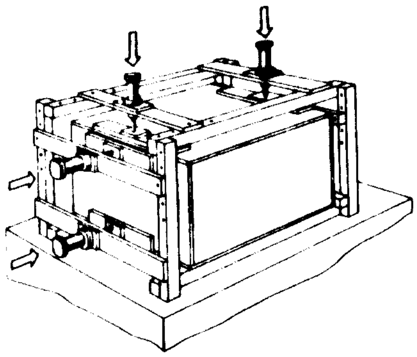


Fig. 30 - Three-dimensional on case clamps can also very easily be constructed to suit individual requirements with pneumatic cylinders and controls. Small and medium scale production runs could find use for such jigs. Adjustable runners can also be provided to accomodate different sizes of products.

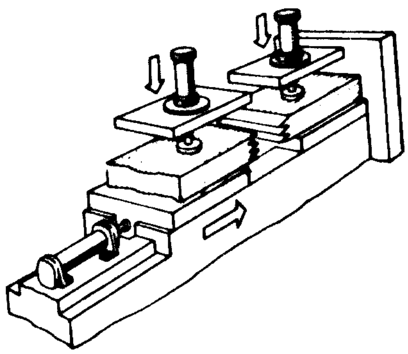


Fig. 31.a - Finger jointing press

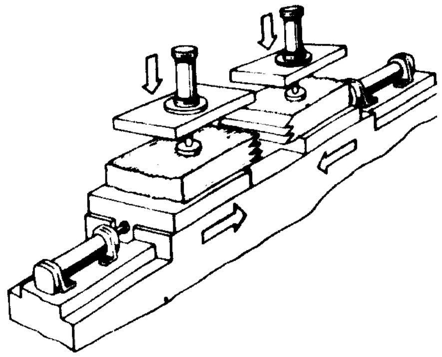


Fig. 31.b - Jointing press for finger jointed pieces. Finger joints one side fixed one side driven (a) both sides driven together (b).

3.2 Multi-functional machine with five clamping devices

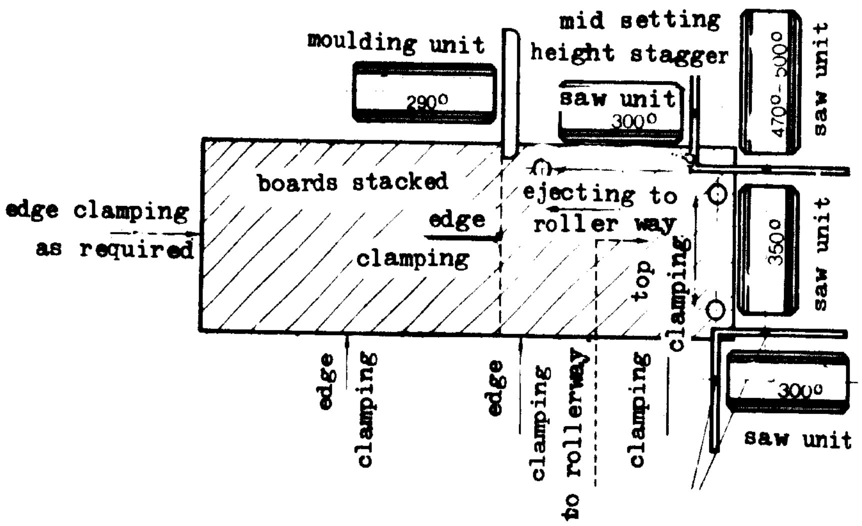


Fig. 32 - The units run at 3000 RPM. Sawing and moulding tools are mounted directly on the motor shafts. Drive and clamping functions all pneumatic.

Contents

Panels can be stacked up to 10 deep for machining and are fed into the machine on a roller bed. When a start signal is given from a two-hand control unit the rollers sink down below the work bed level so that they line-up correctly with the feed in position. Simultaneously the stack is clamped down. Drive motors for the units are at rest positioned below the table and move upwards syncronously to start milling, sawing. At end of operation the pneumatic control system is actuated by means of end stop control valves and returns the units again to their rest position below the table. When all units are once again safely withdrawn and at rest below the clamping is released. Should through any reason any one of the units not completely withdraw to its rest position, the stack will stay firmly clamped on the table.

Sawing cutting operation can be stopped by means of an emergency button whereupon the units all withdraw below the table but without the electrical motors being stopped. An electrical emergency stop button is also provided which stops down everything. Automatic shut down occurs when:

a) power supply fails;
b) any one motor is over-loaded;
c) pneumatic pressure falls.

Costing

a)	Designing time complete machine	158 hrs.
b)	Machine parts building and electric parts	12.185 DM
c)	Pneumatic elements	2.320 DM
d)	Assembly time of pneumatics	69 hrs.

3.3 Pneumatic control of a dowel hole boring machine with four selectable programs

The machine program can be pre-selected from four built-in programs to bore dowel holes in panels. Horizontal and vertical boring units can be mounted on a beam. The distance between, positioning and the number in use can readily be changed to suit requirements.

Workpieces are introduced into the machine by hand and clamping initiated by means of a hand or a foot pedal start valve.

Programme can be pre-selected by a knob on the control console. The four program functions are indicated symbblically on the sonsole panel.

A start button on the console panel then initiates the work cycle driving the boring beam into its boring position. The pre-selected boring program then follows, electric drive motors are also controlled through pneumatically operated AC interuptors. Feed drive from two pneumatic cylinders off set through 90° move the boring beam by means of a compound slide.

When bore depth is reached the borers automatically switch over and withdraw and the beam also moves back to its start position.

The finished workpiece can now be released and removed from the machine.

Control system: all control clamping and moving functions are programed in a fail-safe interdependent manner. The emergency stop will stop the machine at any point in the program and all boring heads will safely withdraw to their fully withdrawn wait position. A clamping fault will automatically shut down the machine.

All connections between the machine and the control console are made through a multipol-connector. The complete pneumatic control system in the console is built separately and delivered ready to work and is very easily connected to the machine. Should any mal-function occur, one can in this case connect a spare console in and send the complete faulty console for repairs. More than 600 such consoles have been produced to date and together with the dowel hole boring machine delivered to all parts of the world.

3.4 Example from a feasibility and costing study for a production machine. Board off cuts made re-usable

A recently developed finger joint cutting, gluing and jointing machine combination - short pieces of valuable wood waste can be processed into useful timber. Waste lengths not smaller than 200 mm long widths between 15 - 125 mm and thicknesses of 8 - 70 mm can be used. The waste lengths are joined together in continuous lengths and can be provided to pre-set lengths for manufacture of window or door frames or other items as required. Production sequences of finger joint cutting, glueing, pressing together cutting to pre-set lengths follow one another continuously.

Finger joint cutting (milling)

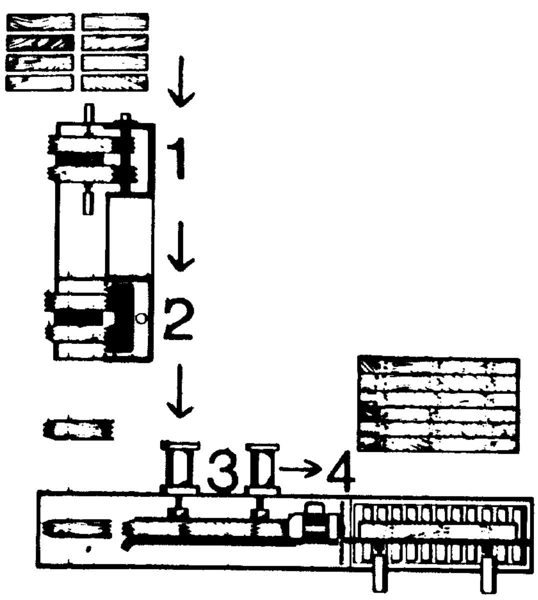
Two workpieces can be milled simultaneously. With table in its upper position two work pieces are fed-in and clamped. The first milling operation takes place with the table moving downwards where the workpieces are removed, turned through 180° and put bask in clamped and the second milling operation takes place with the table moving upwards.

Glue spreading

After milling the workpieces are pressed against the glue spreading die where glue is spread into the fingers. The amount of glue can be adjusted by means of a continuously variable control. A pneumatic pump feeds required amount of glue to the die which transfers this to the workpiece.

Pressing and cutting to length

After glue spreading the work pieoes are fed into the pneumatic press where they are clamped and pressed together. Individual pieces need only be laid on to the machine bed, a foot pedal control starts up the machine cycle. A saw follows the press whioh operates when the workpiece length reaches a pre-set length and actuates a pneumatic valve. After cutting to length the finished piece is automatically ejected by means of a pneumatic oylinder.



1 = Milling
2 = Glue spreading
3 = Pressing together
4 = Cutting to length

Fig. 33 - Finger jointing plant, oonsisting of universal milling machine and press with cross-cut saw. Off cuts can be processed into useful timber starting from 200 mm lengths.

Recommended layouts 1 and 2 man operation

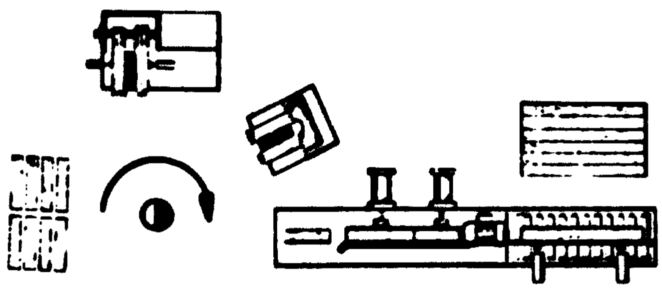


Fig. 34 - Shortest operator movement - 1 operator

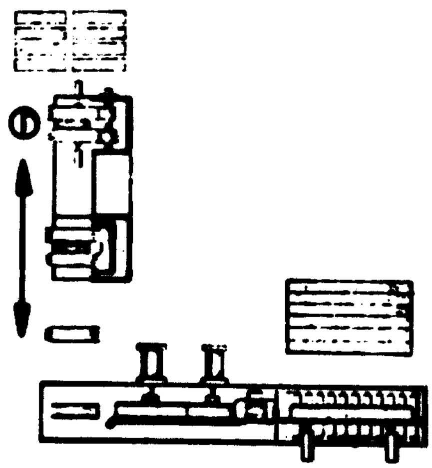


Fig. 35 - Machine layout recommended for space economy - 1 operator

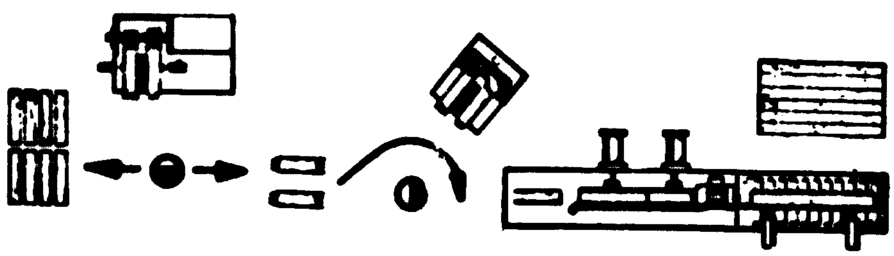


Fig. 36 - Machine layout - 2 operators

Cyole sequence 1

Cycle sequence 2

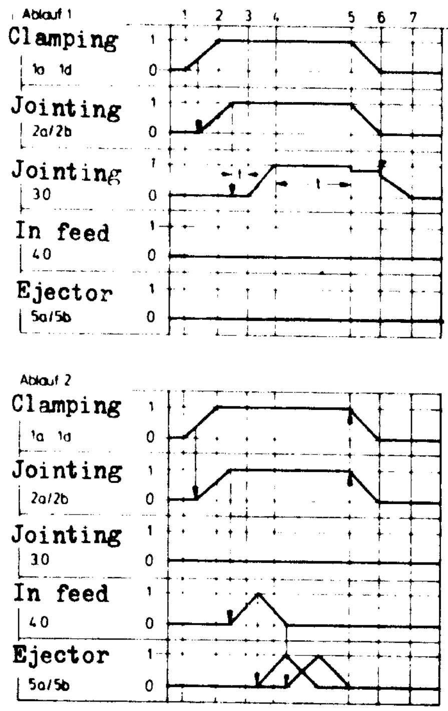


Fig. 37.

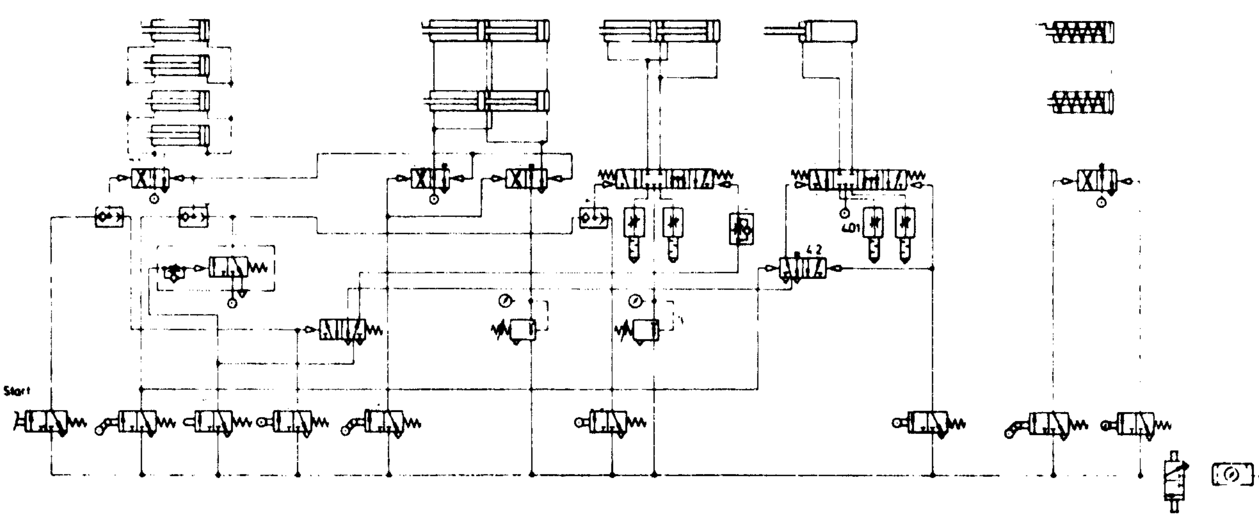


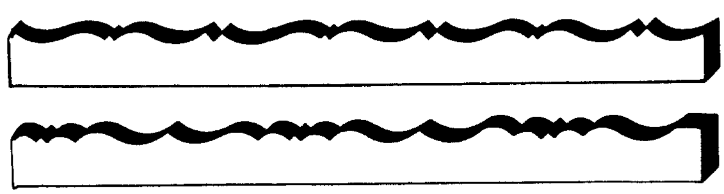
Fig. 38 - Control of finger jointing press and cut off saw.

3.5 Operational sequence of step feeder

Repeated operation to provide a continuous pattern on a work piece can be achieved by means of an adjustable pre-set feeder. Feed length per stroke can be set to a maximum of 200 mm. Several pieces can be machined together up to a maximum height of 100 mm. The feed step position is synchronised to the finger or pattern pitch and can easily be set.

Rational profile cutting (single or double sided) Banister rails, fencing, contoured boards can be machined with a continuously repeating pattern (Fig. 39 - 40).

A continuous pattern can also be built up as shown in this example by first milling along one edge in steps leaving spaces between as shown then rotating the work pieces over 180° to machine out the spaces in between Fig. 41. This produces a mirror image effect and gives a continuous complex pattern with one single tool head.



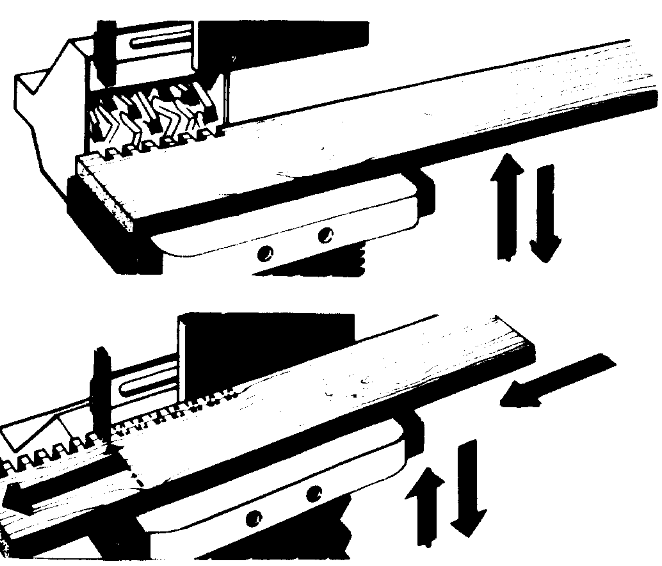


Fig. 39.

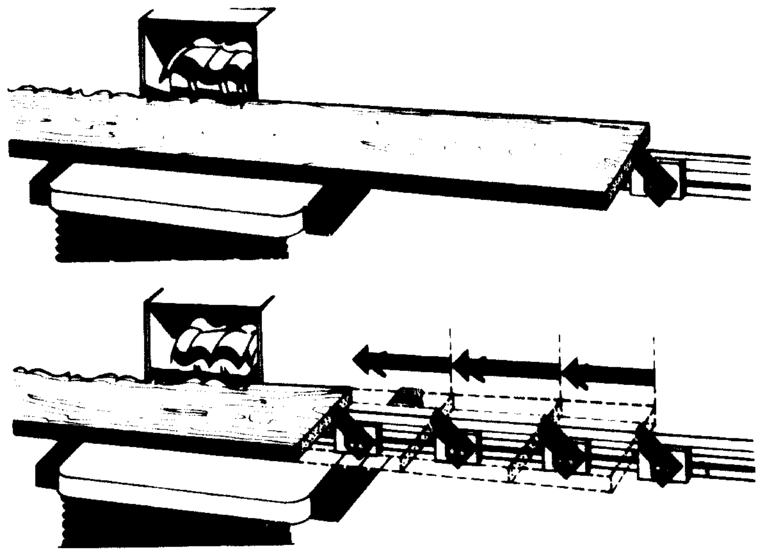


Fig. 40.

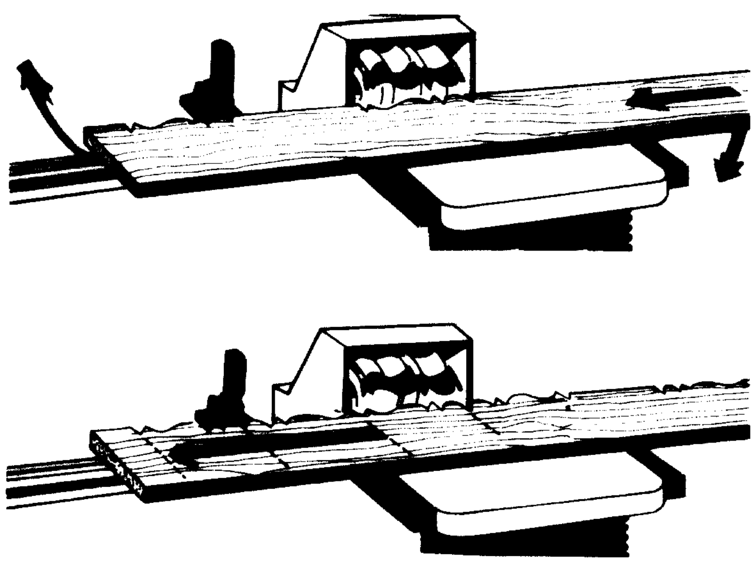
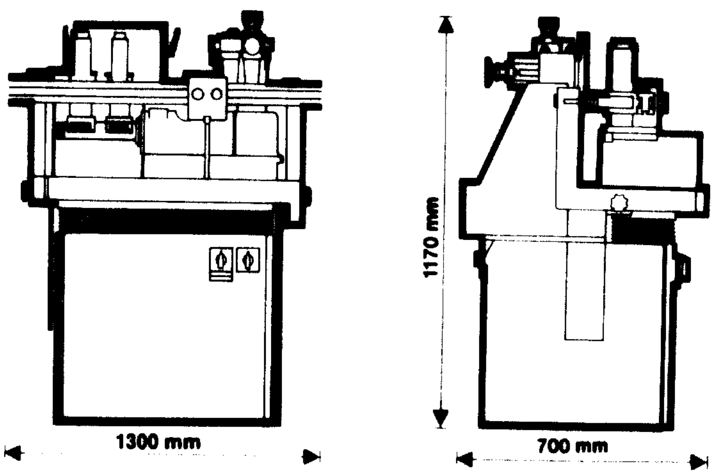


Fig. 41.

The new universal profiler UP can be used for a variety of applications, and in particular for production of styled furniture, transverse machining of profile frames (mitre cutting), for toy manufacture, construction of steps, drawer making (combing), finger jointing etc. Transverse profiling in an axial direction with continuous cycling sequence. Excellent machined finish due to particularly rigid location of the cutter spindle and due to down-feed cutting. Rapid resetting from face-end to longitudinal machining by means of the flexible system of stops. Pneumatic-hydraulic table feed with speed regulation (infinitely variable) and rapid return. Quick tool change by means of hinged clamping attachment. Cyclic working sequence by means of foot valve.



Technioal data

Model	UP 30	UP 65
Ref. No.	691 043	691 04?
Motor rating kW	7,5	7,5
Speed of cutter spindle rpm	6000	4300
Cutting depth max. mm	30	65
Cutting spindle Ø mm	40	40
Tool clamping width mm	200	200
Tool Ø mm	180	250
Cutting speed m/sec.	57	56
Working strokes per minute	3-8	3-8
Working pressure	6	6
Air consumption at 8 strokes l/min	110	110
Workpiece width max. without longitudinal stop	unlimited	
With longitudinal stop	130 + profile	150 + profile
Workpiece height max.	100	100
Machine size (l x w x h) mm	850 x 700 x 1170	
Weight kg	300	300
Exhaust connection (l x w) mm	250 x 140	250 x 140
Air speed m/sec.	25-30	25-30
Air consumption m^3/min.	20	20

Accessories

Operating wrenches, stop, 3 splinter tongues (without profile)

Special accessories

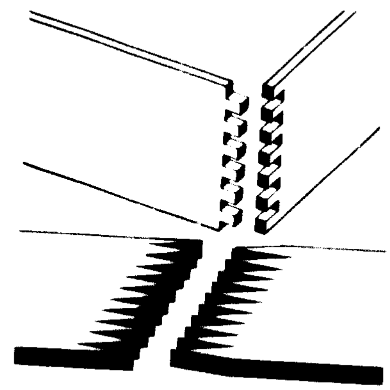
Clamping unit with 1 cylinder EGW-50-25

Pneumatic cross clamping attachment comprising: clamping arm, clamping plates, clamping cylinder AH-35-50 with speed regulating valve GR-1/4.

Longitudinal stop 1.85 m long with 10 folding stops for different longitudinal dimensions.

Profile stop with one stop finger

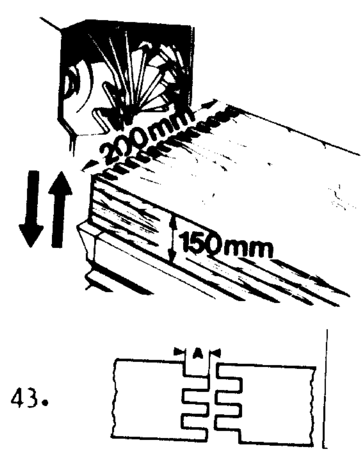
Additional stop finger for profile stop



<u>Automatic finger joint cutting</u>

By means of a stepped feed device finger joints or special shapes can be repeated along workpiece lengths.

Fig. 42.



Cross profiling up to 200 mm wide in one operation.

A max. height of up to 100 mm can be accomodated which means that several thinner pieces can be **machined** together in one operation.

For instance all eight corner joint pieces for two drawers can be worked together and completed within 30 seconds.

Cutting depths A of 30 or 65 mm can be provided.

Fig. 43.

Variations possible with a profile cutting machine.

By changing the position and order of the cutters on a profiler head ten different profiles can be machined.

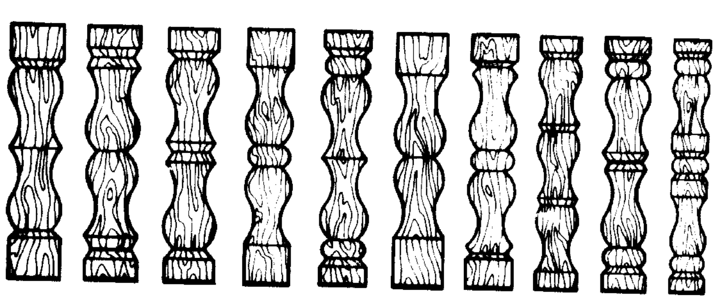


Fig. 44.

1. Introduction

Throughout history wood and woodworking have been closely related to man's activities be it in his leisure, work or home atmosphere.

It is, therefore, not surprising to find that the woodworking industry was amongst the first industries where automation and pneumatic control systems were adopted. This was particularly the case with special purpose machines and custom-built or self designed and operated workshops where pneumatics have always been extremely popular.

We will here separate the machines into two broad categories for convenience:

Firstly, machines and production lines for the woodworking industry bearing in mind the extent and degree of standardization in regular production. Then the standard and universal machines produced for medium and small scale industries, including handicraft trade for one-offs and small quantity production.

The boundaries are not too clearly definable and can be said to vary according to individual requirements or specialization. The machinery required may not always be readily available to purchase.

Woodworking factories are, therefore, often forced to design and build or to have built for them machines to their own special needs. This also holds true for extension or additions to existing factories or production lines. Pneumatic control and automation here can be of decisive value. Various function oriented solutions will come to mind when considering practical technical possibilities. It is intended to promote discussion on and to give some indication of the many various solutions to practical problems and the flexibility and variations possible.

2. Low cost automation using pneumatics

Modifications and attachments to older existing machines which by means of pneumatics provide for an improvement in both quality and quantity of production.

211 Example of add-on pneumatic automation

To increase production it was considered necessary to purchase a new machine. The production capacity of the existing chain mortising machine (6 years old) was too low and it was to be discarded, but then someone thought of looking into modifying it.

3.6 Costing exercise relating to a complete production machine

Complete machine price	DM 11.745
Pneumatic control system	DM 1.280
Assembly time pneumatic	6 hrs
Design pneumatics	9 hrs

Costing study

Universal profiling machine

2 different utilisation rates were considered

1. yearly use 200 hrs operation
2. yearly use 100 hrs operation

To produce the item Fig. 45 the following applies:

Machine + profile step feeder	DM 11.745
Depreciation (longer in practice)	8 years
Working hours	1. 200 hrs/yr
	2. 100 hrs/yr
Interest rate:	10 per cent
Space utilised	10 m^2
Cost of space	DM 6/m^2 per month
Power consumption	7.5 Kw/h
Cost of power 75 per cent operational	DM 15 Kw/h
Maintenance costs	6 per cent/year

Operational time	1) 200 h/year	2) 100h/year
Depreciation	7.34 DM/h	14.68 DM/h
Interest	2.94	5.87
Space	3.6	7.2
Power	0.84	0.843
Maintenance	3.52	7.05
Machine costs per hr. total:	18.24 DM/h	36.64 DM/h

Production time per piece

A) Usual traditional method

Machine time band saw	1 hr	à	22 DM
Hand work finishing	1 hr	à	20 DM
			42 DM

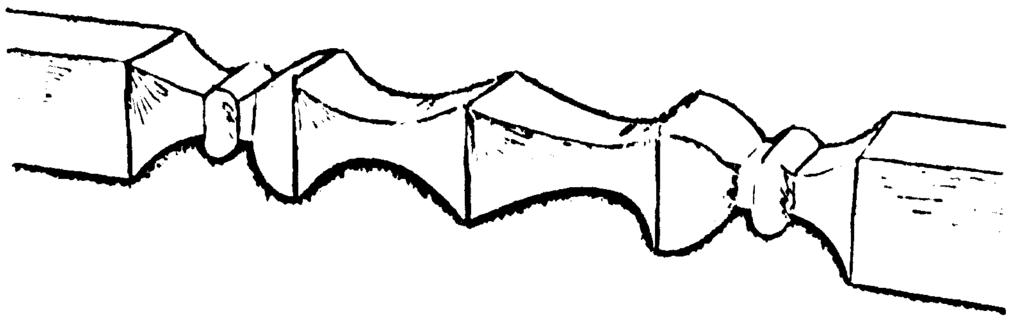


Fig. 45.

B) <u>Produced on universal profiler</u>

		1) 200 h/yr	2) 100 h/yr
Machine time	2 mins	0.61 DM	1.19 DM*
Labor	2 mins	0.67 DM	0.67 DM**
*Tooling costs per hr. Sharpening after 500 pieces	50 DM	0.10 DM	0.1 DM
*Replacement after 1000 pieces	1.860 DM	0.19 DM	0.19 DM
Production costs per piece		1.57 DM	2.15 DM

*These figures will vary in practice and depend upon feed rate and wood hardnes.

**Labour costs involved here will vary but the relationships will still hold.

Profiling machine operating 200 h/yr utilization 13.3 per cent

Traditional production	42 DM
Profile machine production	1.57 DM
Saving per piece	40.43 DM
Cost of machine	11.745DM

Amortised after 11.745 : 40.43 = 291 pieces production of

Profiling machine operating 100 h/yr utilization 6.67 per cent

42 DM
2.15 DM
39.85 DM

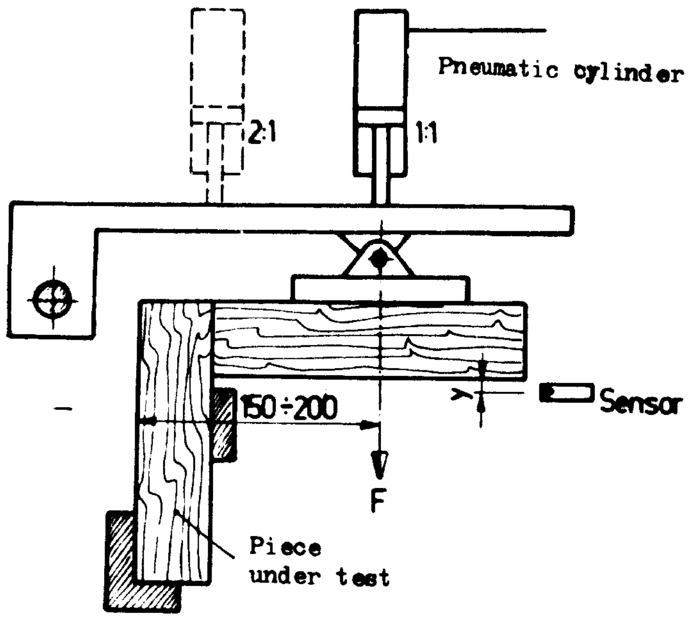
Amortised after 11.745 : 39.85 ˙295 pieces production of

4. Quality control and testing equipment

4.1 Testing machine for corner joints in the wood working industry

A pneumatic pulsator with control system is used to life test corner joints. The joints are subjected to a periodic pulsator stress to determine the breaking stress and number of cycles from which the safe loading level can be determined. Amount of deformation acceptable is empirically established.

Construction of test jig



The test jig consists of:

1 - pulsator cylinder and control valve

1 - sensor and amplifier

1 - console including timer counter and related pneumatic control system

Fig. 46

The test jig is built on a base plate of steel 885 x 545 mm which has rows of mounting holes spread 68 mm apart. Steel runners reinforce the base plate and the whole is mounted on an angle iron framework. Should a larger base plate be required, several units could be joined together, bolt holes are provided along the edges.

Mounting of all elements in various required positions to suit the item being tested is facilitated by the grid of mounting holes provided. As can be seen from the sketch Fig. 46, all elements can be positioned anywhere on the base plate to left or right top or bottom to suit test requirements.

Testing pressure is applied by a pneumatic cylinder through a bracket assembly. Applied pressure can be modified by moving cylinder position on the bracket and the applied air-pressure.

Air Pressure	2	3	4	5	6	7	(bar)
Piston Force	69	104	139	173	208	243	(kp)

Pneumatic control elements are all built into a control console with functional knobs on the front panel. The digital control system provides a rate of drive force which follows the curve shown in Fig. 47.

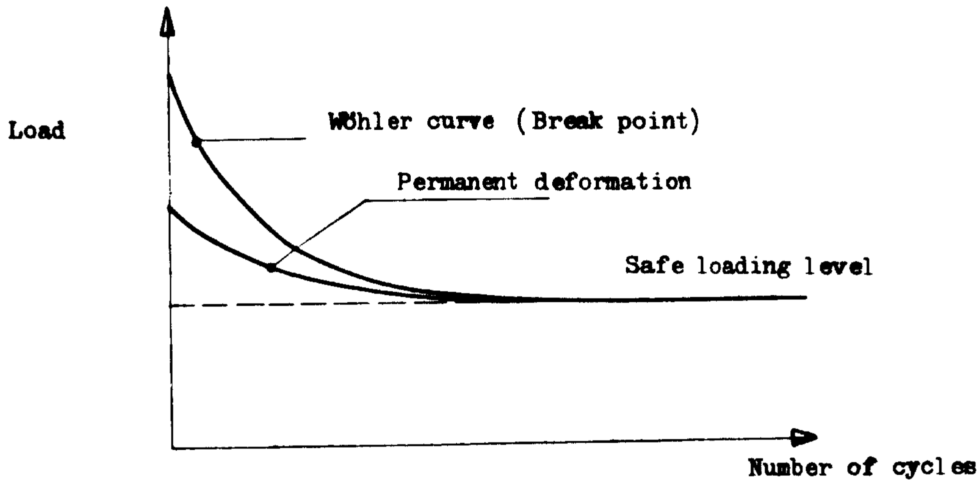


Fig. 47 - Plot of test results

A pressure time relationship of the tester as can be seen from the graph matches the ideal sine wave format closely despite the extremely high impulse power peaks involved (Fig. 48).

The test sequence can be set to stop once a pre-set value (Y = 0.1 = 1 mm) of deformation is detected by the sensor and the number of cycles performed can be read off the pneumatic counter.

To restart a cycle a start button is provided. It can be shown that the pulsator cycle provided approaches the ideal sinusoidal theoretical requirements closely enough for all practical purposes and the pneumatic cylinder pulsator solution given here is simpler and cheaper to build.

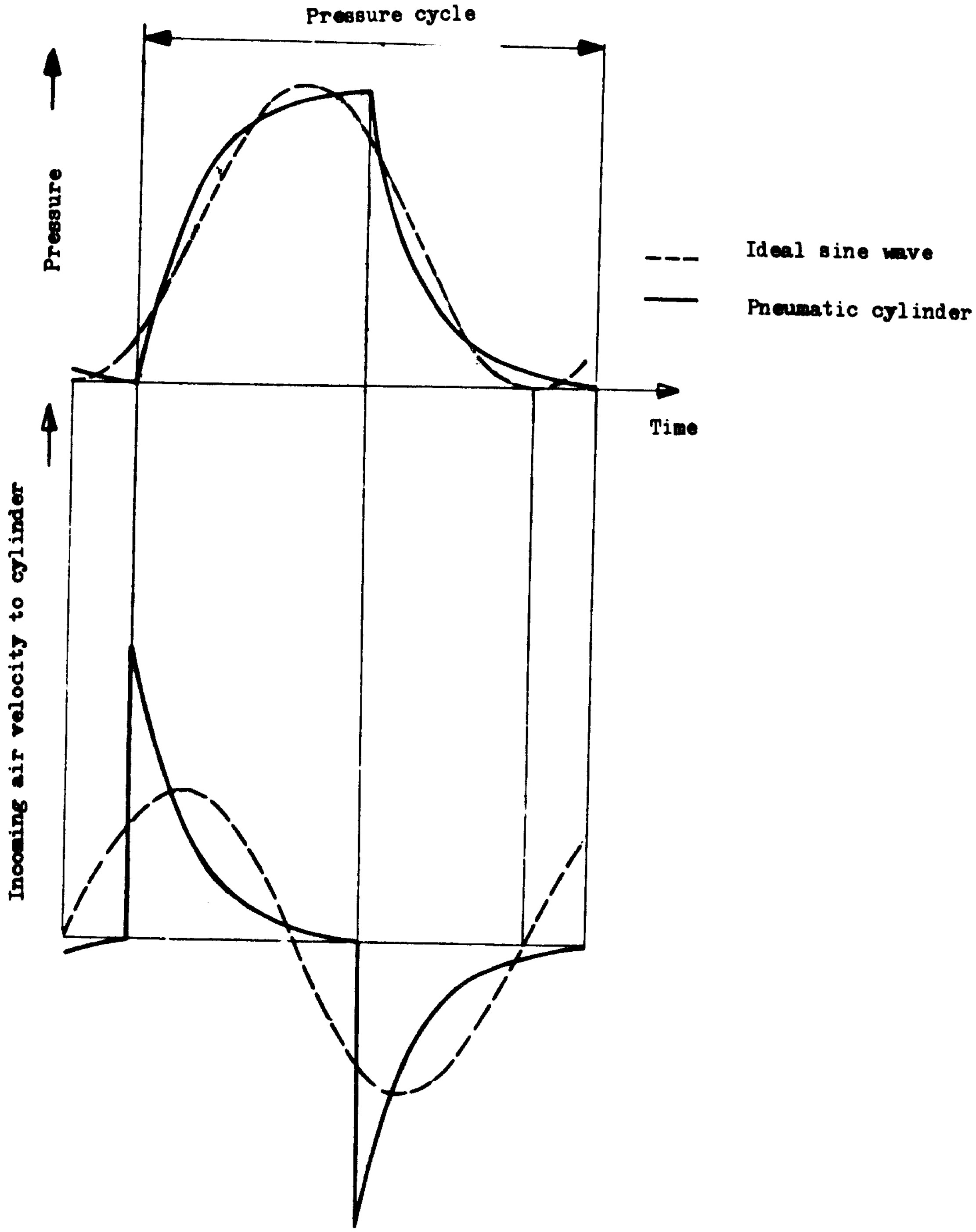


Fig.48 - Cylinder Velocity and Pressure Graph

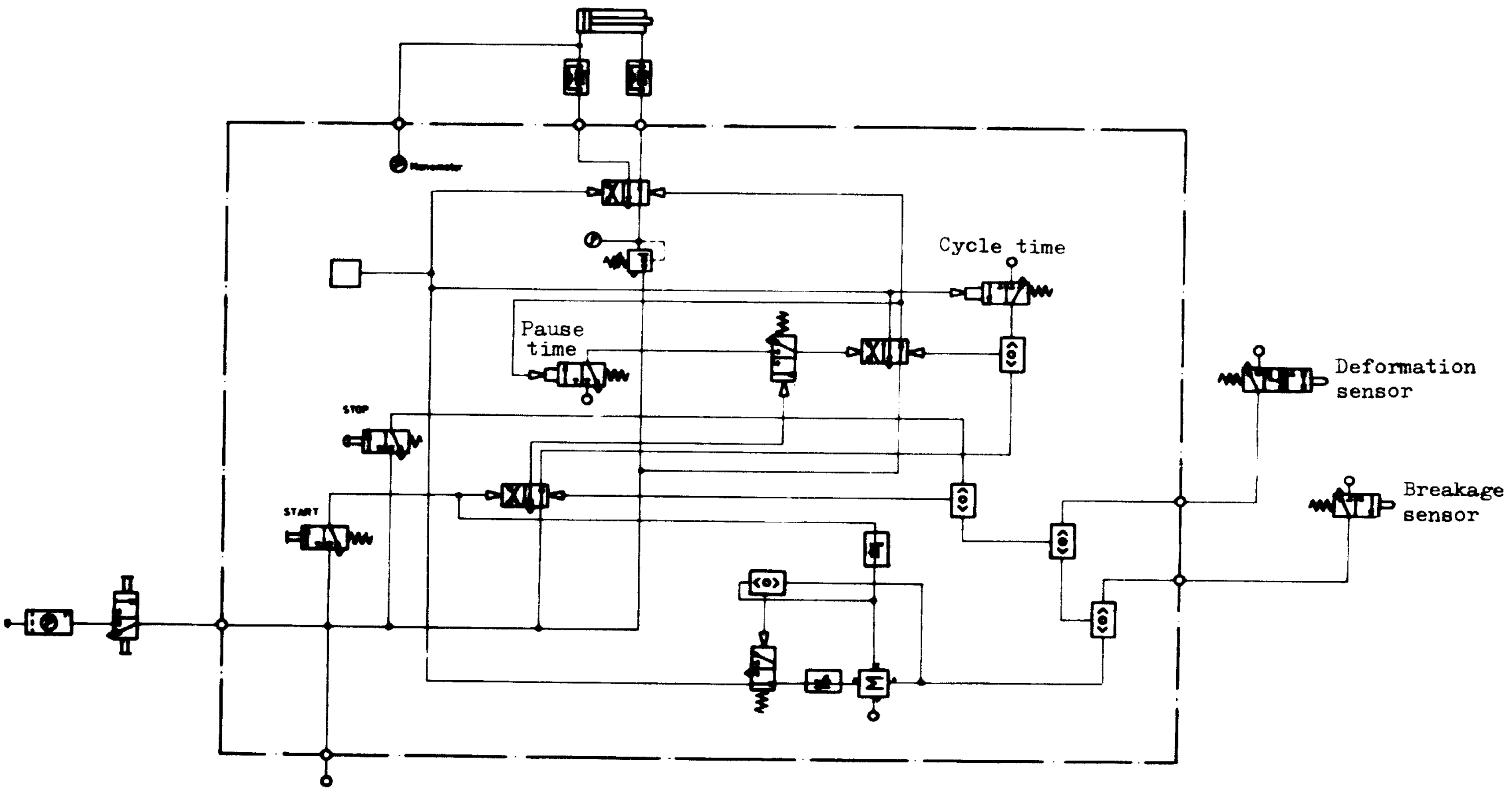


Fig. 48a. Schematic diagram of control system for corner joint tester.

Further notes on test jig construction

All moving parts should be light in construction so as to reduce power lost in acceleration and de-acceleration. Normal factory compressed air line supply is suitable for operating the tester.

Facilities

Piston speed of operation

This can be continuously adjusted by the 2 speed regulator valves provided.

Testing pressure (load)

Continuously adjustable by means of air pressure regulator provided from approximately 1 bar to maximum 8 bar.

Time

Operation and wait interval can both be adjusted individually and independently from one another.
From 0.5 - 10 sec.

Total number of cycles

Can be set on a counter so as to automatically terminate test when number of cycles achieved.

4.2 Furniture testing equipment

Test jig for testing and research institutes as well as manufacturers have been built with a variable profile adjustable frame work so as to be adaptable to test any sizes of tables, chairs, cupboards arm chairs etc. Pneumatic elements can also be moved to appropriate positions to suit the particular test conditions wanted. Life wear strength tests can be performed on all types of furniture. The fifty cycle electrical mains frequency was used in this tester to provide a cheap and convenient timing cycling frequency and control elements are electro pneumatic. Cycles or time to failure or preset counts can be measured. Normal factory air supply is required.

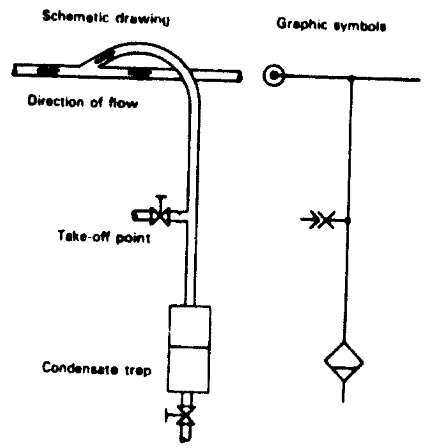


Fig. 49 - Branch line leading off from air main. Branch line should not terminate at air take-off point but should be extended further and end in a condensate trap.

5. Didactic and maintenance of pneumatic systems

5.1 Didactic

It has been found useful to provide special courses to users, larger factories, machine producers and others to instruct various levels of design engineers, maintenance operators etc. from these beginnings has grown-up a complete range of courses, articles, books and special didactics models and equipment. Some extracts from such a course may be of interest here.

Compressed air piping should preferably be installed so as to be accessible for inspection to ensure it is air tight, and in good condition. Horizontal spans should be sloped so as to provide a fall of some 1 - 2 % in the air flow direction. Main down feed supplies should lead direct to a machine user point and the pipe continue down further so as to ensure that any condensate or dirt particles are not fed to the user point but collect below from where they can be occasionally discharged. (Fig. 49).

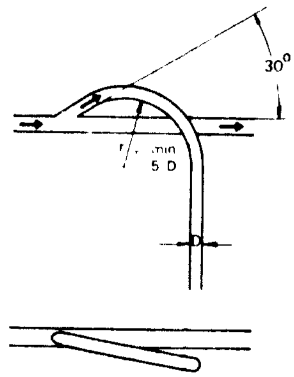


Fig. 50 - Parameters for joining branch line to air main

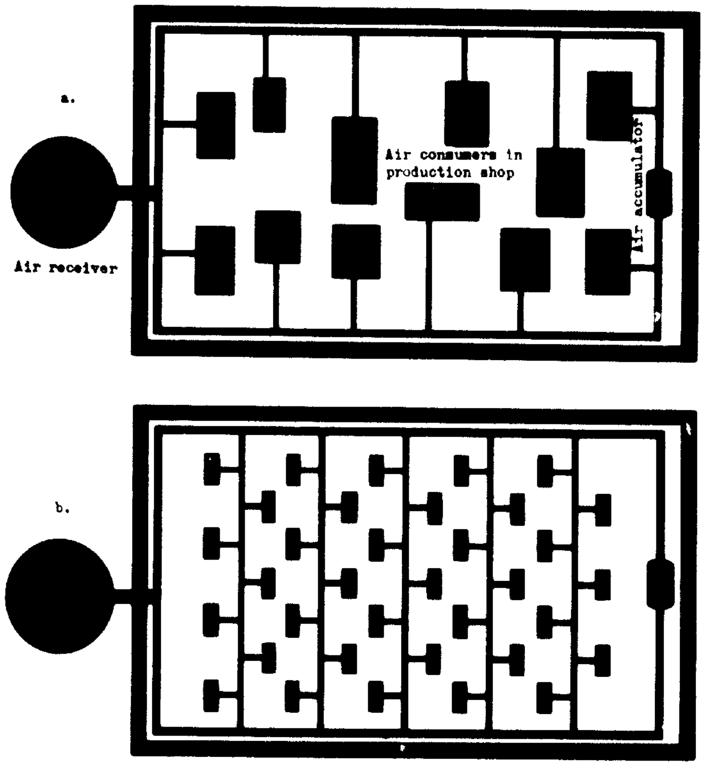


Fig. 51 - Ring air main incorporating air accumulator
a) Branch lines joined to ring main
b) Branch lines joined to cross lines.

Special collectors are available for mounting at the lower ends of supply points for the condensate water some of which empty automatically when the water reaches a certain level. User point piping from the supply should be carried upwards with bends not sharper then R = 2 D (inner radius of bend 2 times pipe outer diameter). A branch from the main supply pipe feeding several high consumption outlets should preferably be connected to the main supply pipe as shown in Fig. 50. Supplies to a complete workshop or room where several machines are supplied are best installed as a ring supply line as shown in Fig. 51. Ideally an additional compressed air reservoir should also be provided. Piping for a ring supply can be some 1/3 the diameter of a similar single pipe supply for the same conditions of pressure loss. Pressure changes in the supply are minimised with a ring supply and the pressures at outlets more even.

Planning a compressed air supply line:

Pipe diameter requirements are determined by the compressed air consumption which should allow for a reasonable reserve (bearing in mind additional equipment requirements that invariably follow soon afterwards). Empirical values have been established for acceptable limits of air flow velocity and pressure drop for optimum cost operation over the years. The determining factors for pipe diameter are:

Permitted air flow velocity
Permitted pressure drop
Working air pressure
Number of built in restrictions
Pipe lengths

Consumption volume 1 min is a readly established value. The air velocity and pressure drop are closely related. Pressure drop is in addition affected by the smoothness of the inner pipe wall and any intermediate connectors. Pressure increases with velocity and length of piping.

Velocity should be chosen to be between 6 and 10 m/s. Design should aim at below 10 m/s as invariably various parts of the systems will have higher velocities due to built in obstacles, restrictions, reducing couplings or temporary consumption surges.

Pressure drop should be kept to under 1 KP/cm^2 up to the user outlets. In practice up to 5 per cent pressure drop is often found. With a design operational pressure of 6 Kp/cm^2 a drop of 0.3 Kp/cm^2 is thus acceptable.

Throttling: connectors, couplings, bends, valves in the piping all tend to throttle the air supply. To calculate the required piping diameter it is normal to allow for the effective throttling by adding a factor to the value of piping length.

Designing a pipeline: example and graphs taken from Festo text book Introduction to pneumatics.

The air consumption in a factory is 400 l/min = 4 m^3/min = 240 m^3/h. The increase over a period of about three years will be 300 per cent. This results in 12 m^3/min (720 m^3/h). The total consumption is 16 m^3/min (960 m^3/h). The pipeline will have a length of 280 m, and it contains 6 T-pieces, 5 normal elbow pieces, 1 two-way valve. The permissible pres-

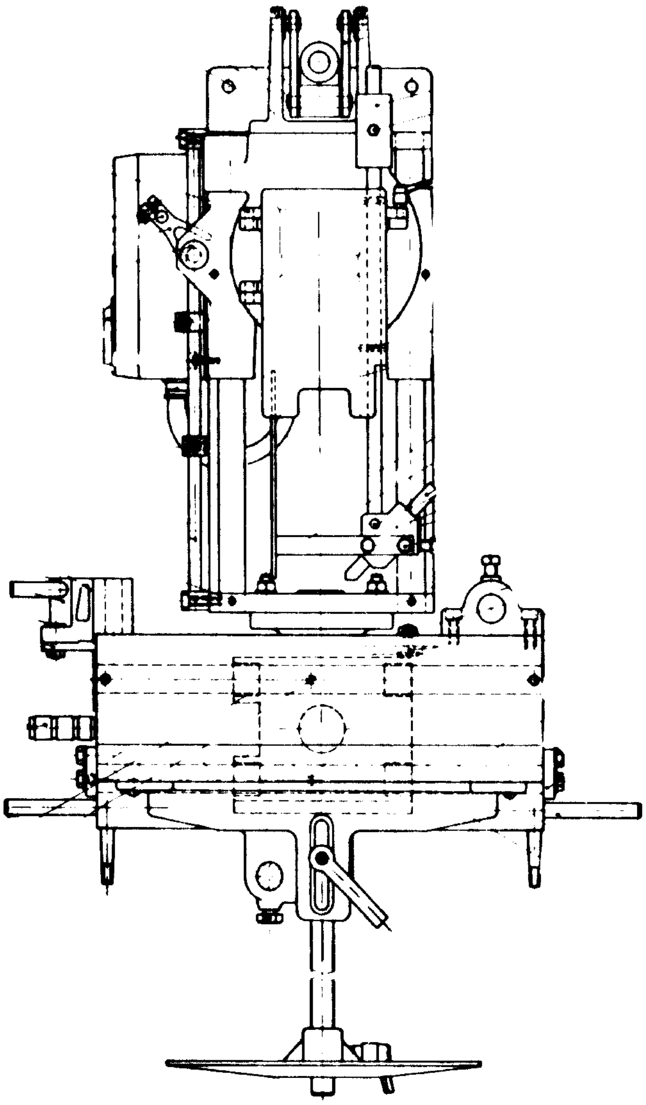


Fig. 1

The idea being to use the existing chain mortising machine and by adding pneumatic automation to produce a purpose built machine capable of handling special production runs and small scale production runs.

sure drop is $\Delta p = 0.1 \times 10^5$ Pa. Working pressure 8×10^5 Pa.

To be calculated : pipe diameter

The provisional pipe diameter is determined in the nomogram using the available data (Fig. 52).

<u>Use nomogram (pipe diameter)</u>

Line A (pipe length) is joined with B (take-in volume) and extended to C (axis 1). Line E (working pressure) is joined with G (pressure loss) and one then obtains an intersection at F (axis 2). The intersections of axis 1 and axis 2 are joined togehter. One obtains an intersection at line D (inside pipe width) and this specifies the pipe diameter. The pipe diameter was designed with 90 mm (chart).

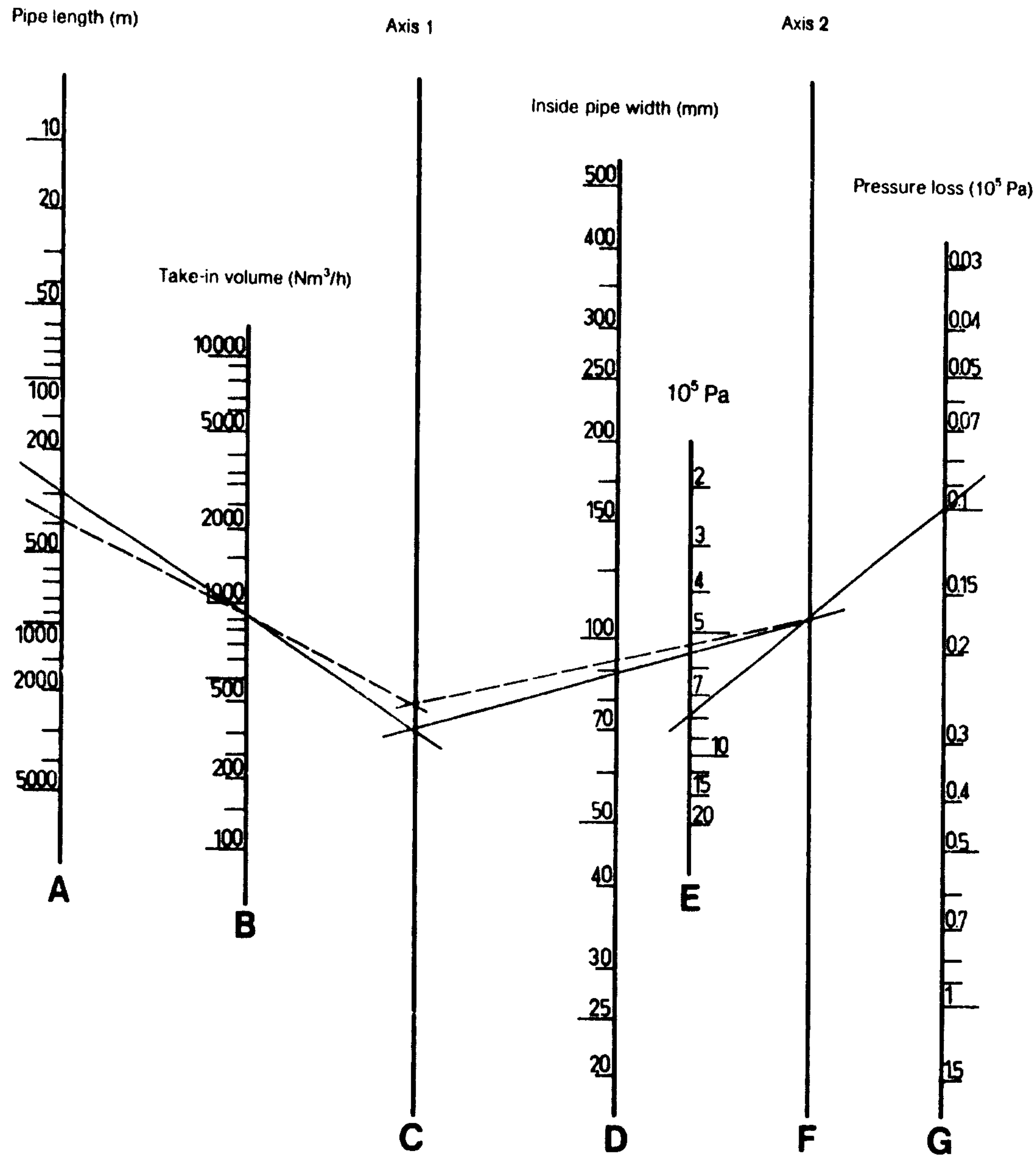


Fig. 52
Calculation of pipe diameter

For the restrictive elements (two-way valve, corner valve, T-piece, slide-valve, normal elbow piece) the resistances are specified in equivalent lengths. Equivalent length is understood to mean the length of a straight pipe having the same resistance to flow as the restrictive element or the point of restriction. The flow cross section of the "equivalent length pipe" is the same as that of the pipe. By means of a second nomogram the equivalent lengths can be established quickly.

Nomogram (equivalent lengths)

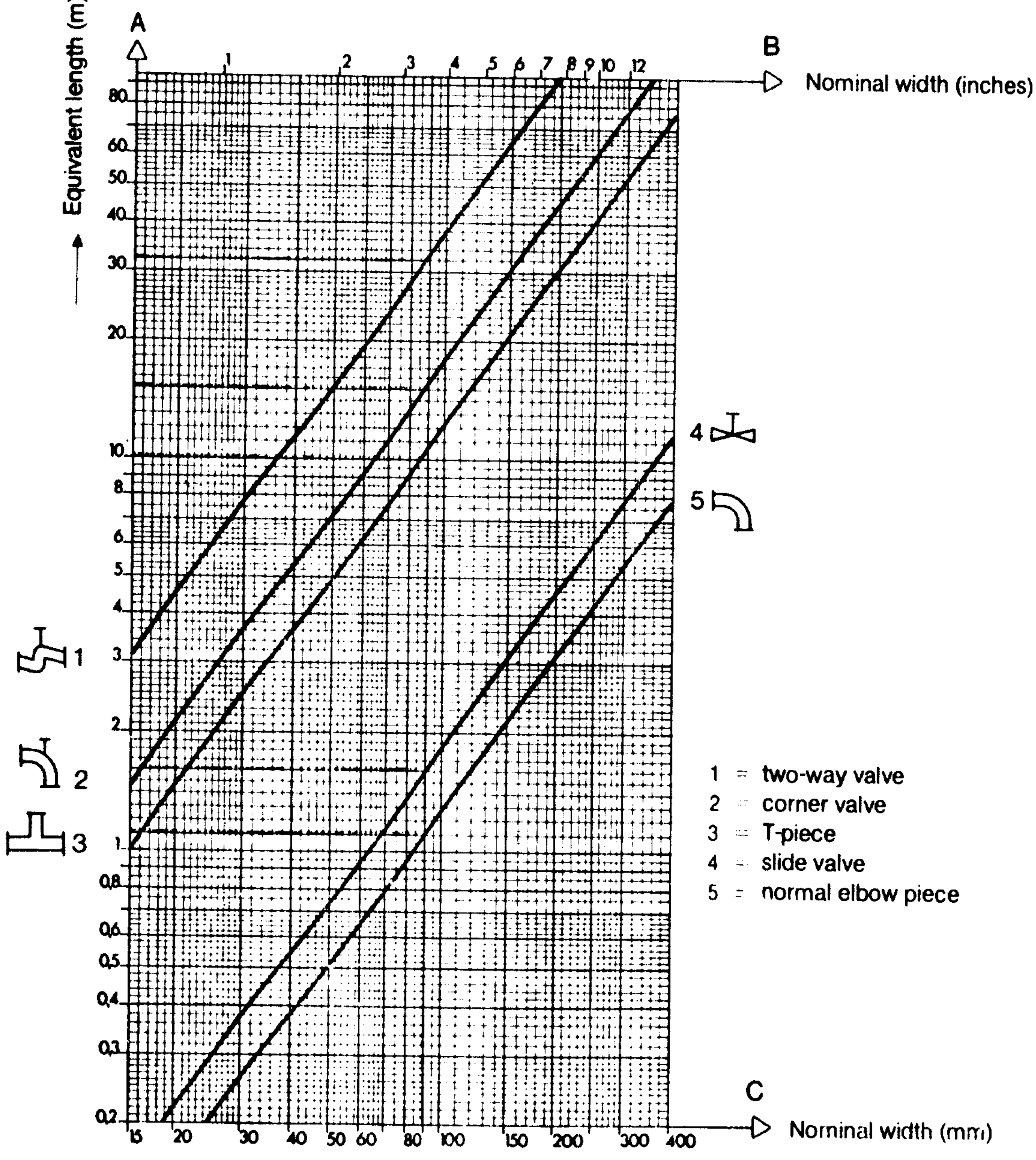


Fig. 53. Calculation of equivalent pipe length

Automatic condensate water separator

Air supply lines and related equipment should not be ignored as permanent fixed fittings once installed but regularly serviced, air filters cleaned or replaced, oilers where fitted refilled pipe line ends regularly opened to empty out accumulated dirt particles and condensate etc.

In addition to regular servicing, however, and particularly where high moisture levels prevail, automatic condensate drains installed at various strategic points in an installation are a must.

Function: The condensate collects in a collector and when a given level is reached, a float mechanism automatically opens a drain outlet and the air blows the condensate out where upon the float once again seals off the drain outlet.

The condensate in the air filter passes through hole 6 into the piston chamber between the sealing washers 1 and 2. As the condensate increases, the float 3 moves upwards.

When a certain condensate level is reached, nozzle 7 opens. The compressed air from the filter bowl flows through the hole and presses the control piston 5 towards the right. This results in sealing washer 1 opening the flow passage for the condensate. Through nozzle 4, the compressed air can flow out at only a slow rate and the through passage is kept open for a longer period of time.

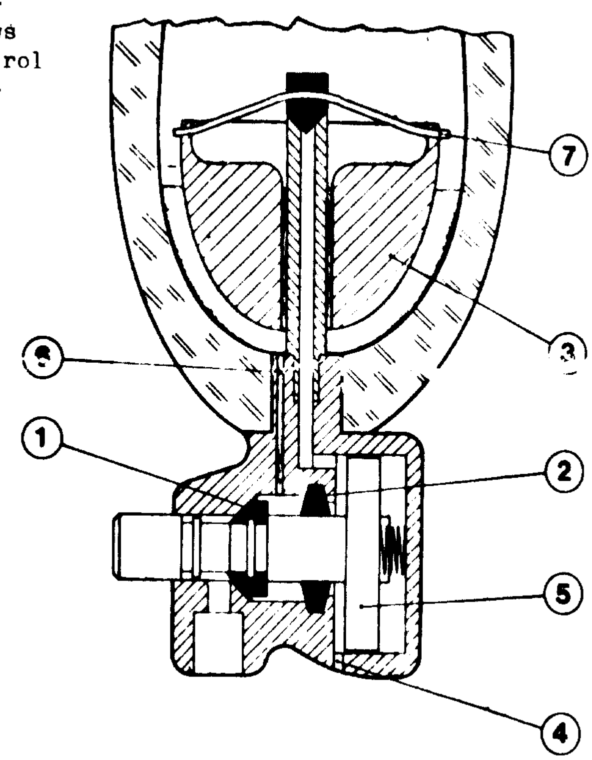


Fig.54. Water separator

5.2 Application of pneumatics to the woodworking industry

Machine	Workpiece Criteria 2 = full 1 = limited 0 = nil			Penumatic control 0–2 = nil 3 = limited 4–6 full	Tool drive Criteria 2 = full 1 = limited 0 = nil			Pneumatic control 0–2 = nil 3 = limited 4–6 full
	Power	Accuracy	Speed		Power	Accuracy	Speed	
Sawing machines								
Framesaw		1	1	2				
Log band saw	1	1	1	3				
Tableband saw	1	1	1	3				
Table disc saw	2	2	1	5	2	2	1	5
Pendulum circular saw	2	2	2	6	1	2	2	5
Beamcross cut	2	2	2	6	1	2	2	5
Panel circular	1	1	1	3	1	1	1	3
Milling machines								
Horizontal	1	2	2	5	1	1	2	4
Vertical frame	1	2	2	5	1	1	2	4
Top	2	2	2	6	1	1	2	4
Bottom	2	2	2	6	1	1	2	4
Finger joint	1	2	2	5	1	1	2	4
Tenoning	1	2	2	5	1	1	2	4
Deep bore	2	2	2	6	1	1	2	4
Chain milling	1	2	2	5	1	1	2	4
Copy miller	1	2	2	5	1	1	2	4
Thickness	1	1	2	4	1		1	2
Grooving	1	1	2	4	1	1	2	4
Boring machines								
Pillar	2	2	2	6	2	2	2	6
Multi-spindle	2	2	2	6	1	2	2	5
Dowel	2	2	2	6	1	2	2	5
Verical	2	2	2	6	2	2	2	6
Knot	2	2	2	6	2	2	2	6
Lathes								
Lathe	1	2	2	5	2	1	2	5
Copy lathe	1	2	2	5	1	1	2	4
Sanders								
Stroke belt	2	2	2	6	2	1	2	5
Pressure bar belt	1	2	2	5	1	1	2	4
Wide belt	1	2	2	5	1	1	2	
Disc	1	2	2	5	2	1	2	5
Copy sanding	1	1	2	4	2	2	2	6
Contour	1	2	2	5	2	1	2	5

Fig. 55

5.3 Recognition of shape size and position by pneumatics

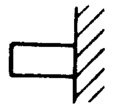
Example	Parameter Sensed	Pneumatic Element
	Length Width Limits	1 mm end stop 3/2 roler actuated valve 1 mm air barrier reflex sensors
	Length Width Limits	1 mm 3/2 roler valve 1 mm air barrier reflex sensors
	Thickness Height	3/2 roler actuated valve air barrier reflex sensor
	Cut-away	Back pressure nozzle reflex sensor air barrier
	Bore	air barrier cylinder (stroke position)
	Flag Cam	Back pressure nozzle Air barrier
	Recess	0.1 mm reflex sensor
	End position	3/2 roler actuated valve back pressure nozzle
	Cut-away	Reflex sensor

Fig. 56

5.4 Typical applications of pneumatic components and assemblies for specific work and tool handling functions

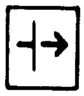
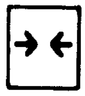
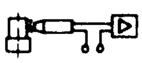
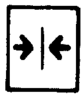
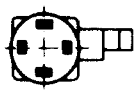
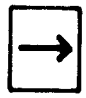
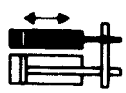
Function	Symbol	Principle	Functional elements	Operating characteristics
Bin loading			Multivibrator	E.g., cylinder with 12 mm piston diameter, frequency 7 c/s (adjustable)
Magazine loading			Single- and double-acting cylinders	1 to 100 parts/min
Advance (Material feed)			Single- and double-acting cylinders	1 to 100 parts/min 60 cm/min to 60 m/min 1 to 2000 mm piston stroke
Position control			Impact nozzle Reflex nozzle Interruptible jet	Maximum spacing 3, 4.5, 6.5, 15 or 100 mm
Turning			Rotary cylinder	Max. 90 or 290 degrees (adjustable)
Positive or non-positive clamping			Single- and double-acting cylinders Vise	1 to 1000 mm, 1 to 2500 kgf 2000 to 7000 kgf
Transfer (Rotary indexing)			Rotary indexing table	Divisions 15, 30, 45, 60, 90 or 120 degrees
Transfer (Linear indexing)			Strip feeder Single- and double-acting cylinders	Progression adjustable up to 250 mm Material thickness up to 2 mm
Machining (Tool feed)			Pneumatic and air-hydraulic feed units	Feed rate 30 to 6000 mm/min
Ejection			Impulse ejector Single- and double-acting cylinders	Up to 480 blasts/min 1 to 100 parts/min

Fig. 57

5.2

A didactics course to instruct personnel in the art of pneumatics is desireable not only for design and machine building engineers but also for service and maintenance personnel. The following are some descriptive drawings for explaining the inner construction and workings of some parts from a text book (Festo didactic) for just such a course.

Single acting cylinder

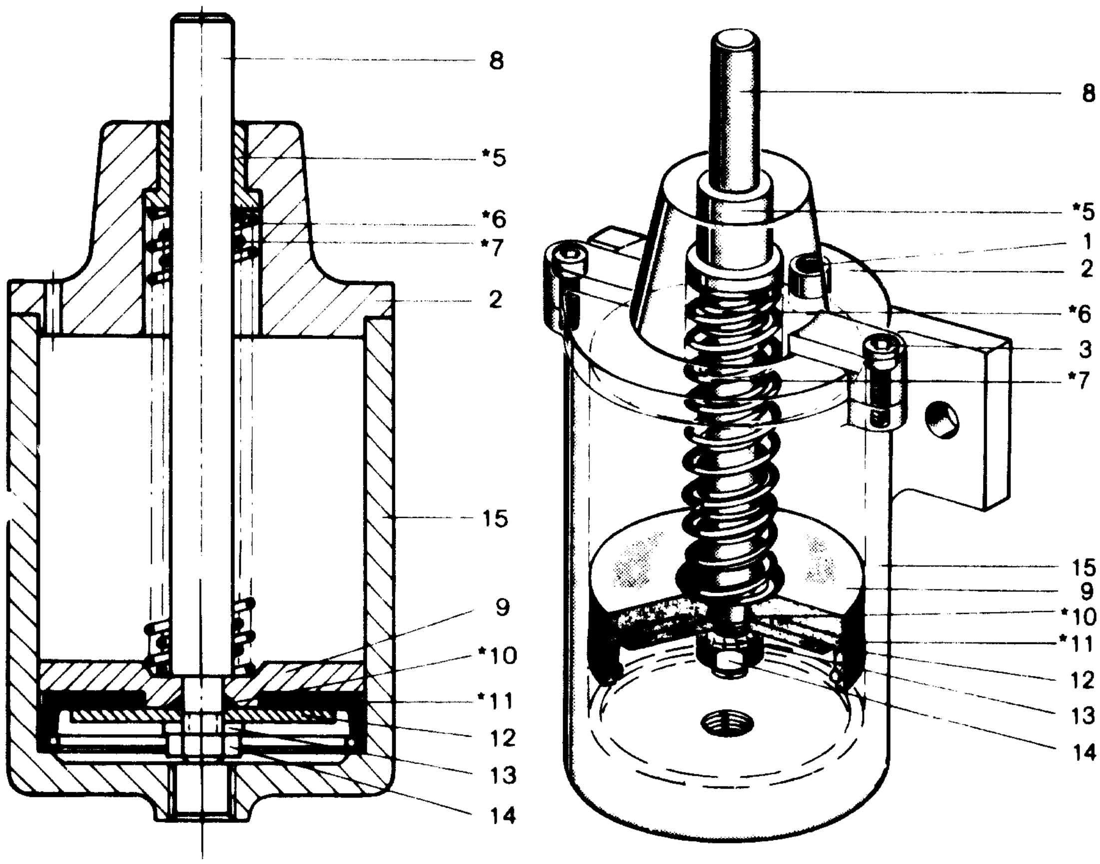
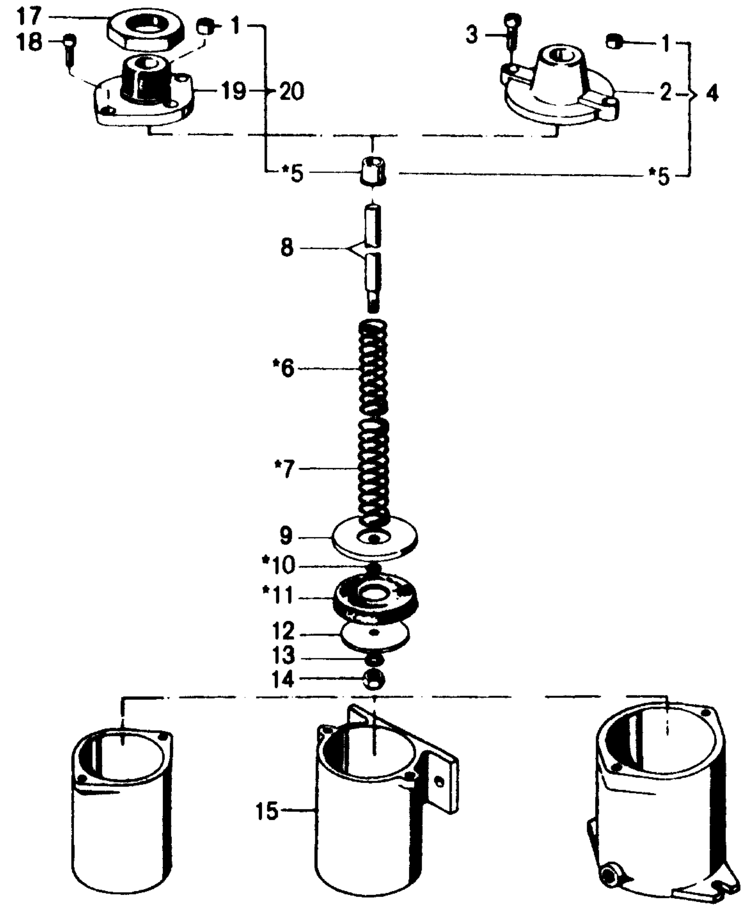


Fig. 58. Parts of the single acting cylinder

Item	Name	Item	Name
1	Filter element	9	Piston disc
2	Bearing cap	*10	O-ring
3	Cheese-head screw	*11	Cup packing
4	Bearing cap, complete	12	Tightening disc
*5	Bearing bushing	13	Serrated spring washer
*6	Compression spring	14	Hexagon nut
*7	Compression spring	15	Cylinder barrel
8	Piston rod		

Functional description

Air enters through cylinder barrel (15), air is applied to the cup packing (11). Piston rod travels out. When the cylinder is exhausted, springs (6) and (7) push the piston and piston rod back into the initial position.



Wearing parts

Bearing bushing	5
Compression spring	6
Compression spring	7
O-ring	10
Cup packing	11

Contamination

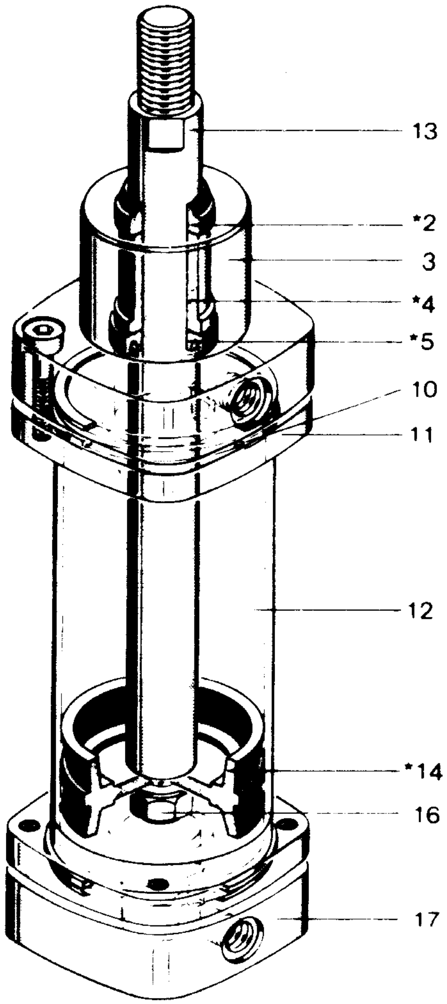
Too much oil in the cylinder barrel, the piston travels out slowly.

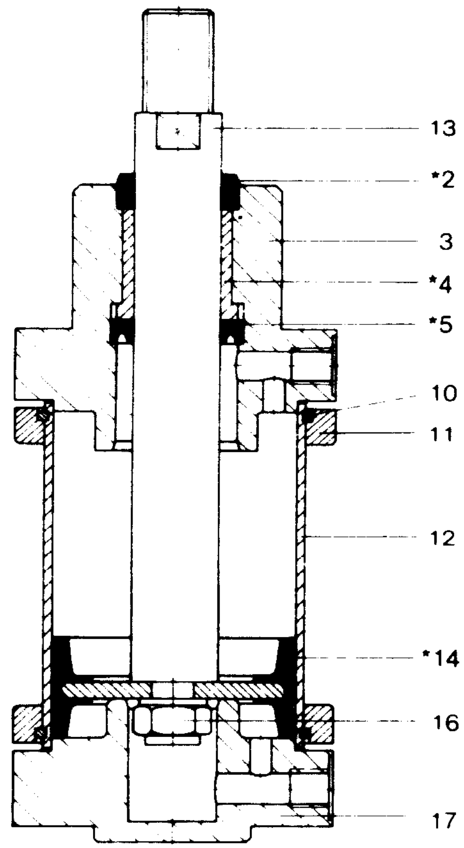
List of faults

Type of disturbance	Possible cause	Rectification
Piston rod (8) does not return to the end position	Compression spring (6) and (7) damaged	Fit new spring
	Air filter is blinded	Clean air filter
The air escapes to atmosphere at the bearing bushing (5)	Cup packing (11) not tight, worn	Replace the cup packing (11)
	Cup packing (11) mounted the wrong way round	Reverse the cup packing (11)
Piston rod (7) is not guided smoothly	Bearing bushing (5) worn	Replace the bearing bushing (5)

Fig. 58a

Fig. 59 — **Double-Acting Cylinder**





Item	Name
1	Cheese-head screw
*2	Scraper ring
3	Bearing cap
*4	Flange bushing
*5	Groove ring
6	Flange
7	Cheese-head screw
*9	Sealing ring
10	Spring washer
11	Clamping ring
12	Cylinder barrel
13	Piston rod
*14	Double cup packing
15	Washer
16	Hexagon nut
17	End cap
18	Cheese-head screw
19	Swivel flange
20	Cheese-head screw
21	Clamping foot

Functional description

The air is supplied to the piston through the end cap (17). The piston rod (13) travels out. The return **stroke** is effected by pressure being applied to the piston rod side of the piston through the bearing cap (3).

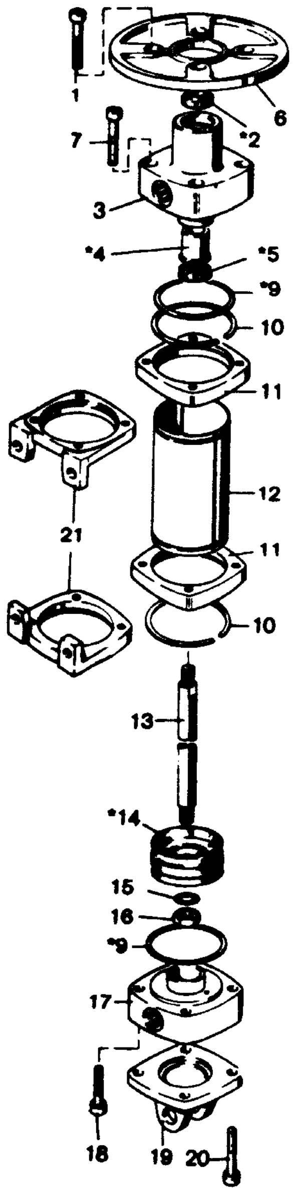


Fig. 60 – Parts of double-acting cylinder

Wearing parts

Scraper ring	2
Flange bushing	4
Groove ring	5
Seal ring	9
Double cup packing	14

Contamination

Too much oil or water in the cylinder, the cylinder becomes slower. Wear is increased.

List of faults

Type of disturbance	Possible cause	Rectification
The connected valve vents air through the vent hole	The double cup packing (14) leaks or is loose	Fit new packing Tighten packing
Air escapes at the piston rod	Groove ring (5) is defective	Fit a new groove ring
Special-purpose cylinder: End position cushioning In a cylinder with end position cushioning, the cushioning does not respond.	Lip seal on the cushioning plunger leaks or has been fitted the wrong way round	Fit a new lip seal Refit the lip seal

5.6 Maintenance

Trained maintenance personnel cost money but proper maintenance is very important and will always pay in the long run. Pneumatic equipment and systems also need appropriate periodic maintenance even though it can be said they just work on air.

For any larger pneumatic installation a separate check list should be prepared for maintenance which should include a functional and schematic diagram. This should facilitate maintenance and trouble shooting in case of faulty operation. Various elements or machine parts as well as the compressed air lines can also develop leakages and regular checks are desirable. Components can develop leaks that in extreme cases can cause damage well in excess of the value of the component itself.

A common problem in the woodworking industry is of course the continuously accumulating dust everywhere. This dust can destroy machine and air cylinder bearings, block vents and cause other misfunctioning when it accumulates in the wrong places.

Points for a maintenance plan are listed below:

Daily maintenance checks

- Empty condensate in filters
- Check, top-up oil level in oilers
- Oil grease points
- Special points (where applicable)

Weekly maintenance

- Clean, check and test signal valves, cams, rollers - replace if faulty
- Check for frays, wear, leaks on piping, tubing
- Check tightness, leakage on tubing, couplings
- Check manometer on pressure reducer
- Test oiler functioning
- Check oiler rate drops minute, reset if necessary
- Special points on some machines

The following details show how this particular problem was solved:

Machine for cutting mortises in ladder runners (Fig. 2)
For step-ladders (right angled tread)
For step-ladders (angled tread)

The runners are clamped in a stationary position for machining and the chain mortising attachment is moved in steps from notch to notch. In this way the space requirement of the machine is kept to a minimum. Should the runners be moved step by step under a stationary mortising attachment, the space taken up by the machine would be doubled.

A machine capacity of 1000 slots/hour was achieved with fully automatic operation. The installation consists of five essential parts:

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

a. The machine pedestal is of welded construction and consists of the frame, the tool head, guide rails and the step spacing for setting the distance between mortises. A wooden insert is provided on the machine bed to avoid fraying at the slot edges. The pedestal can be dismantled for ease to transport.

b. The chain mortising attachment is a standard production item with hydro-pneumatic feed. It has in addition a swivel mount attachment which allows mortising of right angled mortises for ladders, as well as angled slots for step ladders.

c. The transport carriage with pneumatic feed unit consists of two moving carriages, mounted on rollers. On the larger of the two carraiges is mounted the mortising head. Precise positioning is controlled and determined by the step spacing and stop cylinder.

Monthly maintenance

- Inspection of all parts of the installation for leaks, loose couplings
- Check all valves, cylinders and their vents
- Clean, wash out filter in petrol or clean in air blast
- Check air supplies to cylinders and cylinder seals, replace if necessary
- Check operation of automatic condensate drains, no air leakage
- Special points as required

Half-yearly maintenance

- Inspect cylinder shafts for wear or leakage, replace bushes seals or complete unit if required
- Check all units for correct operation
- Replace silencer elements where dirty
- Special points as required

The maintenance plan for a complete installation will of course not only be for the pneumatic installation but should encompass all aspects and equipment, mechanical, electrical, pneumatic water sewage services, etc. Naturally one expects to have trained electricians to look after the electrical equipment and one should also expect to have trained people for pneumatic maintenance and repairs. The inner construction details of some pneumatic cylinders valves and elements can look just as complicated as the innards of an electrical unit to the uninitiated. Didactic courses books and information are available for training such personnel today.

Trouble shooting

In a small, simple pneumatic control system trouble shooting can be quite simple but in a more complex installation with many interdependent machine functions, it could be like looking for a needle in a haystack unless systematically approached. It is, therefore, very important to keep accurate schematic and detailed drawings of all installations and particularly to record any changes, modifications or improvements and additions to the system.

System for detecting faults

If one considers the pneumatic controls on simple or complicated machinery in factories in various branches, servicing and maintenance appear to be very difficult and call for a variety of skills. If one considers the matter more closely, however, one finds that many of these pneumatic controls have a lot in common.

Signal output elements

Working elements (cylinders, motors)

Signal processing elements

Actuating elements (3/2, 4/2, 5/2 way valves)
Control elements (shuttle valves, 2-pressure valves, etc.)

Signal input elements

Signal elements (3/2, 4/2, 5/2 way valves)

One recognizes the same components and control groups time and again in the controls, and these are found in different combinations in the machines.

If damage (faults) occur in the systems, systematic fault tracing is most helpful. Repair (servicing) become much easier by systematic fault tracing, and above all the repair time is reduced.

6. Conclusion

Low cost automation possibilities in the wood working industries are virtually unlimited and this short paper can only hope to have touched upon some perhaps more general applications. As individual workshop requirements are likely to vary we can but trust that some of the examples described or the references listed will help guide any interested party towards an appropriate solution or choice for his particular problem.

7. Literature

Pneumatic Control,[1] ISBN 3-8023-0102-1;
Pneumatik in der Holzverarbeitung,[1] ISBN 3-8023-0143-9;
Pneumatic Tips,[2],[3];
Pneumatic Application,[1] ISBN 3-8023-0112-9;
Low Cost Automation for the Furniture and Joinery Industry, UNIDO ID/154;
Maintenance of Pneumatic Equipment and Systems,[2] ISBN 3-8127-0841-8;
Introduction to Pneumatics,[2] ISBN 3-8127-0811-6.

1) Vogel Verlag, 8700 Würzburg, Max Planck Strasse 8, Postfach 8000, W. Germany.
2) Festo Didactic, D-73 Esslingen I. Berkheim, Postfach 6040, W. Germany.
3) Festo Didactic, A-1171 Wien, Haslingergasse 11, Austria.

ANNEX I

Air consumption

The air consumption of a plant is very important for the supply of compressed air and for the determination of energy costs. The air consumption can be simply calculated by means of the air consumption chart.

Chart of air consumption for pneumatic cylinders

cyl. Ø mm	operating pressure . . . atm / air consumption in L/cm (liters/cm) stroke of the cylinders														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6	0,0005	0,0008	0,0011	0,0014	0,0016	0,0019	0,0022	0,0025	0,0027	0,0030	0,0033	0,0036	0,0038	0,0041	0,0044
12	0,002	0,003	0,004	0,006	0,007	0,008	0,009	0,010	0,011	0,012	0,013	0,014	0,015	0,016	0,018
16	0,004	0,006	0,008	0,010	0,011	0,014	0,016	0,018	0,020	0,022	0,024	0,026	0,028	0,029	0,032
25	0,010	0,014	0,019	0,024	0,029	0,033	0,038	0,043	0,048	0,052	0,057	0,062	0,067	0,071	0,076
35	0,019	0,028	0,038	0,047	0,056	0,066	0,075	0,084	0,093	0,103	0,112	0,121	0,131	0,140	0,149
40	0,025	0,037	0,049	0,061	0,073	0,085	0,097	0,110	0,122	0,135	0,146	0,157	0,171	0,183	0,195
50	0,039	0,058	0,077	0,096	0,115	0,134	0,153	0,172	0,191	0,210	0,229	0,248	0,267	0,286	0,305
70	0,076	0,113	0,150	0,187	0,225	0,262	0,299	0,335	0,374	0,411	0,448	0,485	0,523	0,560	0,597
100	0,155	0,231	0,307	0,383	0,459	0,535	0,611	0,687	0,763	0,839	0,915	0,991	1,067	1,143	1,219
140	0,303	0,452	0,601	0,750	0,899	1,048	1,197	1,346	1,495	1,644	1,793	1,942	2,091	2,240	2,389
200	0,618	0,923	1,227	1,531	1,835	2,139	2,443	2,747	3,052	3,356	3,660	3,964	4,268	4,572	4,876
250	0,966	1,441	1,916	2,392	2,867	3,342	3,817	4,292	4,768	5,243	5,718	6,193	6,668	7,144	7,619

These should be considered especially for determining the air consumption when long lines are in use.

Calculation of the air consumption

Q = total air consumption L/MM
q = air consumption per stroke in L
s = cm stroke
n = numbers of stroke per min.

a) single acting cylinder
air consumption $Q = s \cdot n \cdot q$ (L/min.)

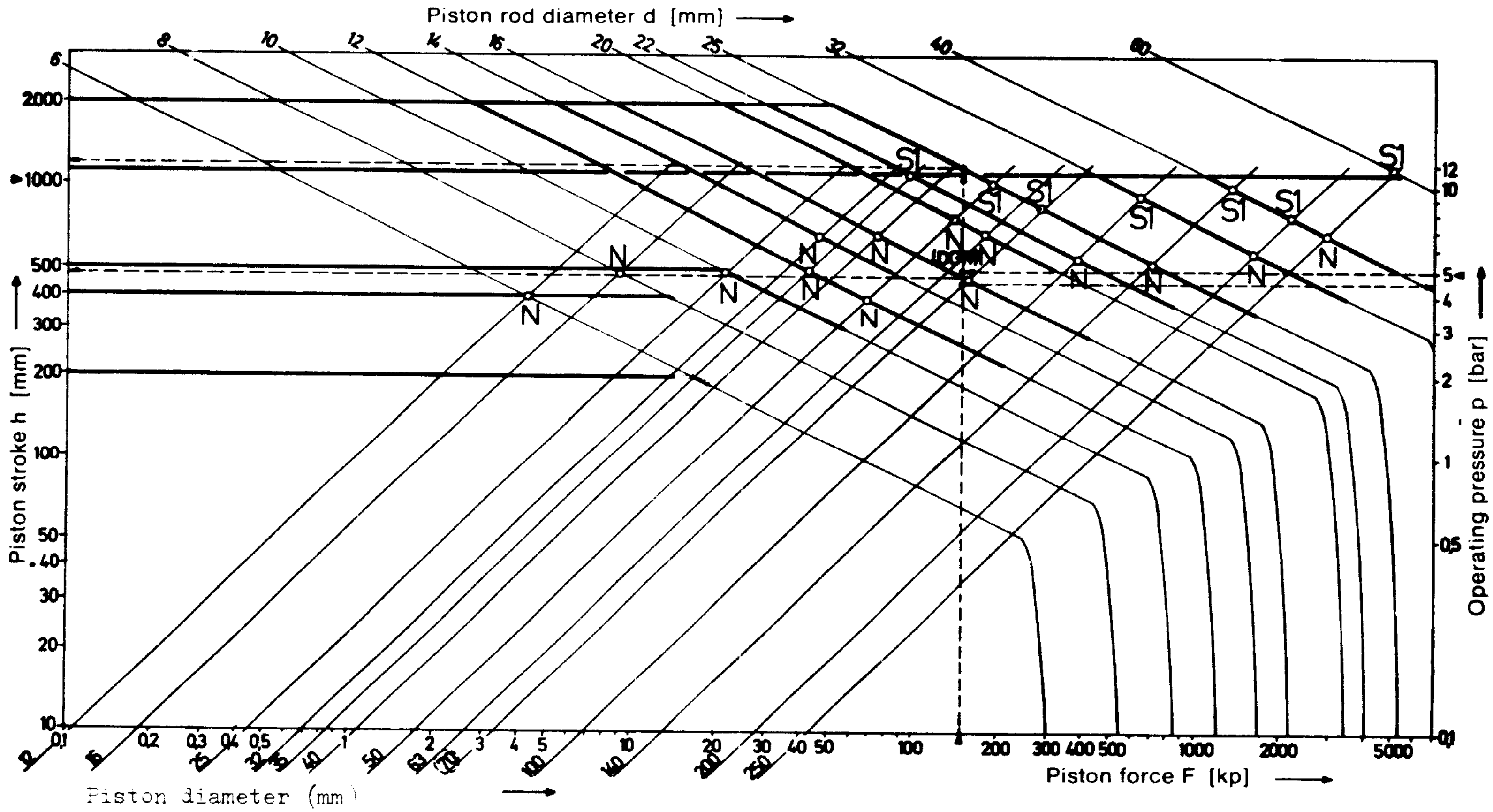
b) double acting cylinder
air consumption $Q = 2 (s \cdot n \cdot q)$ (L/min.)

Example: A double acting cylinder with a diameter of 50 mm and 140 mm stroke must be operated at 6 atm. The number of switching cycles amounts to 50 strokes per minute. How much air is required in L (swept volume) per minute?

$Q = 2 (s \cdot n \cdot q)$
s = 14 cm
n = 50 strokes/min
q = 0,134 L/cm per stroke (after table)
Q = 2 (14 cm · 50 strokes/min. · 0,134 L/cm stroke)
Q = 187,6 L/min

ANNEX II

Calculation of piston force



Example

Given: Load 150 kp
Max. available supply pressure 5 bar
Required piston stroke 1000 mm

Required: Order designation for DC-cylinder, piston diameter, type (normal or reinforced piston rod) and regulated supply pressure.

Solution

1. Locate intersection point between 150 kp force line and 5 bar supply pressure line. Read off the piston diameter of the next higher value = 70 mm diameter.
2. Locate intersection point between 150 kp line and the selected piston diameter. Regulated operating pressure = 4.5 bar
3. The inter-related intersecting-lines for piston and piston rod diameters are indicated, N = Normal rating, S 1 = reinforced piston rod.

From the intersection point for 150 kp with a piston rod diameter of 16 mm (N Rating for 70 mm diameter) gives a maximum permissible stroke of 470 mm.

Conclusion: The rod is too thin and a danger of buckling exists.

4. Locate the S1 marking on the 70 mm diameter line. Read off the piston rod diameter = 25 mm. Locate the intersection between the 150 kp line and the 25 mm diameter line. Read off the maximum piston stroke = 1150 mm

Conclusion

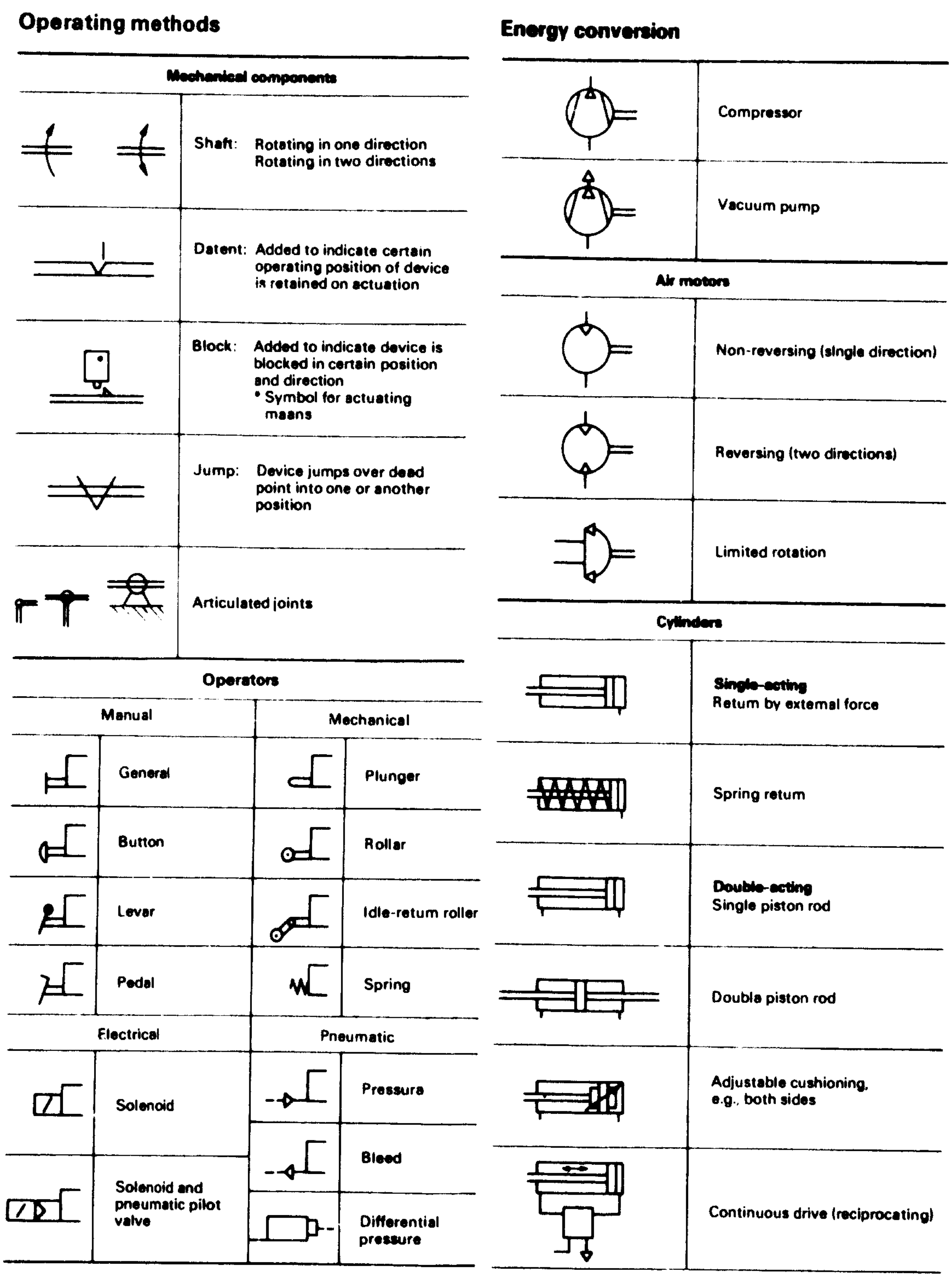
Piston rod of 25 mm diameter is appropriate for a 1000 mm stroke with no danger of buckling.

Required order designation:
DC-70-1000-S1

Thick lines indicate the pneumatic load capacity of the piston rods. They terminate at the maximum piston force (N-piston X maximum permissible (operating pressure) and the longest available stroke. A factor of safety of five is assumed and trunnion mounting considered (unfavourable loading method).

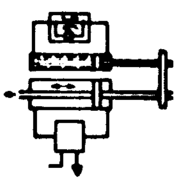
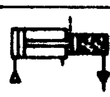
For front flange mounted cylinders the permitted maximum stroke may be increased by 50%.

ANNEX III/1

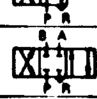


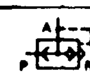
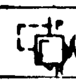
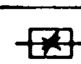
Summary of common pneumatic graphical signals (standardized in DIN 24300)

ANNEX III/2

	Feed unit with continuous drive and hydraulic check cylinder
	Intensifier (air-hydraulic)
	Air-oil reservoir

Energy control and regulation

Directional valves	
	2/2-way valve Flow P to A closed in normal position
	2/2-way valve Flow P to A open in normal position
	3/2-way valve Flow P to A closed in normal position
	3/2-way valve Flow P to A open in normal position
	3/3-way valve Closed center (all ports closed in normal position)
	4/2-way valve
	4/3-way valve Closed center (all ports closed in normal position)
	4/3-way valve Open center (operating outlets B and A open to exhaust. Inlet P closed in normal position)
Non-return valves	
	Check valve

	Shuttle valve
	Restrictor check valve, adjustable restrictor (speed control valve)
	Quick-exhaust valve
	Two-pressure valve
Pressure control valves	
	Pressure limiting valve
	Sequence valve
	Pressure regulator, no relief port
	Pressure regulator, with relief port
Flow control valves	
	Restrictor valve
	Orifice valve
	Adjustable restrictor valve
	Restrictor valve, mechanically adjustable by lever actuator, spring return
Shutoff valve	
	Simplified symbol

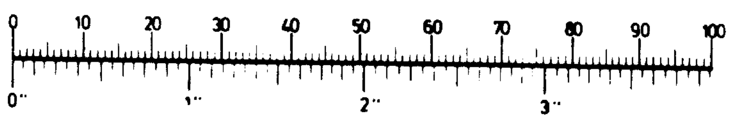
Identification of ports

Working outlets	A, B, C ...
Air inlet, air main connection	P
Exhaust, relief	R, S, T ...
Leakage liquid	L
Control or pilot lines	Z, Y, X ...

ANNEX IV/1

Length

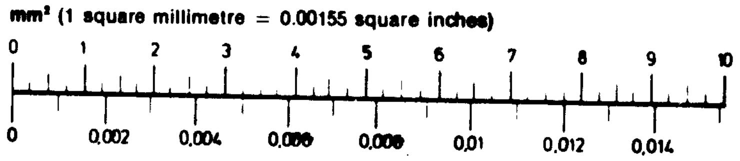
mm (1 millimetre = 0.0394 inches)



in. (1 inch = 25.400 millimetres)

Area

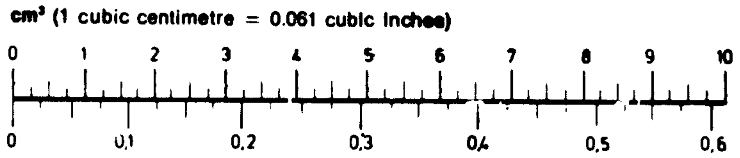
mm² (1 square millimetre = 0.00155 square inches)



sq. in. (1 square inch = 645.2 square millimetres)

Volume

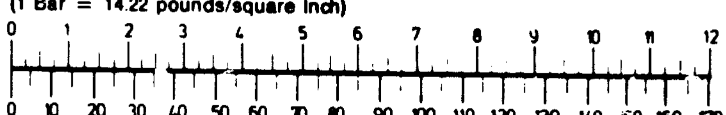
cm³ (1 cubic centimetre = 0.061 cubic inches)



cu. in. (1 cubic inch = 16.387 cubic centimetres)

Pressure

bar = 10^5 Pa = 0.1 MPa (1 Bar = 100 000 Pascal)
(1 Bar = 14.22 pounds/square inch)

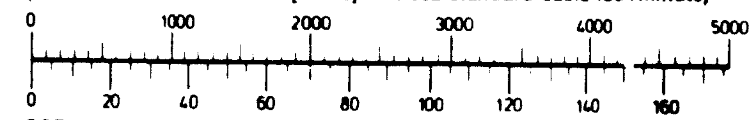


PSIG (1 pound/square inch = 0.070 Bar = 7030 Pascal)

ANNEX IV/2

Flow capacity

l/min (1 litre/minute = 0.0353 standard cubic feet/minute)
(1 cubic centimetre/second [cm³/s] = 0.002 standard cubic feet/minute)



SCFM (1 standard cubic foot/minute 28.316 litre/minute)

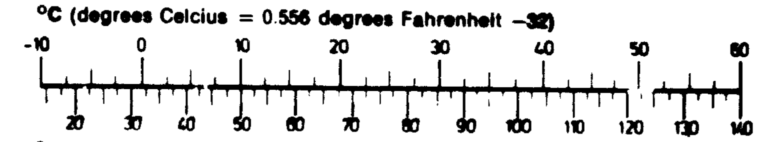
Weight

kg (1 kilogram = 2.202 pounds)

lb. (1 pound = 0.454 kilograms)

Temperature

°C (degrees Celcius = 0.556 degrees Fahrenheit −32)



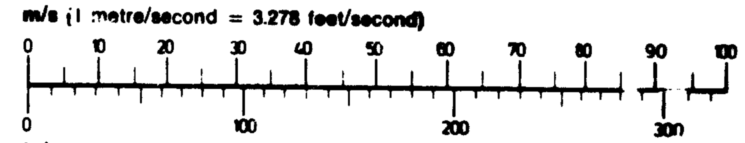
° F (degrees Fahrenheit = 1.8 degrees Celsius +32)

Force

kp (1 kilopond = 9.81 kilogrammetre/square second)

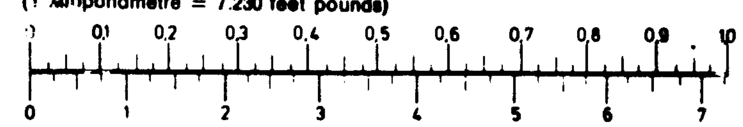
Miscellaneous

m/s (1 metre/second = 3.278 feet/second)



ft./s. (1 foot/second = 0.305 metres/second)

kpm (1 kilopondmetre = 9.81 Joule = 9.81 Newtonmetre)
(1 kilopondmetre = 7.230 feet pounds)



ft.lb. (1 foot pound = 0.1383 kilopondmetre)
SW = width over flats of hexagonal nut (hex)

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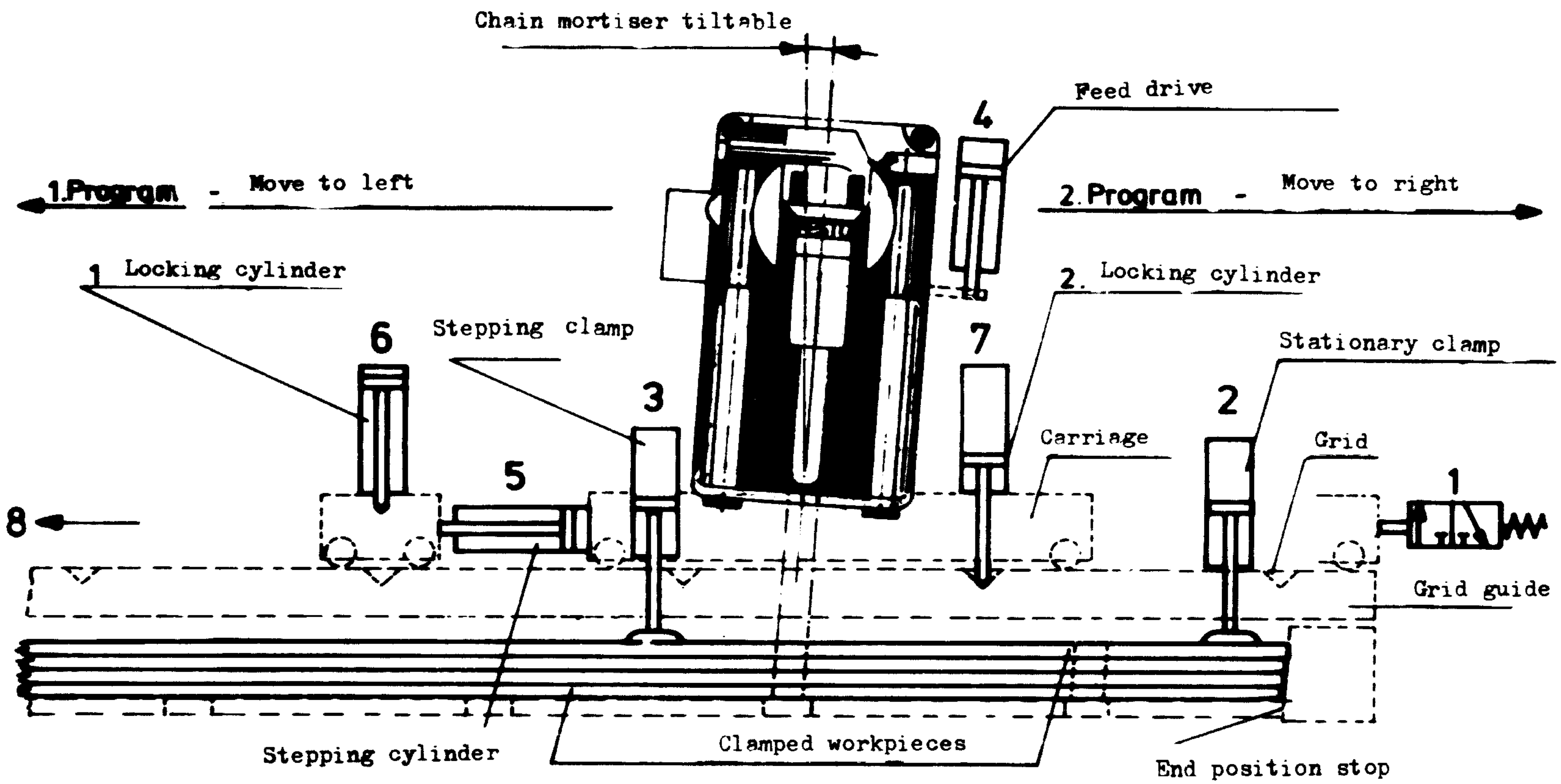


Working direction

Note: Numbers 1–8 correspond to those on **Schematic**

Fig. 2

d. The work piece clamp consists of two pieces. The stationary part is activated for the whole operational cycle. Whereas the movable part mounted on the larger transport carriage is activated during the forward feed to the next step position of work piece. Workpieces are clamped with pressure shoes from the front and from above to ensure firm anchoring during machining.

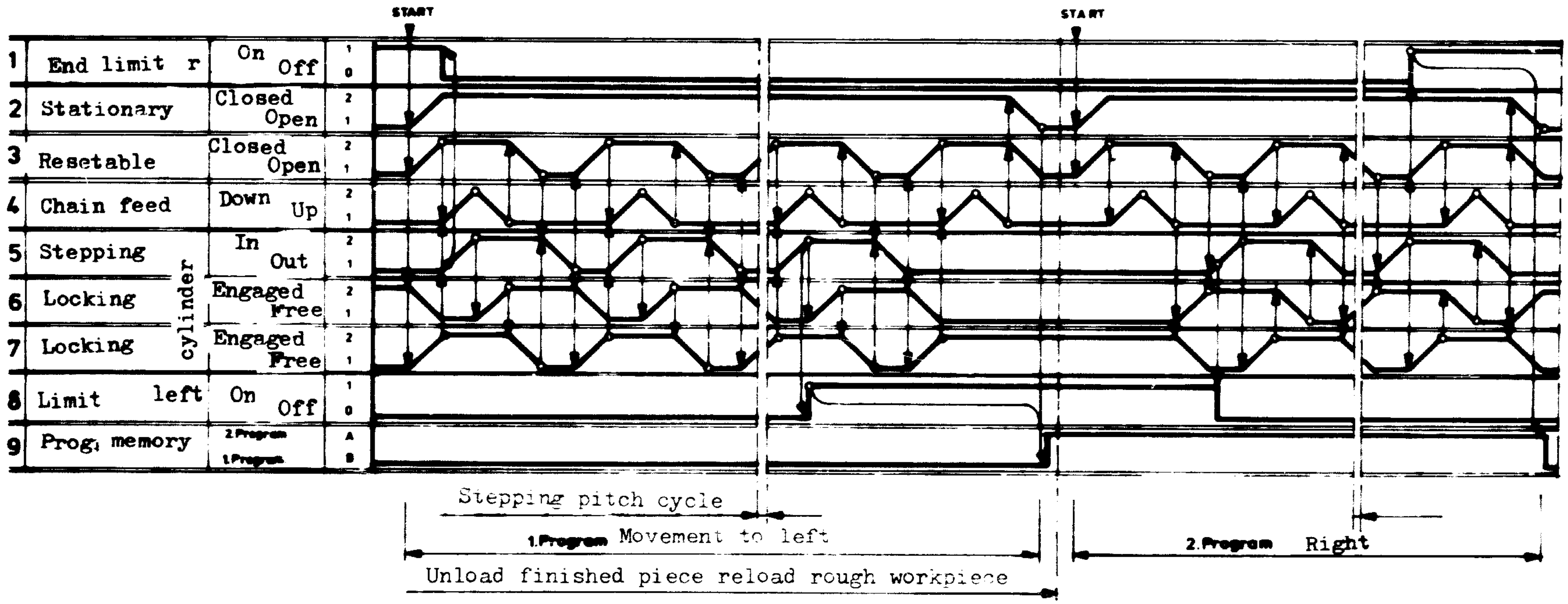
e. Carriage stop holds the carraige firm in the step positions during machining. The carriage feed cylinder coupling will accomodate various step pitches which can be chosen to suit different requirements.

f. Controlconsole contains all pneumatic elements and the front panel has command controls which consist of a stop button and two start buttons. Start button 1 is used to start a normal operation cycle whilst start button 2 allows one to restart the machine after an emergency interruption of operation. The emergency stop button interrupts operation and the mortising attachment is withdrawn.

Compressed air supply to the whole equipment is supplied through a hand operated stopcock. The sequential operational cycle is shown in a schematic form in fig. 3.

Technical data:

Air supply	6 bar
Slot width	4 - 25 mm
Slot length	20 - 60 mm
Mortising depth	max. 175 mm
Slot pitch	according to requirement
Adjustable angle	max. 10°
Work piece length	max. 6000 mm
Mortising drive	AC motor, 2.2 KW capacity
Cycle time	8 - 12 seconds, dependent on feeder drive speed by milling 4 work pieces together, time per slot is reduced to 2 - 3 seconds per slot.
Air consumption	approx. 200 l/min
Weight	approx. 1000 kg



Operational cycle diagram

Fig. 3

1 OF 1

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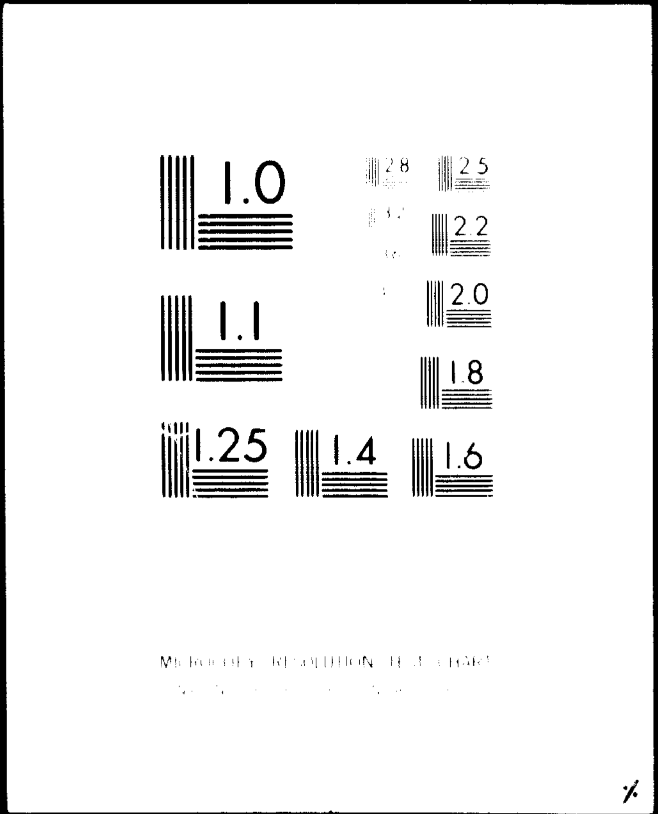
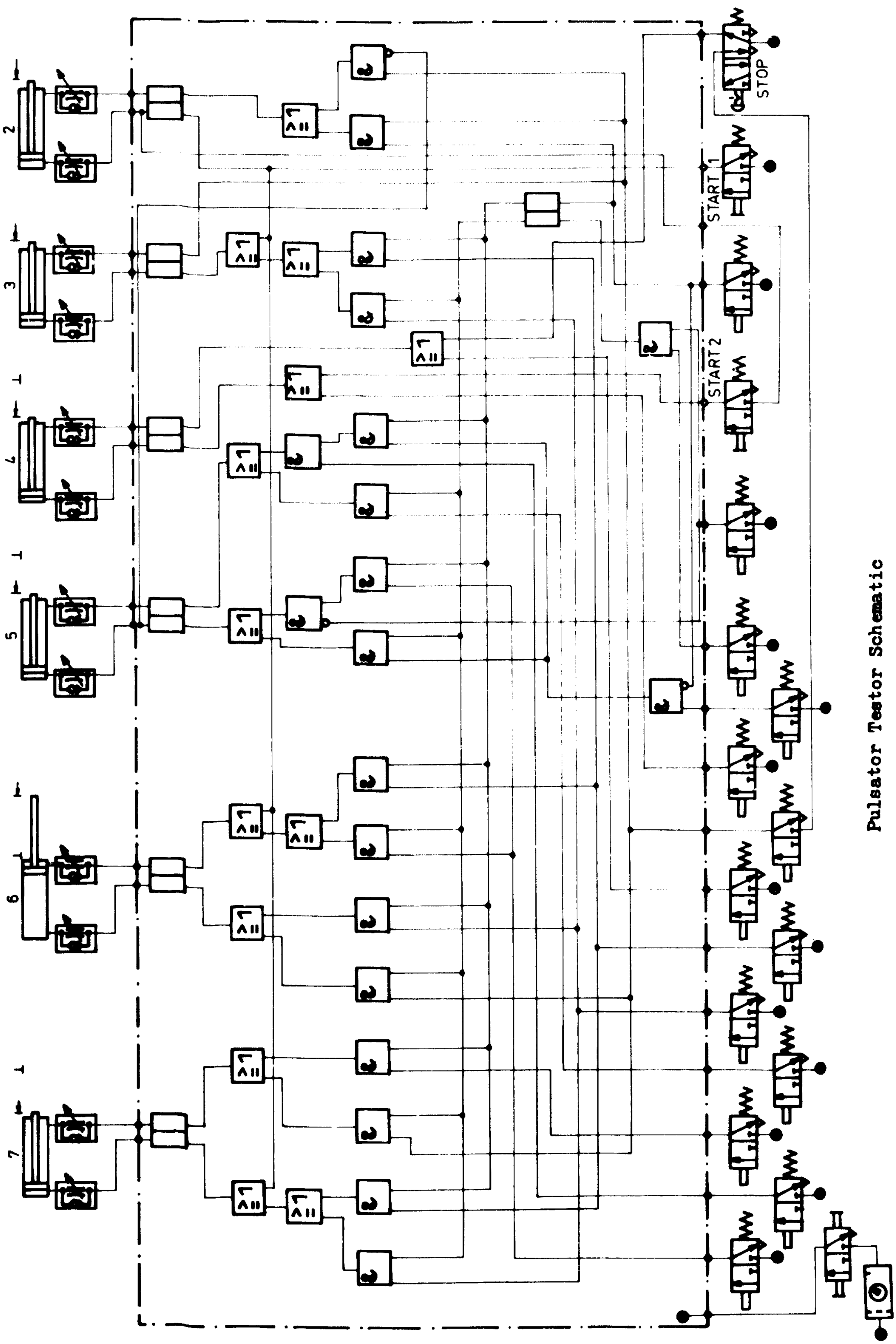


24x

D



Pulsator Testor Schematic

Fig. 3.1

2.1.1 Costing

			DM
a)	1 old (6 years old) mortising machine (≈ 5000,- DM new value)	Current value	2.500
b)	Designing time for modified machine	121 hours	
c)	Preparation of machine		6.650
d)	Pneumatic fitting		3.740
e)	Assembly time for the pneumatic control system	78 hours	

2.1.2	Purchase price of new special machine	estimated	27.000
2.1.3	Prior production work time	12 sec. per mortise	
	Current production time	3 sec. per mortise	

2.2 Another example shows application of pneumatics to a wide belt sanding machine

Object of exercise is to extend the working life of the sanding belt and to produce a "super finish effect" on the work piece. By imparting an oscillatory movement to the sanding belt loose sand particles are more readily removed. Continuously variable adjustment of the oscillatory movement is desirable and is dependent upon grade of sanding belts in use.

Sanding belts of up to 2000 mm wide are used in the furniture industry and the oscillatory movement must be applied in a direction at right angles to the motion of the belt.

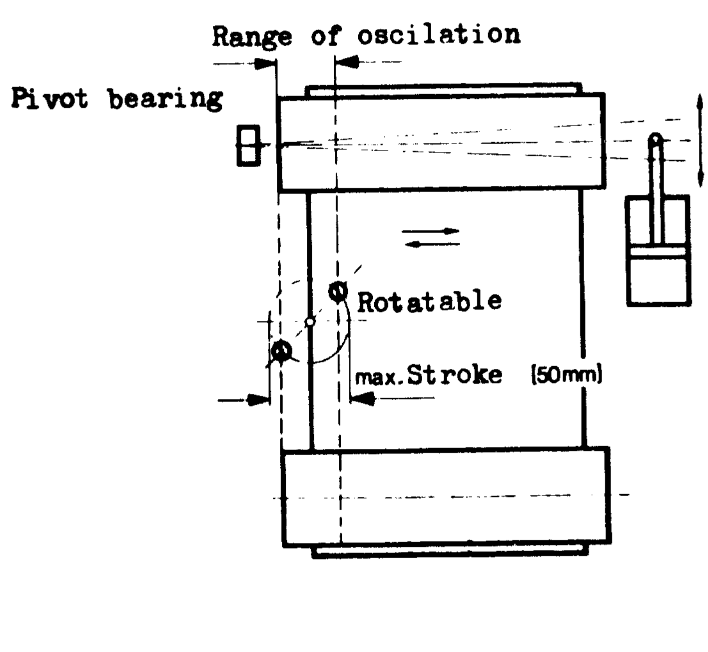


Fig. 4

Various manufacturers of wide belt sanding machines have adopted differing techniques and methods for the oscillatory movement. Pneumatic systems are in general widely used for this purpose, whereby a pneumatic cylinder is used to move the axis of a belt sander roller at one end, about a pivot center at the opposite bearing, thus forcing the belt to move over to the left or right on the roller.

When the cylinder pushes the roller upwards, the sanding belt moves to the left and when the cylinder pulls the roller axis downwards, it moves to the right. Continuous to and fro operation of the cylinder thus causes an oscillatory sanding action in conjunction with the speed of sanding belt.

In one example of such a machine the pneumatic control system used a high pressure air nozzle for sensing the position of the belt. The nozzle with a 2 mm opening being mounted under the belt, movement of the belt covers and uncovers the jet from the nozzle thus producing a control signal to move the roller axis setting. The jet of air from the nozzle was sensed in a spoon shaped collecter and directly operated a four way pneumatic spring return type valve which in turn controlled the cylinders acting upon the roller axis.

The oscillatory movement of the belt then covered the nozzle again, the spring return four-way valve returned to its original position, till the nozzle was once again uncovered. Oscillations are in this way dependent upon the whole inter-play of belt movement and speed, roller position (alignement) and nozzle. With an air supply of six bars as required for satisfactory operation of the four-way valve 360 1 of air was required per minute. This high rate of air consumption was the reason for wanting to change the control system to a low pressure operating system.

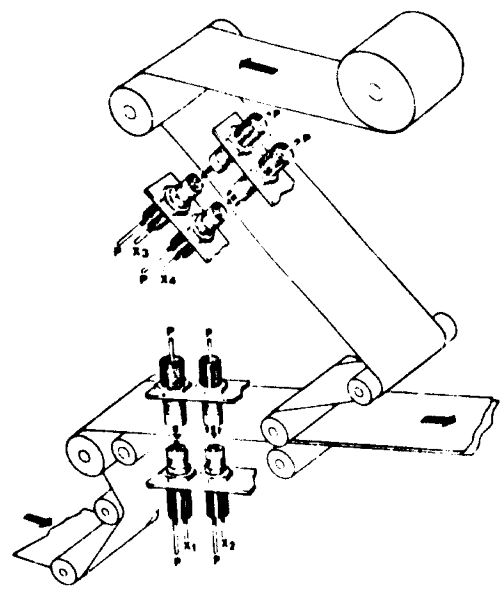


Fig. 5: Sanding belt tracking control.

Sensing of belt edge position with low-pressure air barrier and nozzle sensors.

A double belt system is shown here with two low-pressure air nozzles and sensors for each belt. One sensor is set such that the low-pressure air jet reaches its sensor beyond the edge of the belt and produces a signal. The second one is set further in the distance between the two positions provides a deviation for the belt edge position and could be some tenths of a milimeter to say a couple of milimeters. Air flow to the second sensor is interrupted by the belt. Therefore, no signal is present from the second sensor. When the belt moves too far to the right then the air jet from nozzle 2 will reach sensor 2 and a signal will also be given from sensor 2.

We will now have two signals which through an "and" gate and control system alter the roller setting so as to move the belt back towards the first nozzle. Similarly should the belt move too far to the left then the air path to the first sensor is interrupted and both reset in the oposite direction to move the belt back to the right.

One can observe the following sequence:

Sensor 1	Sensor 2	Roller axis movement
1	0	0
1	1	+ 1
0	0	- 1

The distance between the two sensors near the edge of the belt determines the range or amount of the oscillatory motion of the sanding belt. By altering the distance between the two sets of nozzles and sensors it is possible to alter the amount of the oscillation. By mounting both sets of nozzles and sensors on a rotatable plate, one can easily adjust the amount of oscillation by simply rotating the plate thus achieving a continuously variable facility. A 0 - 50 mm max continuously variable oscillation range was achieved on the machine here described.

The newly installed pneumatic control system allows the precise presetting of required amount of oscillatory motion. Low-pressure nozzle and sensor elements in addition drastically reduce the compressed air requirements and energy consumption. They require a working air pressure of only 0.2 bar normally, in this application, however, a working pressure of 0,5 bar was chosen to ensure immunity from any influence from the strong suction currents of the built-in suction cleaner.

With a nozzle width of 1,5 mm and pressure of 0,5 bar some 50 l/min of air is required. This is only 14 per cent of earlier consumption i.e. a saving of some 86 per cent of compressed air requirements. Sensors and nozzles are mounted on the main machine frame. Other pneumatic control system elements are mounted on a panel and fixed to the machine, on this panel are mounted all elements including the low-pressure regulator filter and gate valves etc. Energetic moving parts of the control system are mounted in the machine frame. Two sanding belts of different grades are controlled on the machine. The cylinder strokes required are quite short as only a slight alteration of the roller axis is necessary.

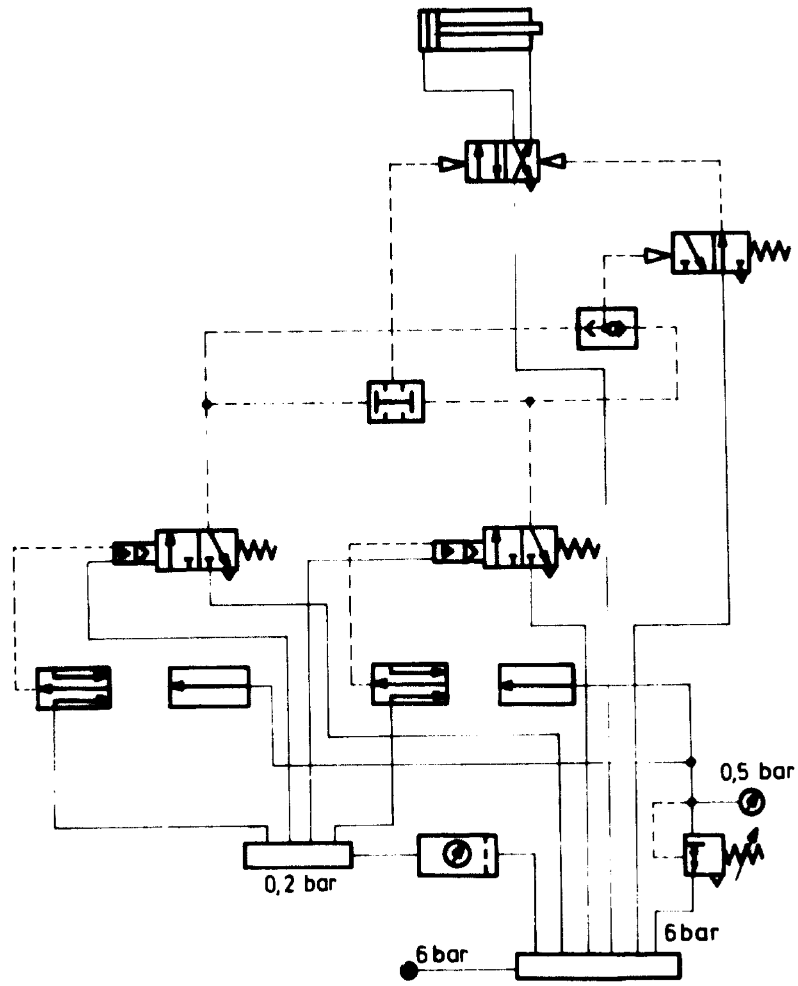


Fig. 6 - Circuit diagram of the pneumatic control system

The basic control elements are duplicated for each controlled roller. In the works where this modification was carried out eight such complete systems were installed and since 1974 have been operating trouble free at a rate of some 30.000 operations per working day. The extent of saving of compressed air:

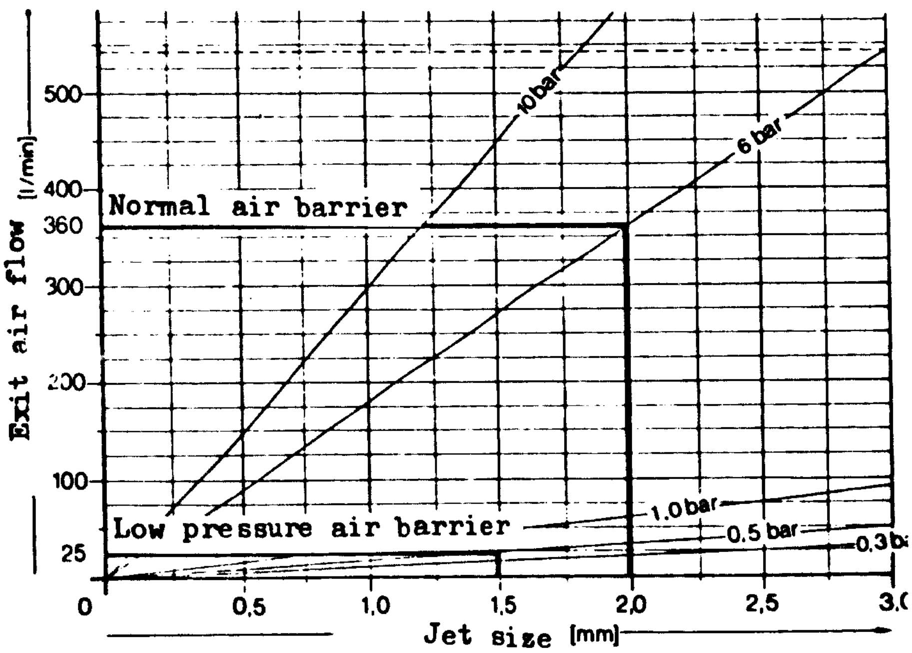
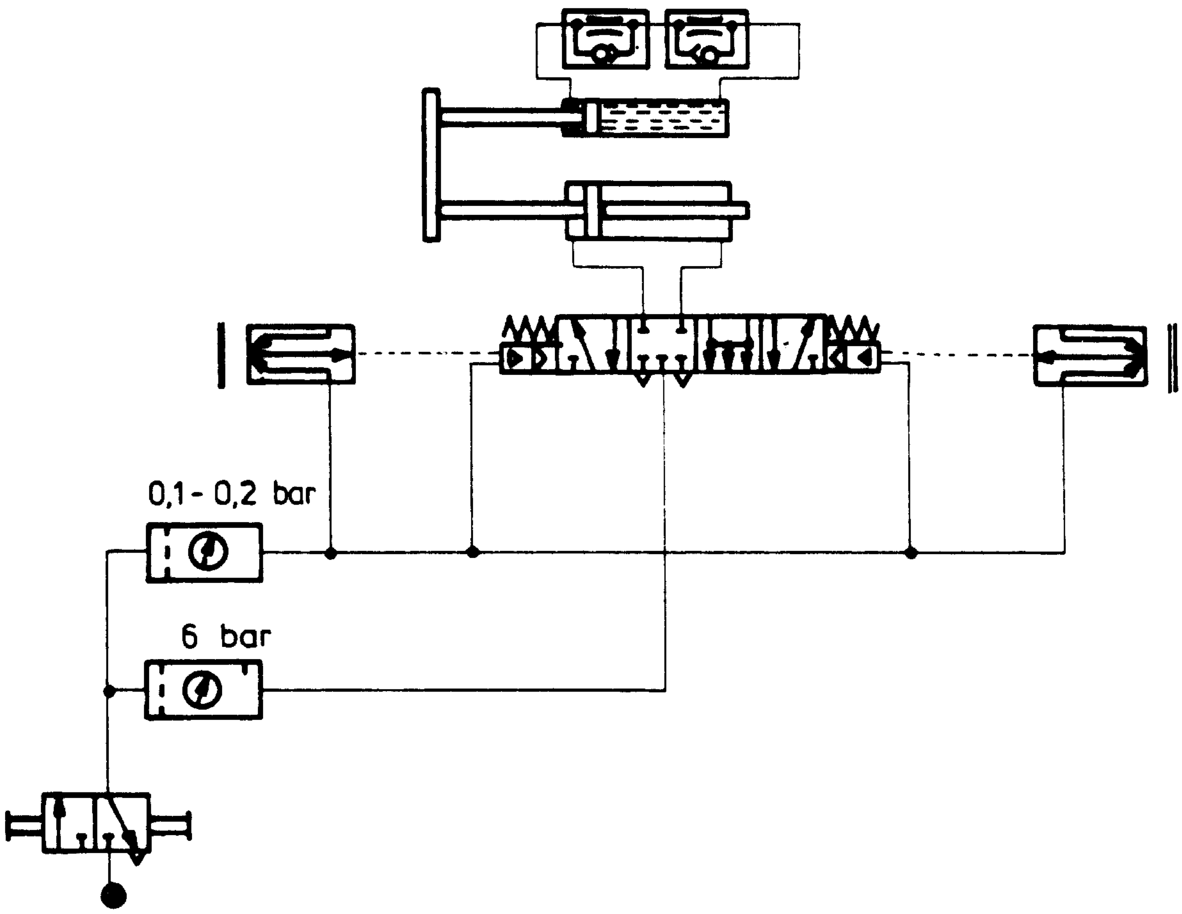


Fig. 7 - Air consumption versus pressure for various jet sizes.



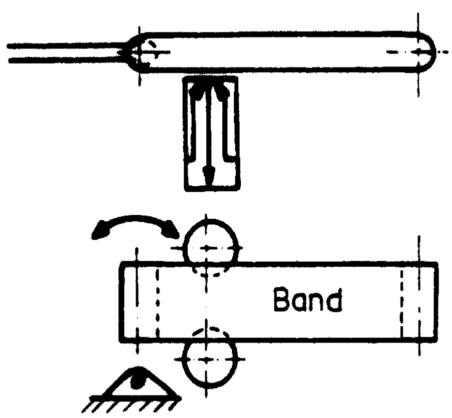


Fig. 8 - Another variant for belt sander oscillation control.

2.3 Further examples will illustrate the range of possible simple ideas that can be applied in low-cost automation

Automatic press clamp and drilling jig

This special purpose machine was designed for assembling drawer parts and simultaneous for boring the lock holes. Various clamping programmes can be selected by the hand operated programme selector knob. Programme start signal is initiated by means of a foot operated pedal valve.

Five electro pneumatic drilling plus feed attachments are provided and controlled pneumatically. The drilling attachments can be adjusted and preset in any position and can also be fitted out with multi-splindle heads.

Assembling of drawer parts is done in a frame clamp. Five pneumatic cylinders are provided for holding and clamping together with two cylinders providing a positioning function.

The special machine is used for rationalised production in small series manufacture but could also be used to advantage for larger scale mass production runs. Assembly times are short and presetting or programming of the machine is easy and quickly achieved.

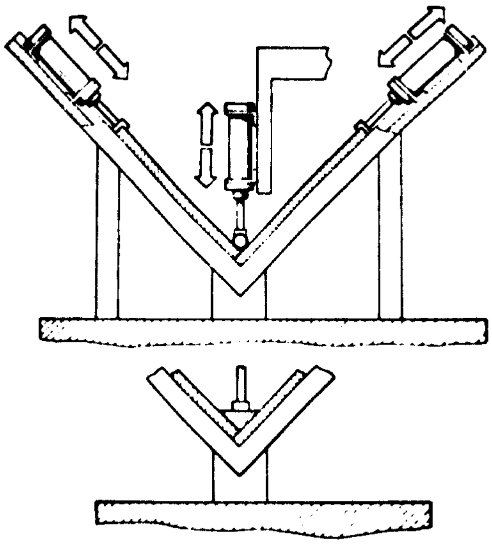


Fig. 9 - Jig used for corner jointing

In woodworking the tool heads, milling, mortising, boring, sanding etc. are normally electrically driven whilst other functions such as clamping, drive-feed, positioning, transport etc. in pneumatically operated equipment are achieved by means of pneumatically operated cylinders. This is the case here for all given examples of milling machines.

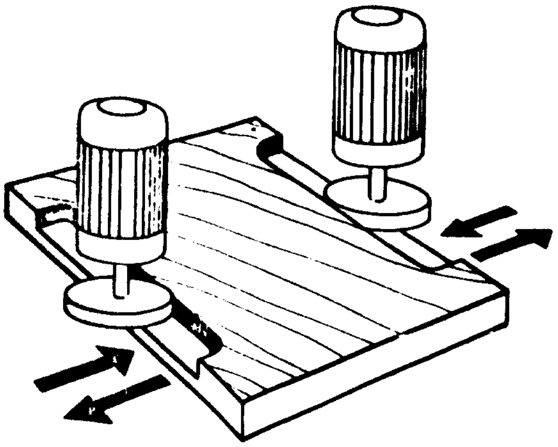


Fig. 10: Double-edge jump profiling.

In double-end profiling equipment the work piece is fed through the machine while edges are profiled simultaneously. Double acting pneumatic cylinders move the profiling cutters in a jump action to machine stopped profiles. Fig. 10 indicates with arrows the directions in which the pneumatic cylinders move the tool units.

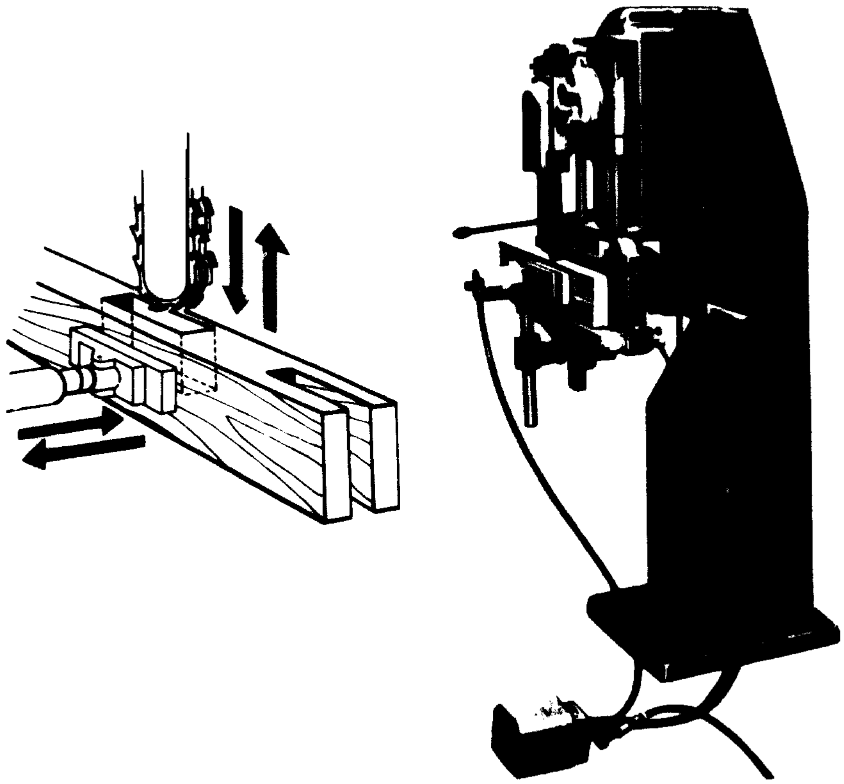


Fig. 11 - Chain mortiser.

The chain mortising machine is controlled by a pneumatic foot pedal allowing the operator both hands free for locating the work piece. The foot pedal initiates operation of the spring return single acting clamp cylinder as well as the double-acting feed drive cylinder controlling the chain mortisehead. Feed-rate is readily adjustable by means of a speed regulating valve.

Pneumatic control system of the corner locking and finger jointing machine is functionally similar to that of the chain mortiser. The tool shaft is fixed while the work piece table performs a rise and fall action. The work table automatically returns to its rest position after each work cycle and the clamp cylinder releases. Each work cycle is restarted by the foot pedal.

The usually flat or squared work pieces in woodworking lend themselves readily to gravity hopper feed.

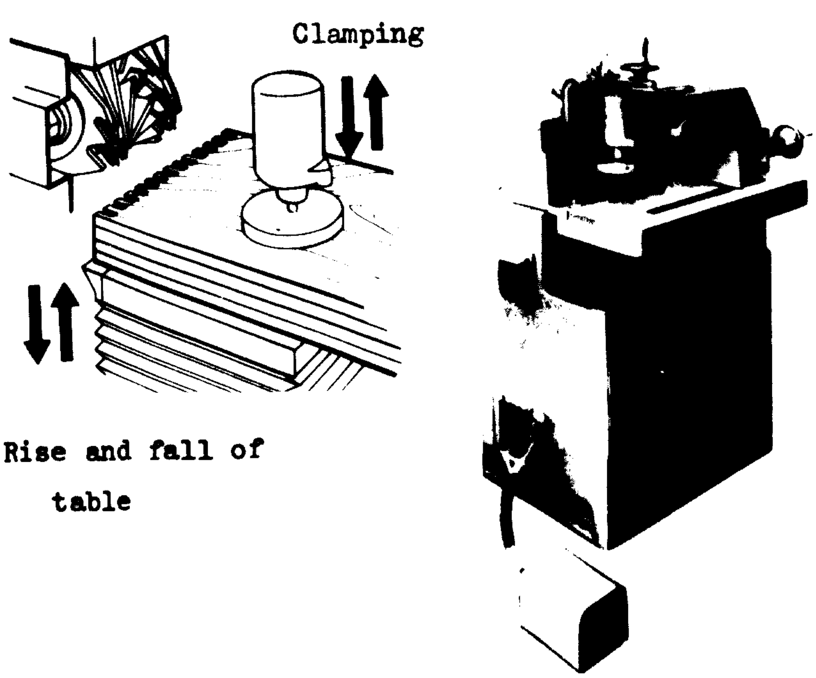


Fig. 12 - Corner looking and finger jointing machine.

Distr.
LIMITED

ID/WG.296/2/Rev. 1
11 May 1981
ENGLISH

United Nations Industrial Development Organization

Seminar on Wood Processing Industries
Cologne and Hannover, 16 - 30 May 1979

CALCULATION OF PNEUMATIC SYSTEMS FOR FURNITURE AND JOINERY INDUSTRIES *

by

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and

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Work pieces stacked into a hopper can bery easily be fed one by one automatically to the machine bed for machining.

In a vertically loaded hopper workpieces can be loaded as required from above where gravity alone will drop them down in position and the ejector mechanism (air cylinder usually) automatically advances Fig. 13. Single stack vertically loaded hoppers are more general as dictated by the larger work piece sizes. Hopper size (number or work pieces held) depends upon machining speed (parts per unit of time). For smaller wori pieces multi-stock hoppers can be constructed allowing for higher rates of production with reasonable time intervals for restacking the hopper (Fig. 14). Multi-stack vertical stores also allow a larger number of pieces to be stored in a given height of the hopper. Some machines may require a lift hopper for feeding work pieces from the top of the stack Fig. 15. Such a construction does not readily lend itself to loading during operation of the machine. A number of hoppers are then necessary which can be loaded separately and then brought to the machine to replace empty pallets.

Movements and positional changes

All fixtures or attachments for the feeding or positioning of workpieces imply movement and change in position. These include such items as conveyors, feeder units, drive units and embrace a large number of diverse individual mechanisms and devices. Conveyor belts, conveyor chain - roller beds or slideways will not be discussed here as these are normally purchased complete.

Some idea of the range of pneumatic fixtures and facilities that can be provided or built on to machines can be obtained by looking at existing products and state of the art. Sketches will show some pneumatically operated equipment grouped together according to three functions.

The operations of feeding-in and distribution generally also implies the further function of separation.

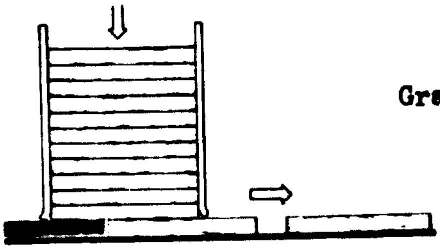


Fig. 13

Gravity Hoppers

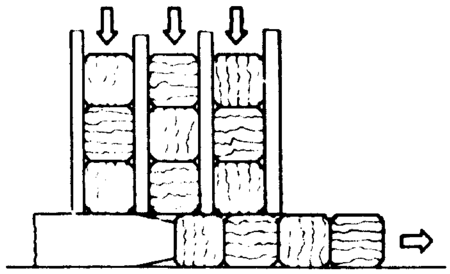


Fig. 14

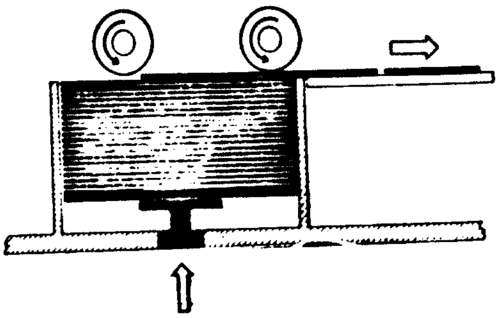


Fig. 15: **Lift Hoppers**

Hopper feed systems

Seperation or selection is usually combined with the feed-in function and often the same device simultaneously performs both operations. Machining of separate piece parts (as against continuously fed long stock) are fed-in one at a time as the machine generally can only machine individual pieces or in some special cases a group of pieces when held together. Selection and feeder action is combined in stack hoppers where the principle of operation is the same irrespective of general construction. Pieces are stacked one on top of another and the lowest or upper most piece as may be required is selected and pushed out when called for. The pneumatic cylinder to which is attached an appropriately shaped and length of ejector arm operates in rythm with the machine cycle pushing out and feeding in a work piece as required. The operation cycle is usually set and originates from the machine that follows the hopper. A start signal can simultaneously be given to start other related operations.

Command signals can also be initiated by a chain link in a chain driven conveyor which carries the work pieces to the machine. Cycle sequence can thereby also be a function of time.

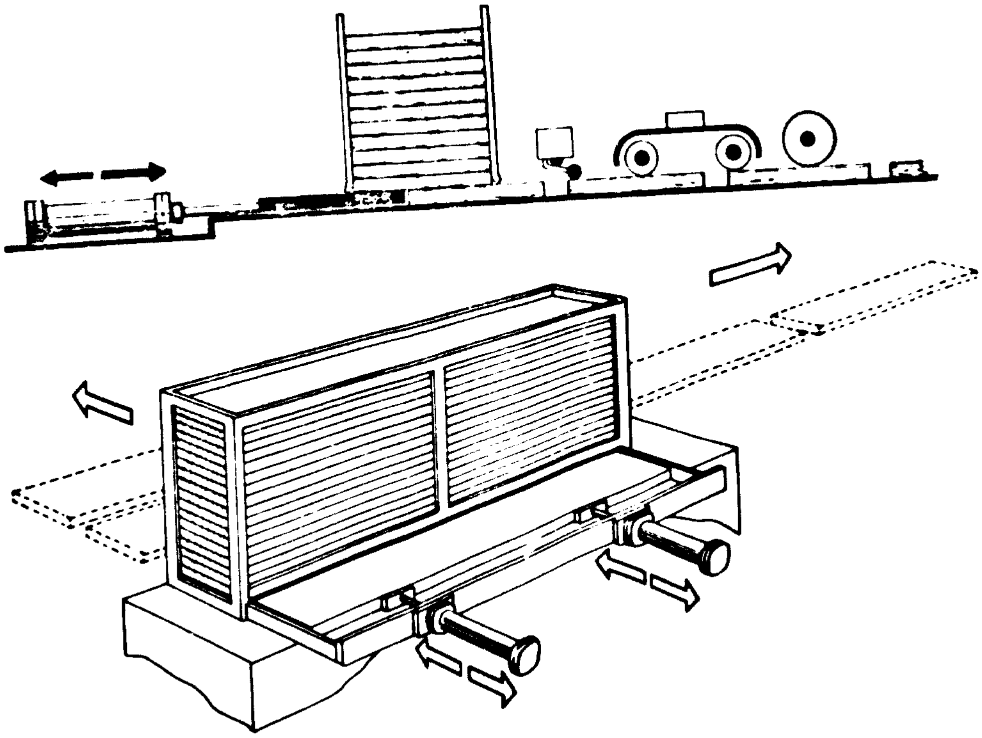


Fig. 16 - Stacked hopper with pneumatic ejector operating cross wise the board axis. Additional optional feed can also be provided along length axis.

For work pieces with an edge ratio greater than 1:3, it may be better to arrange for the work pieces to be ejected along their shorter axis. Where the work piece surface is smooth, it may still be possible to push it along its longer axis particularly when not too many pieces are stacked on top. When ejection of the lower workpiece against the friction and weight of others stacked on top may be problematical then ejection along the shortest axis may be better even when a further direction change by means of a further fixture is necessary.

Two or more pneumatic cylinders can also be used together, instead of 1 large one, for extra large or heavy pieces. Thecohoice of one or more cylinders depends upon various factors and a detailed study of a given application and the corresponding selector mechanism is often necessary to decide upon the most apt configuration. Other details to consider are tolerances and range of movement required, various mounts swivel joints fork ended couplers are available for cylinders to suit mechanical construction adopted and to allow suitable flexibility in the coupling.

Longitudinal ejectors naturally require a longer stroke pneumatic cylinder and more space. The cylinder can be mounted so as to eject from the right hand side or left as preferred or if necessary to pull instead of push.

In the latter case, the pulling arm and the cylinder will need to be mounted under or above the stack.

Feeder units of this sort with a single stroke length of up to 2 m for various functions are well established.

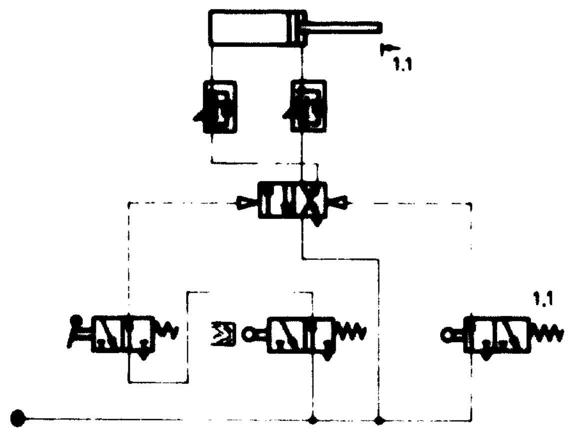


Fig. 17 - Cylinder feeder control

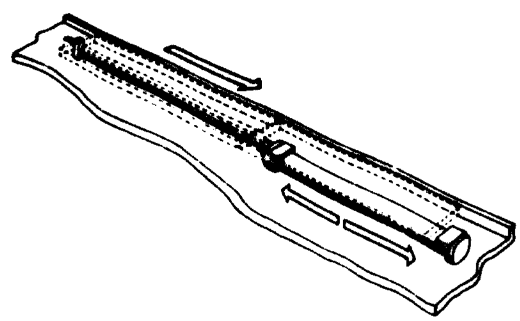


Fig. 18 - Selection and ejection lengthwise

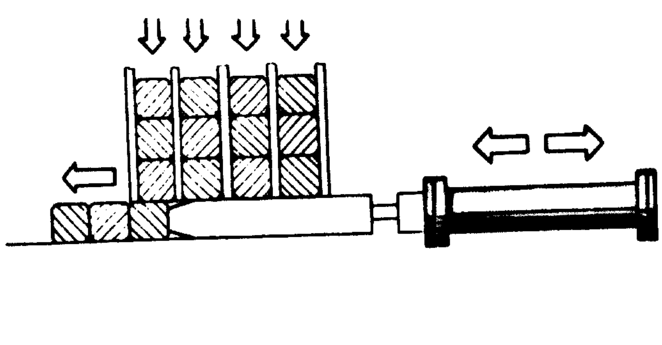


Fig. 19 - Multi-stack hopper with pneumatic cylinder pusher. Ejector construction and operation similar to standard stack or gravity feed store hopper but with multiple work piece delivery.

Multi-stack storage hopper: Pneumatic cylinders can also be used for selecting and feeding workpieces from these but the construction and principle of operation, number of cylinders will vary, dependent upon whether work pieces are called for individually or in batches.

Cylinder stroke is selected to match the total length of the stack hopper (Fig. 19) in this construction normally as many pieces as chanels provided are fed out each stroke, in Fig. 19, 4 are shown unless some chanels are empty. Additional external means of control can, however, be provided to limit the number of blocks (work pieces) pushed out to one or more as may be required. A simple way of achieving this when workpieces are led on to the machine at right angles to the stack hopper ejector feed axis is by means of a guide rail stop set as required to one or more blocks wide.

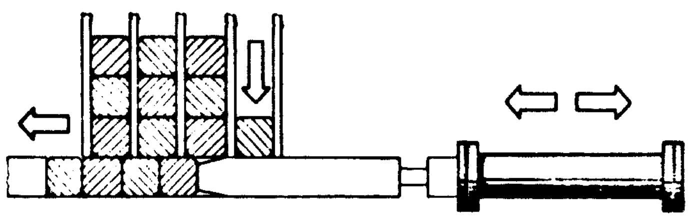


Fig. 20

The cylinder always starting from its fully withdrawn position pushes out one block to the stop rail per cycle down to the last block irrespective of the **stack** order.

A multi-stack-hopper has certain advantages where the time interval between refills is irregular due to its relatively larger reserve capacity.

Provision can also be made for a pneumatic signal to be given to stop operation or give a warning signal etc. when the number of pieces in the hopper falls below a pre-set number. This can be **designed** and set to suit individual machine requirements.

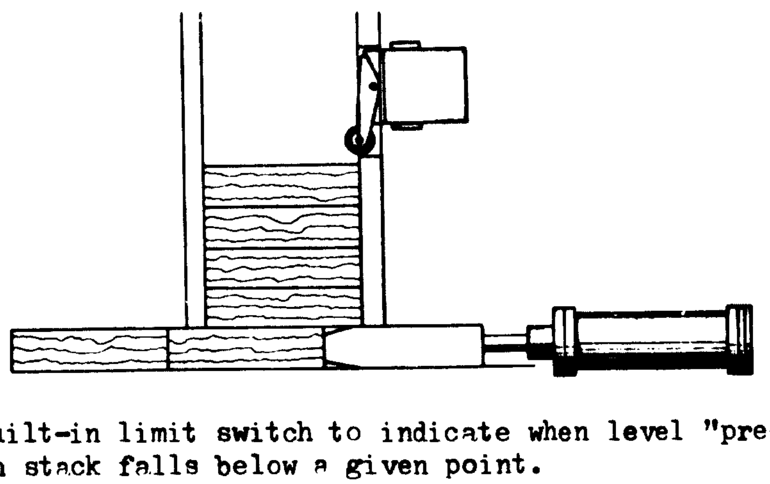


Fig. 21 - Built-in limit switch to indicate when level "pre-set number" in stack falls below a given point.

In the multi-stack hopper of figures 19 - 20, the workpieces are shown with rounded corners, hoppers of this sort should provide a loose fit and the workpieces need to have slightly rounded corners otherwise blocking and jamming can occur.

Where workpieces have sharper corners practical experience has shown that a canted construction as in Fig. 22 is desirable. An angle of just 1 - 3^{o} is usually sufficient to avoid jamming.

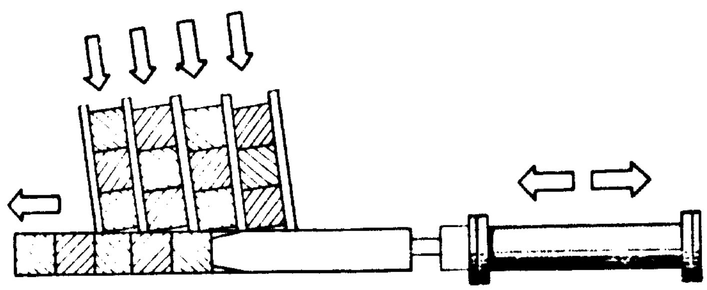
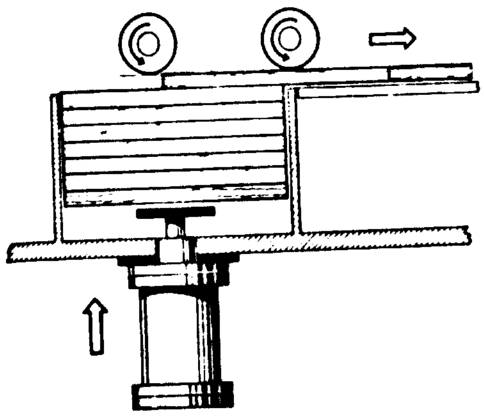


Fig. 22 - Multi-stack hopper construction for sharpercornered workpieces. The stack guides are canted towards the direction of push from the cylinder by some 3^{o} degrees. Thus reducing the danger of jamming.



"Lift Hopper"

Fig. 23 - Stack-hopper feed-out at top. The pneumatic cylinder holds the stack against the feed mechanism above, air pressure can be pre-set over a wide range to suit requirements refilling from top in-situ not possible.

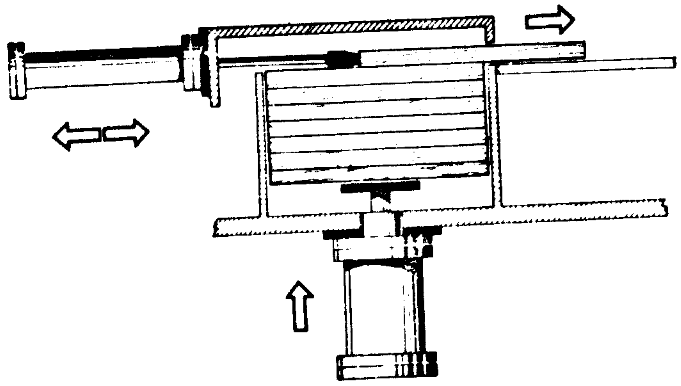


Fig. 24 - Channel/stack hopper feed out at top or side tensioning and push-out by means of pneumatic cylinders.

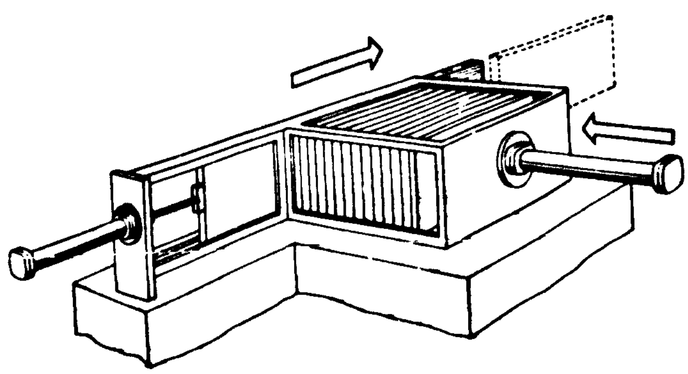


Fig. 25 - Adjustable hopper side feed onto machining bed and end-feed into machining position. Two pneumatic cyliders are used.

Frame clamps are particularly popular in the construction of window and door frames or similar items. The general principle of operation can, however, be adapted to various other production items. The difference only being one of the number of workpieces to be clamped together and of shape. However, one of the most important points is to ensure that various pieces are firmly held together in the frame for the duration of the machine drilling, boring, glueing operation, and during cycle. Fixed form or adjustable frames can be built according to requirements or output quantity. Clamping action is performed by single acting pneumatic cylinders from two sides simultaneously against opposing fixed supports Fig. 26. This is in fact a classic example of a simple frame clamp and can be used vertically or horizontally as required. Horizontal clamps are usually only used for smaller products such as windows, picture frames, furniture parts, door frames, furniture etc. Larger sizes are usually easier to handle in up-right clamps.

3. Pneumatic systems applied in wood processing industries

3.1 Pneumatic controls were first used to solve the simplest operations

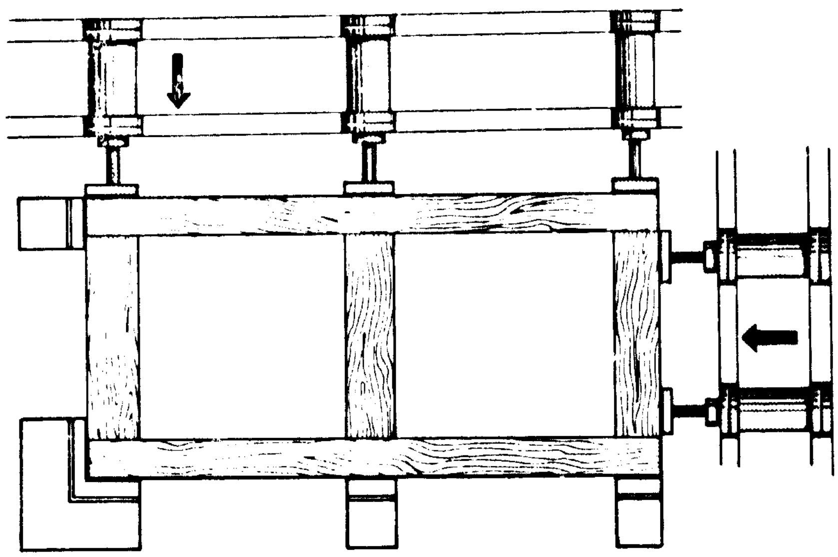


Fig. 26 - Frame clamp which may be arranged vertically, inclined or horizontal. The clamping cylinders are adjustable.

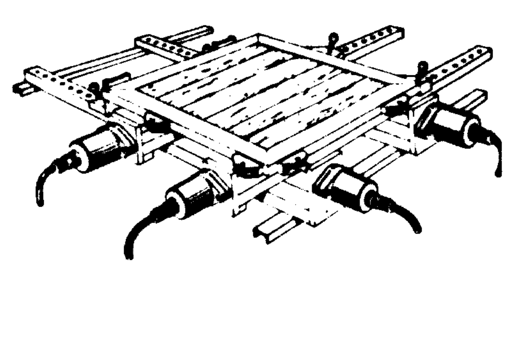


Fig. 27 - Clamping jig with adjustable frame size.

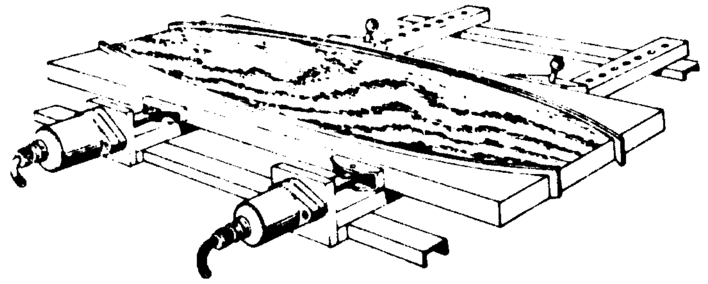


Fig. 28 - Edge lipping press. The width and the shape is roughly fixed by two adjustable fixed stops, clamping is by the two pneumatic cylinders which can be sliding freely over the whole length of the rails.

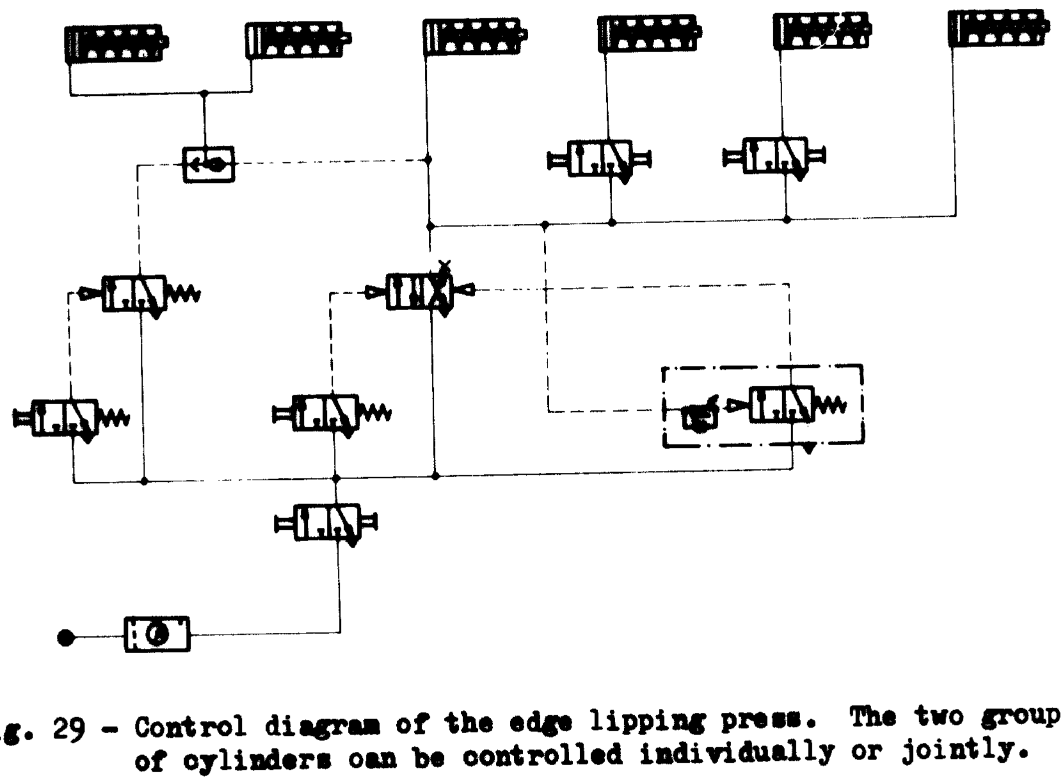


Fig. 29 - Control diagram of the edge lipping press. The two groups of cylinders can be controlled individually or jointly.

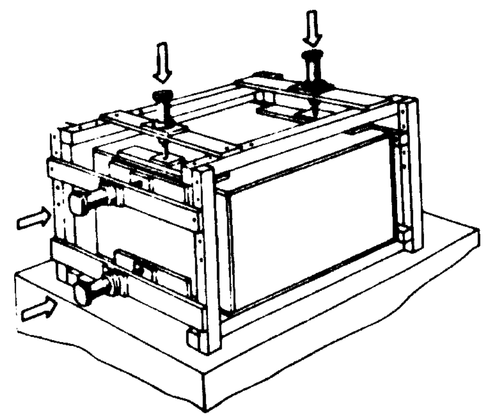


Fig. 30 - Three-dimensional on case clamps can also very easily be oonstructed to suit individual requirements with pneumatic cylinders and controls. Small and medium scale production runs could find use for such jigs. Adjustable runners can also be provided to accomodate different sizes of products.

Jointing presses for finger jointed pieces.

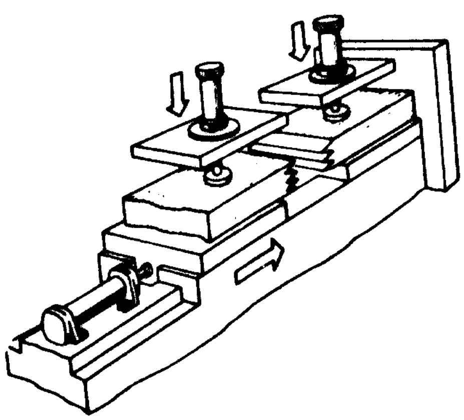


Fig. 31.a - One end fixed the other part driven.

Contents

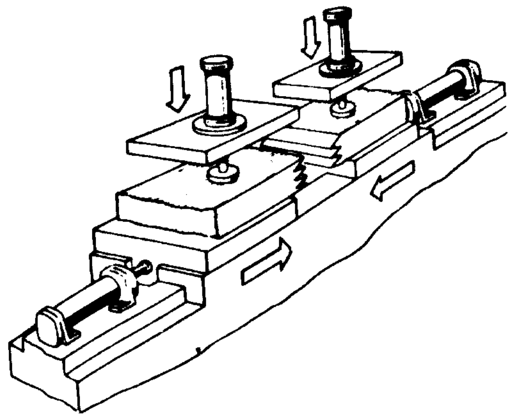


Fig. 31.b - Both parts driven against each other.

3.2 <u>Multi-functional machine with five clamping devices</u>

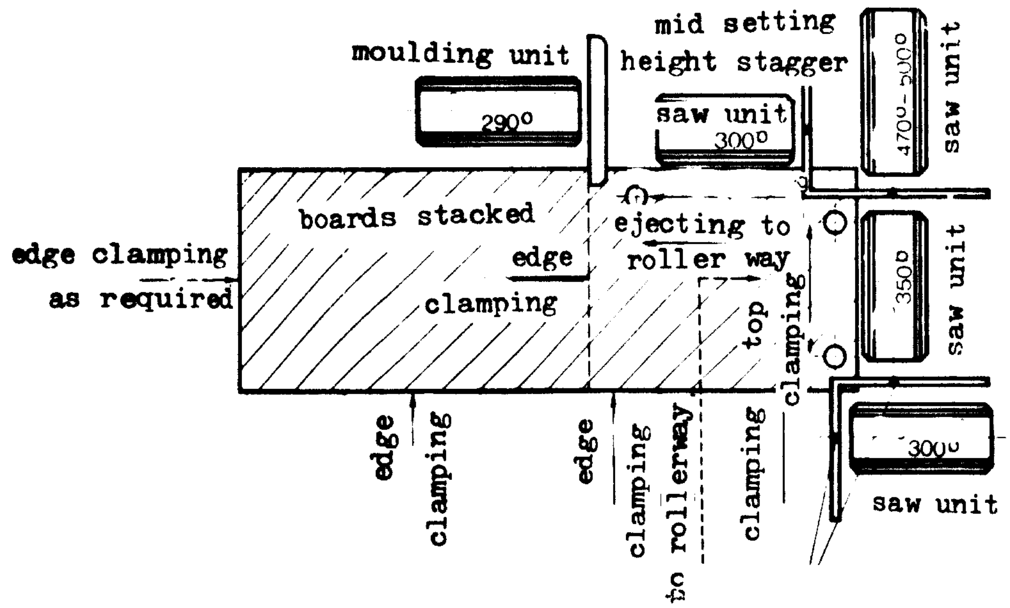


Fig. 32 - The units run at 3000 RPM. Sawing and moulding tools are mounted directly on the motor shafts. Drive and clamping functions all pneumatic.

Panels can be stacked up to 10 deep for machining and are fed into the machine on a roller bed. When a start signal is given from a two-hand control unit the rollers sink down below the work bed level so that they line-up correctly with the feed in position. Simultaneously the stack is clamped down. Drive motors for the units are at rest positioned below the table and move upwards syncronously to start milling, sawing. At end of operation the pneumatic control system is actuated by means of end stop control valves and returns the units again to their rest position below the table. When all units are once again safely withdrawn and at rest below the clamping is released. Should through any reason any one of the units not completely withdraw to its rest position, the stack will stay firmly clamped on the table.

Sawing cutting operation can be stopped by means of an emergency button whereupon the units all withdraw below the table but without the electrical motors being stopped. An electrical emergency stop button is also provided which stops down everything. Automatic shut down occurs when:

a) power supply fails;
b) any one motor is over-loaded;
c) pneumatic pressure falls.

Costing

a)	Designing time complete machine	158 hrs.
b)	Machine parts building and electric parts	12.185 DM
c)	Pneumatic elements	2.320 DM
d)	Assembly time of pneumatics	69 hrs.

3.3 Pneumatic control of a dowel hole boring machine with four selectable programs

The machine program can be pre-selected from four built-in programs to bore dowel holes in panels. Horizontal and vertical boring units can be mounted on a beam. The distance between, positioning and the number in use can readily be changed to suit requirements.

Workpieces are introduced into the machine by hand and clamping initiated by means of a hand or a foot pedal start valve.

Programme can be pre-selected by a knob on the control console. The four program functions are indicated symbblically on the console panel.

A start button on the console panel then initiates the work cycle driving the boring beam into its boring position. The pre-selected boring program then follows, electric drive motors are also controlled through pneumatically operated AC interuptors. Feed drive from two pneumatic cylinders off set through 90° move the boring beam by means of a compound slide.

When bore depth is reached the borers automatically switch over and withdraw and the beam also moves back to its start position.

The finished workpiece can now be released and removed from the machine.

Control system: all control clamping and moving functions are programed in a fail-safe interdependent manner. The emergency stop will stop the machine at any point in the program and all boring heads will safely withdraw to their fully withdrawn wait position. A clamping fault will automatically shut down the machine.

All connections between the machine and the control console are made through a multipol-connector. The complete pneumatic control system in the console is built separately and delivered ready to work and is very easily connected to the machine. Should any mal-function occur, one can in this case connect a spare console in and send the complete faulty console for repairs. More than 600 such consoles have been produced to date and together with the dowel hole boring machine delivered to all parts of the world.

3.4 <u>Example from a feasibility and costing study for a production machine. Board off cuts made re-usable</u>

A recently developed finger joint cutting, gluing and jointing machine combination - short pieces of valuable wood waste can be processed into useful timber. Waste lengths not smaller than 200 mm long widths between 15 - 125 mm and thicknesses of 8 - 70 mm can be used. The waste lengths are joined together in continuous lengths and can be provided to pre-set lengths for manufacture of window or door frames or other items as required. Production sequences of finger joint cutting, glueing, pressing together cutting to pre-set lengths follow one another continuously.

Finger joint cutting (milling)

Two workpieces can be milled simultaneously. With table in its upper position two work pieces are loaded and clamped. The first milling operation takes place with the table moving downwards where the workpieces are removed, turned through 180° and put back in clamped and the second milling operation takes place with the table moving upwards.

Glue spreading

After milling the workpieces are pressed against the glue spreading die where glue is spread into the fingers. The amount of glue can be adjusted by means of a continuously variable control. A pneumatic pump feeds required amount of glue to the die which transfers this to the workpiece.

Pressing and cutting to length

After glue spreading the work pieces are fed into the pneumatic press where they are clamped and pressed together. Individual pieces need only be laid on to the machine bed, a foot pedal control starts up the machine cycle. A saw follows the press which operates when the workpiece length reaches a pre-set length and actuates a pneumatic valve. After cutting to length the finished piece is automatically ejected by means of a pneumatic cylinder.

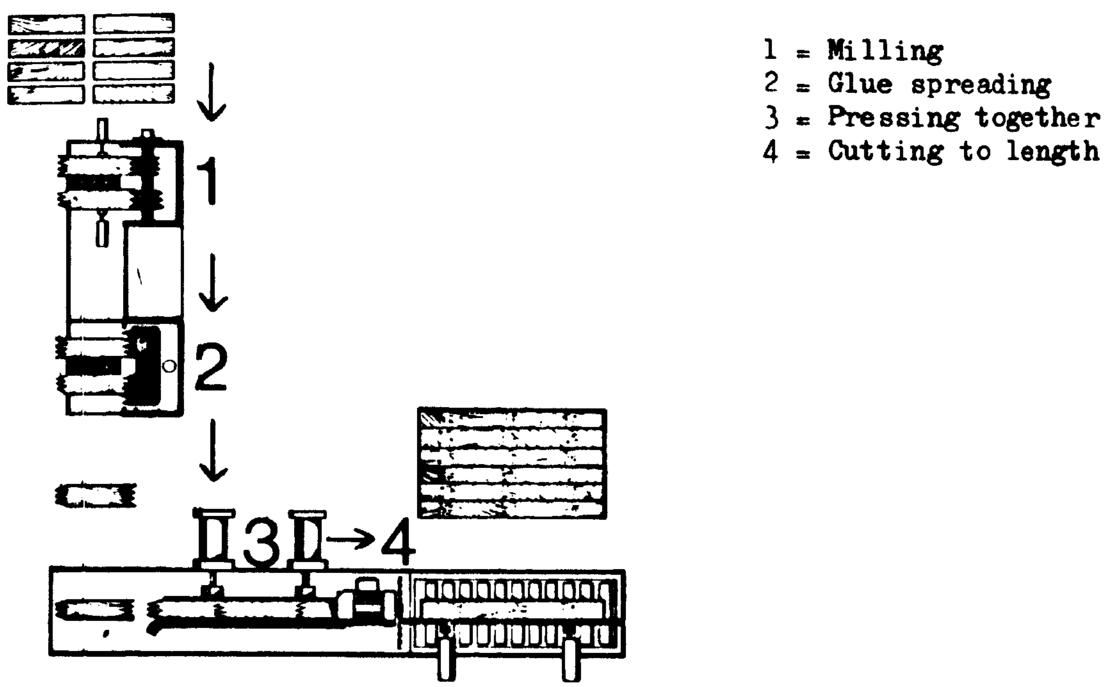


Fig. 33 - Finger jointing plant, consisting of universal milling machine and press with cross-cut saw. Off cuts can be processed into useful timber starting from 200 mm lengths.

Recommended layouts 1 and 2 man operation

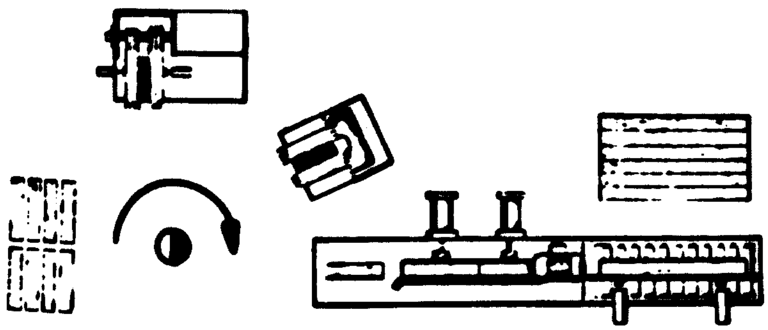


Fig. 34 - Shortest operator movement - 1 operator

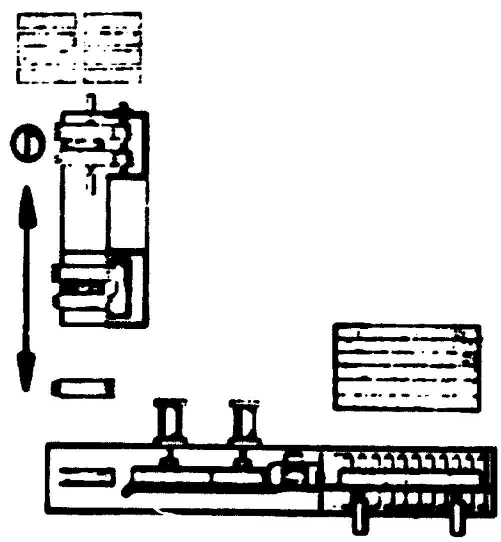


Fig. 35 - Machine layout recommended for space economy - 1 operator

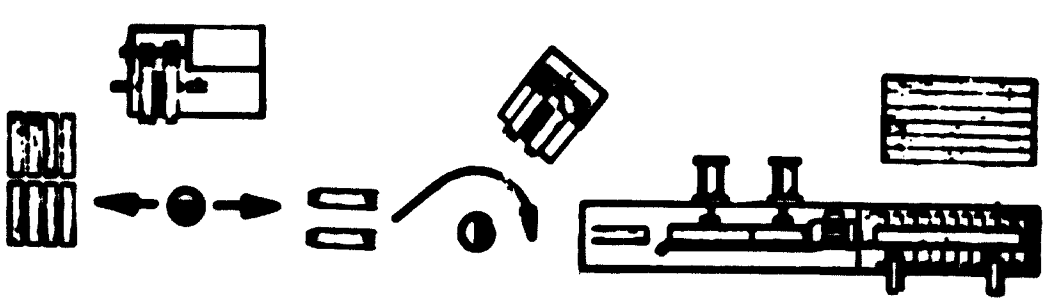


Fig. 36 - Machine layout - 2 operators

Cycle sequence 1

Cycle sequence 2

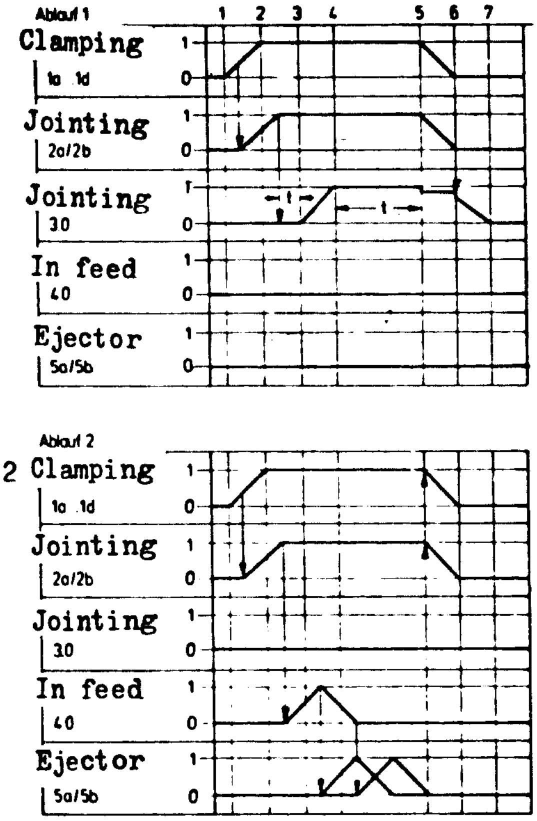


Fig. 37.

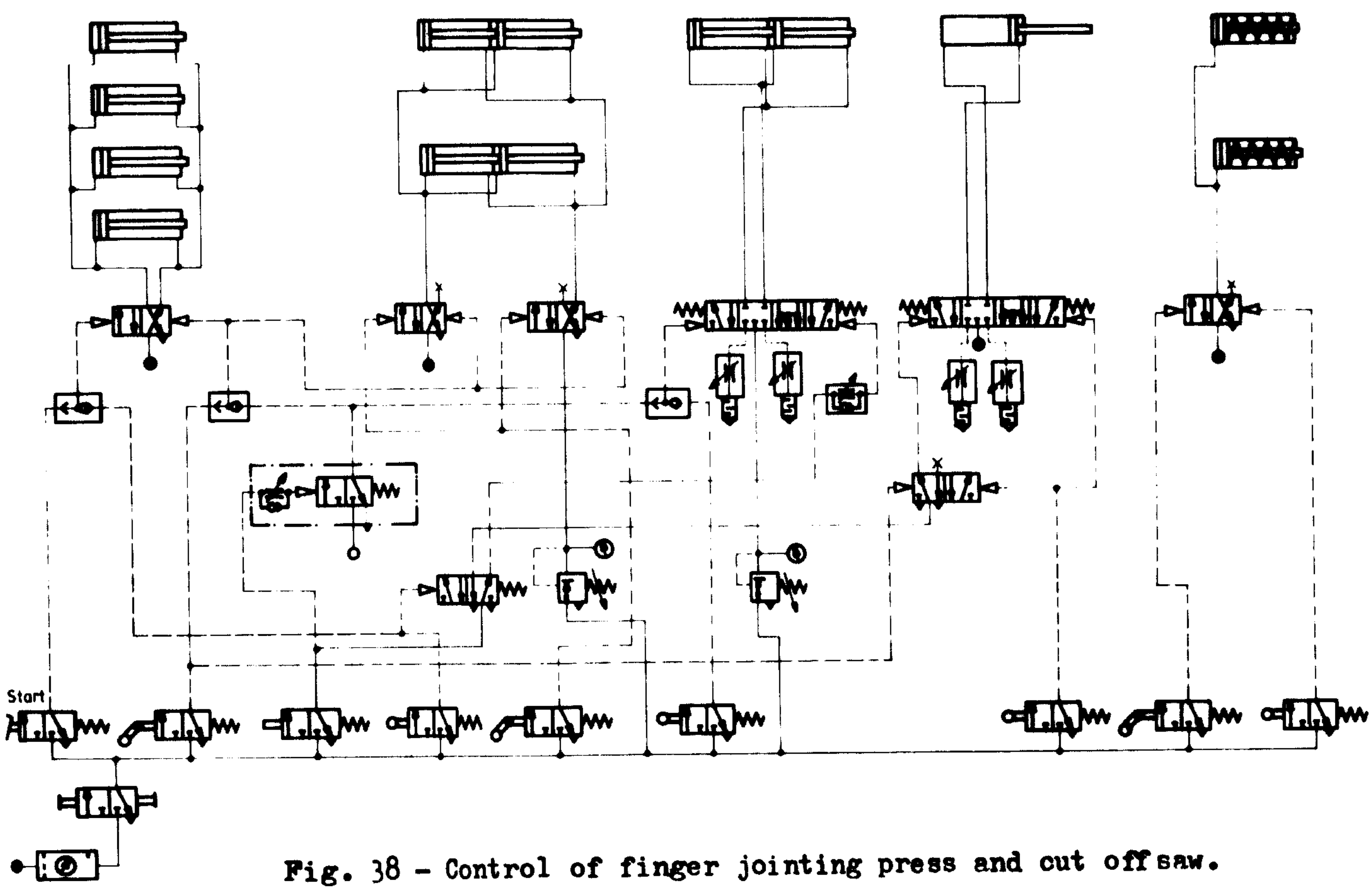


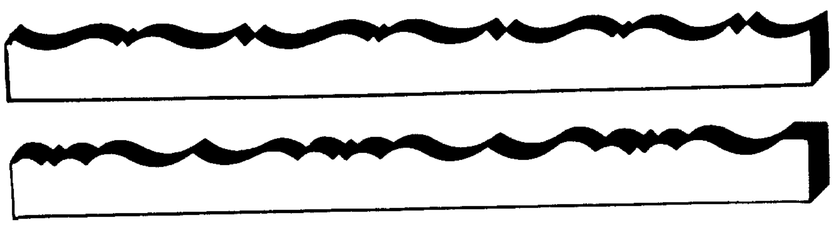
Fig. 38 - Control of finger jointing press and cut off saw.

3.5 Operational sequence of step feeder

Repeated operation to provide a continuous pattern on a work piece can be achieved by means of an adjustable pre-set feeder. Feed length per stroke can be set to a maximum of 200 mm. Several pieces can be machined together up to a maximum height of 100 mm. The feed step position is synchronised to the finger or pattern pitch and can easily be set.

Rational profile cutting (**single** or double sided) Banister rails, fencing, contoured boards can be machined with a continuously repeating pattern (Fig. 39 - 40).

A continuous pattern can also be built up as shown in this example by first milling along one edge in steps leaving spaces between as shown then rotating the work pieces over 180° to machine out the spaces in between Fig. 41. This produces a mirror image effect and gives a continuous complex pattern with one single tool head.



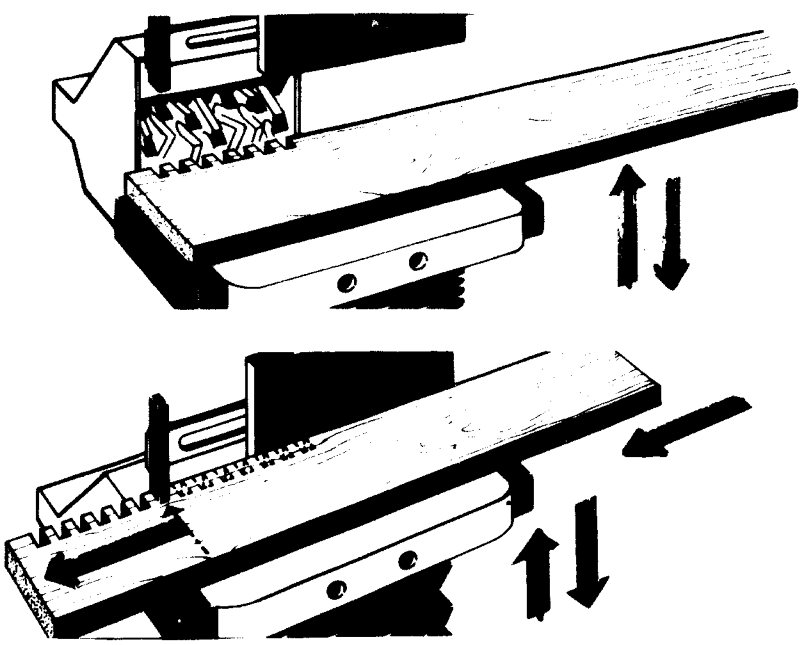


Fig. 39.

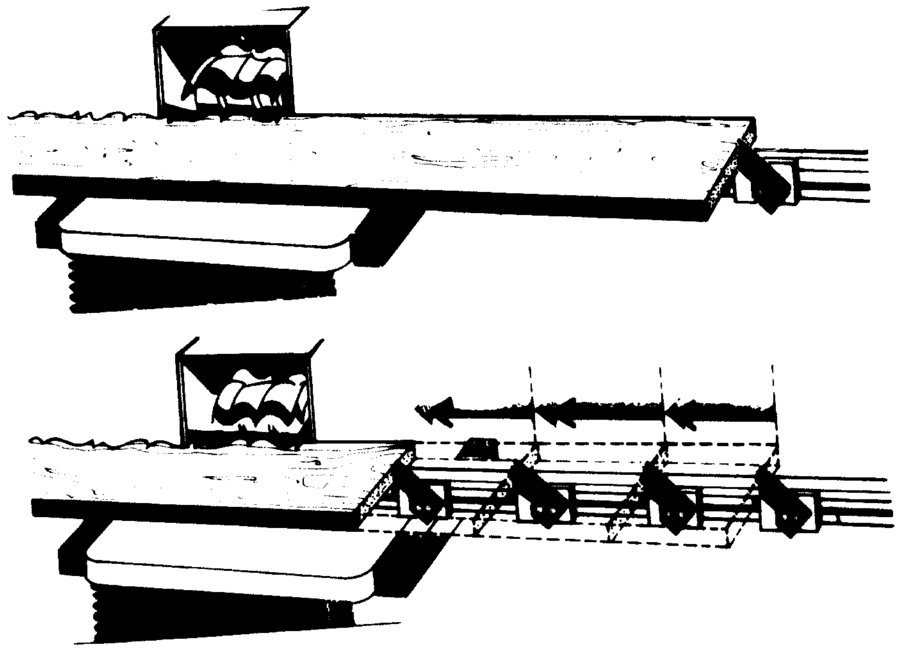


Fig. 40: Stepped cross profiling with multiple stops.

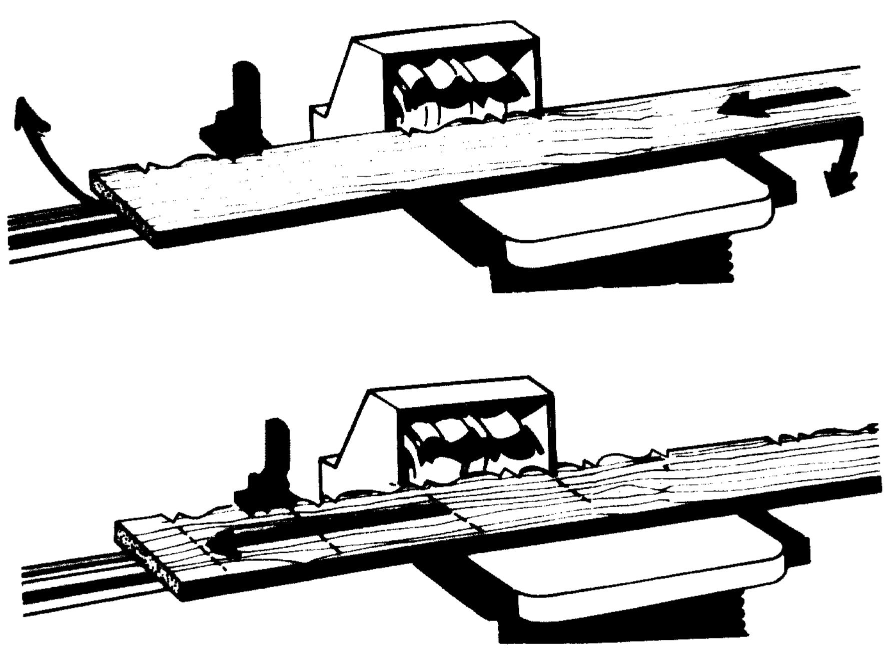
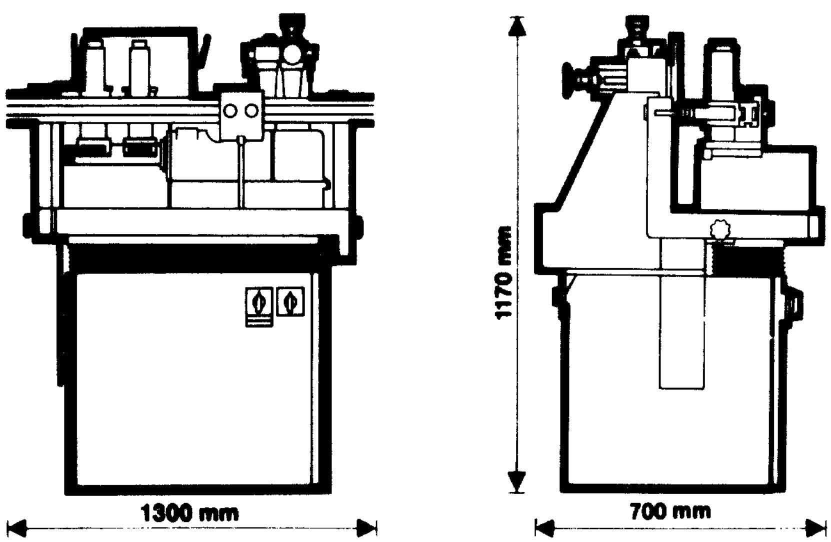


Fig. 41: Different profiles through turnover of work piece.

The new universal profiler UP can be used for a variety of applications, and in particular for production of styled furniture, transverse machining of profile frames (mitre cutting), for toy manufacture, construction of steps, drawer making (combing), finger jointing etc. Transverse profiling in an axial direction with continuous cycling sequence. Excellent machined finish due to particularly rigid location of the cutter spindle and due to down-feed cutting. Rapid resetting from face-end to longitudinal machining by means of the flexible system of stops. Pneumatic-hydraulic table feed with speed regulation (infinitely variable) and rapid return. Quick tool change by means of hinged clamping attachment. Cyclic working sequence by means of foot valve.



Universal corner locking and profiling machine.

Technical data

Model	UP 30	UP 65
Ref. No.	691 043	691 042
Motor rating kW	7,5	7,5
Speed of cutter spindle rpm	6000	4300
Cutting depth max. mm	30	65
Cutting spindle ∅ mm	40	40
Tool clamping width mm	200	200
Tool ∅ mm	180	250
Cutting speed m/sec.	57	56
Working strokes per minute	3-8	3-8
Working pressure	6	6
Air consumption at 8 strokes l/min	110	110
Workpiece width max. without longitudinal stop	unlimited	
With longitudinal stop	130 + profile	150 + profile
Workpiece height max.	100	100
Machine size (l x w x h) mm	850 x 700 x 1170	
Weight kg	300	300
Exhaust connection (l x w) mm	250 x 140	250 x 140
Air speed m/sec.	25-30	25-30
Air consumption m^3/min.	20	20

Accessories

Operating wrenches, stop, 3 splinter tongues (without profile)

Special accessories

Clamping unit with 1 cylinder ECW-50-25

Pneumatic cross clamping attachment comprising: clamping arm, clamping plates, clamping cylinder AH-35-50 with speed regulating valve GR-1/4.

Longitudinal stop 1.85 m long with 10 folding stops for different longitudinal dimensions.

Profile stop with one stop finger

Additional stop finger for profile stop

1. Introduction

Throughout history wood and woodworking have been closely related to man's activities be it in his leisure, work or home atmosphere.

It is, therefore, not surprising to find that the woodworking industry was amongst the first industries where automation and pneumatic control systems were adopted. This was particularly the case with special purpose machines and custom-built or self designed and operated workshops where pneumatics have always been extremely popular.

We will here separate the machines into two broad categories for convenience;

Firstly, machines and production lines for the woodworking industry bearing in mind the extent and degree of standardization in regular production. Then the standard and universal machines produced for medium and small scale industries, including handicraft trade for one-offs and small quantity production.

The boundaries are not too clearly definable and can be said to vary according to individual requirements or specialization. The machinery required may not always be readily available to purchase.

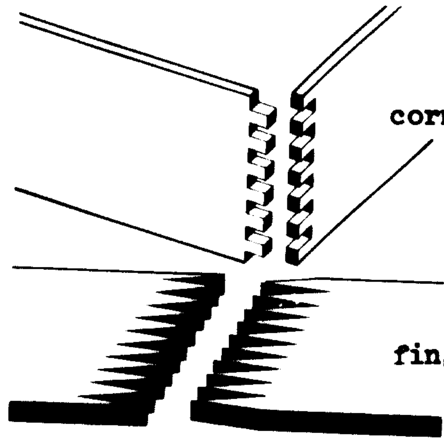
Woodworking factories are, therefore, often forced to design and build or to have built for them machines to their own special needs. This also holds true for extension or additions to existing factories or production lines. Pneumatic control and automation here can be of decisive value. Various function oriented solutions will come to mind when considering practical technical possibilities. It is intended to promote discussion on and to give some indication of the many various solutions to practical problems and the flexibility and variations possible.

2. Low cost automation using pneumatics

Modifications and attachments to older existing machines which by means of pneumatics provide for an improvement in both quality and quantity of production.

211 Example of add-on pneumatic systems

To increase production it was considered necessary to purchase a new machine. The production capacity of the existing chain mortising machine (6 years old) was too low and it was to be discarded, but then someone thought of looking into modifying it.



Automatic finger joint cutting

By means of a stepped feed device finger joints or special shapes can be repeated along workpiece lengths.

Fig. 42.

Cross profiling up to 200 mm wide in one operation. (**square turning**)

A max. height of up to 100 mm can be accomodated which means that several thinner pieces can be **machined**together in one operation.

For instance all eight corner joint pieces for two drawers can be worked together and completed within 30 seconds.

Cutting depths A of 30 or 65 mm can be provided.

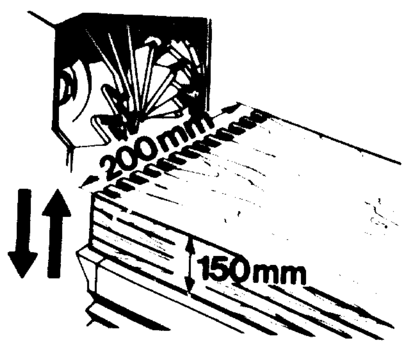
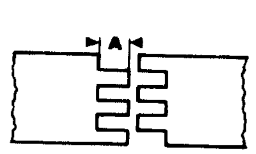


Fig. 43.



Variations possible with a profile cutting machine.

By changing the position and order of the cutters on a profiler head ten different profiles can be machined.

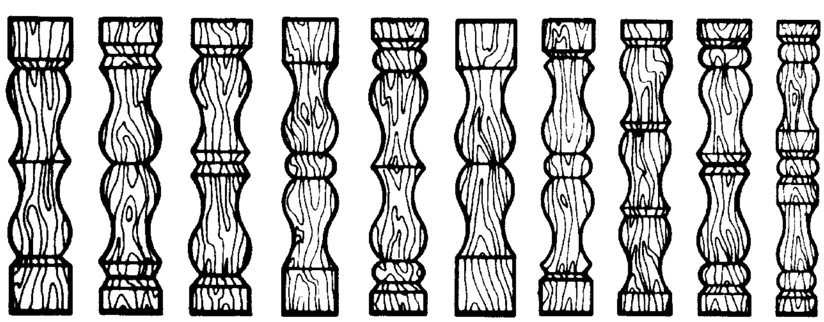


Fig. 44: Examples of square turned parts.

3.6 Costing exercise relating to a complete production machine

Complete machine price	DM 11.745
Pneumatic control system	DM 1.280
Assembly time pneumatic	6 hrs
Design pneuma ics	9 hrs

Costing study

Universal profiling machine

2 different utilisation rates were considered

1. yearly use 200 hrs operation
2. yearly use 100 hrs operation

To produce the item Fig. 45 the following applies:

Machine + profile step feeder	DM 11.745
Depreciation (longer in practice)	8 years
Working hours	1. 200 hrs/yr
	2. 100 hrs/yr
Interest rate:	10 per cent
Space utilised	10 m^2
Cost of space	DM 6/m^2 per month
Power consumption	7.5 Kw/h
Cost of power 75 per cent operational	DM 15 Kw/h
Maintenance costs	6 per cent/year

Operational time	1) 200 h/year	2) 100h/year
Depreciation	7.34 DM/h	14.68 DM/h
Interest	2.94	5.87
Space	3.6	7.2
Power	0.84	0.843
Maintenance	3.52	7.05
Machine costs per hr. total:	18.24 DM/h	36.64 DM/h

Production time per piece

A) Usual traditional method

Machine time band saw	1 hr	à	22 DM
Hand work finishing	1 hr	à	20 DM
			42 DM

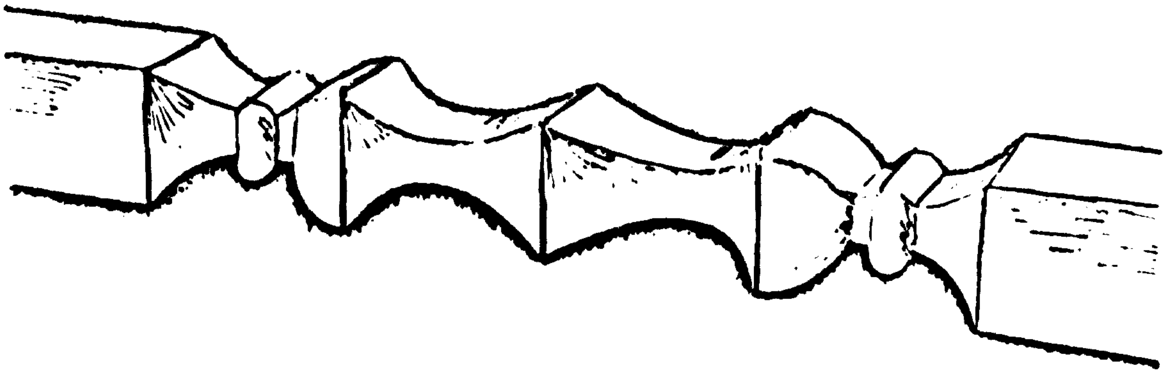


Fig. 45.

B) <u>Produced on universal profiler</u>

		1) 200 h/yr	2) 100 h/yr
Machine time	2 mins	0.61 DM	1.19 DM*
Labor	2 mins	0.67 DM	0.67 DM**
*Tooling costs per hr. Sharpening after 500 pieces	50 DM	0.10 DM	0.1 DM
*Replacement after 1000 pieces	1.860 DM	0.19 DM	0.19 DM
Production costs per piece		1.57 DM	2.15 DM

*These figures will vary in practice and depend upon feed rate and wood hardnes.

**Labour costs involved here will vary but the relationships will still hold.

Profiling machine operating 200 h/yr utilization 13.3 per cent

Traditional production	42 DM
Profile machine production	1.57 DM
Saving per piece	40.43 DM
Cost of machine	11.745DM

Amortised after 11.745 : 40.43 = 291 pieces
production of

Profiling machine operating 100 h/yr utilisation 6.67 per cent

42 DM
2.15 DM
39.85 DM

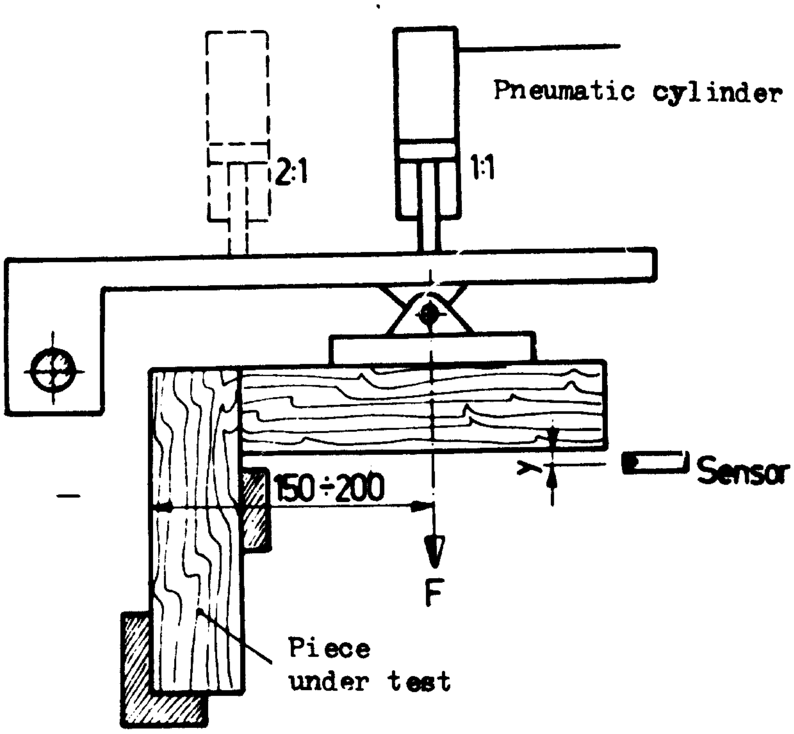
Amortised after 11.745 : 39.85 295 pieces
production of

4. Quality control and testing equipment

4.1 Testing machine for corner joints in the wood working industry

A pneumatic pulsator with control system is used to life test corner joints. The joints are subjected to a periodic pulsator stress to determine the breaking stress and number of cycles from which the safe loading level can be determined. Amount of deformation acceptable is empirically established.

Construction of test jig



The test jig consists of:

1 - pulsator cylinder and control valve

1 - sensor and amplifier

1 - console including timer counter and related pneumatic control system

Fig. 46

The test jig is built on a base plate of steel 885 x 545 mm which has rows of mounting holes spread 68 mm apart. Steel runners reinforce the base plate and the whole is mounted on an angle iron framework. Should a larger base plate be required, several units could be joined together, bolt holes are provided along the edges.

Mounting of all elements in various required positions to suit the item being tested is facilitated by the grid of mounting holes provided. As can be seen from the sketch Fig. 46, all elements can be positioned anywhere on the base plate to left or right top or bottom to suit test requirements.

Testing pressure is applied by a pneumatic cylinder through a bracket assembly. Applied pressure can be modified by moving cylinder position on the bracket and the applied air-pressure.

Air Pressure	2	3	4	5	6	7	(bar)
Piston Force	69	104	139	173	208	243	(kp)

Pneumatic control elements are all built into a control console with functional knobs on the front panel. The digital control system provides a rate of drive force which follows the curve shown in Fig. 47.

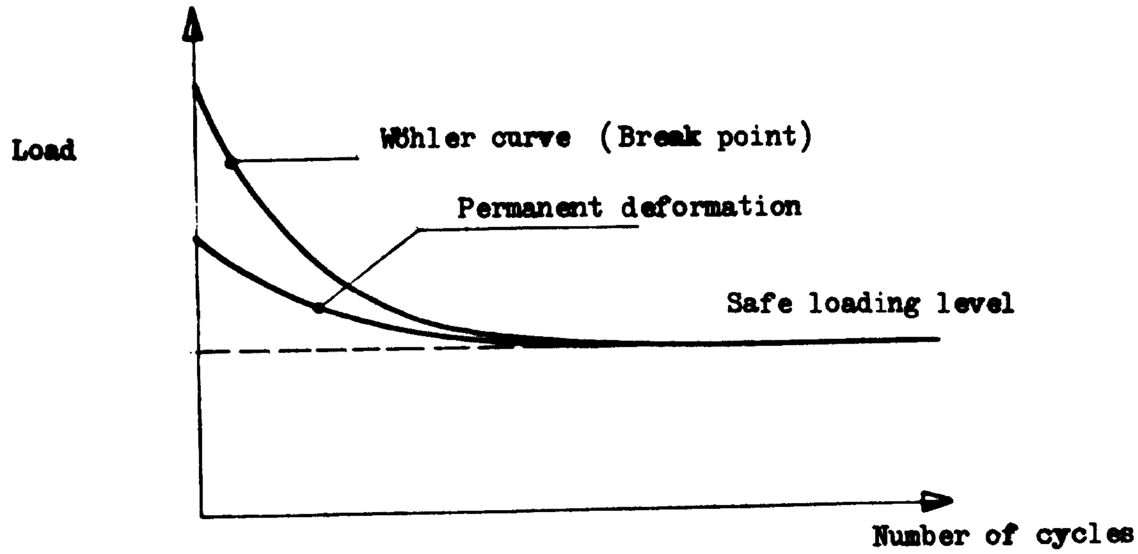


Fig. 47 - Plot of test results

A pressure time relationship of the tester as can be seen from the graph matches the ideal sine wave format closely despite the extremely high impulse power peaks involved (Fig. 48).

The test sequence can be set to stop once a pre-set value (Y = 0.1 = 1 mm) of deformation is detected by the sensor and the number of cycles performed can be read off the pneumatic counter.

To restart a cycle a start button is provided. It can be shown that the pulsator cycle provided approaches the ideal sinusoidal theoretical requirements closely enough for all practical purposes and the pneumatic cylinder pulsator solution given here is simpler and cheaper to build.

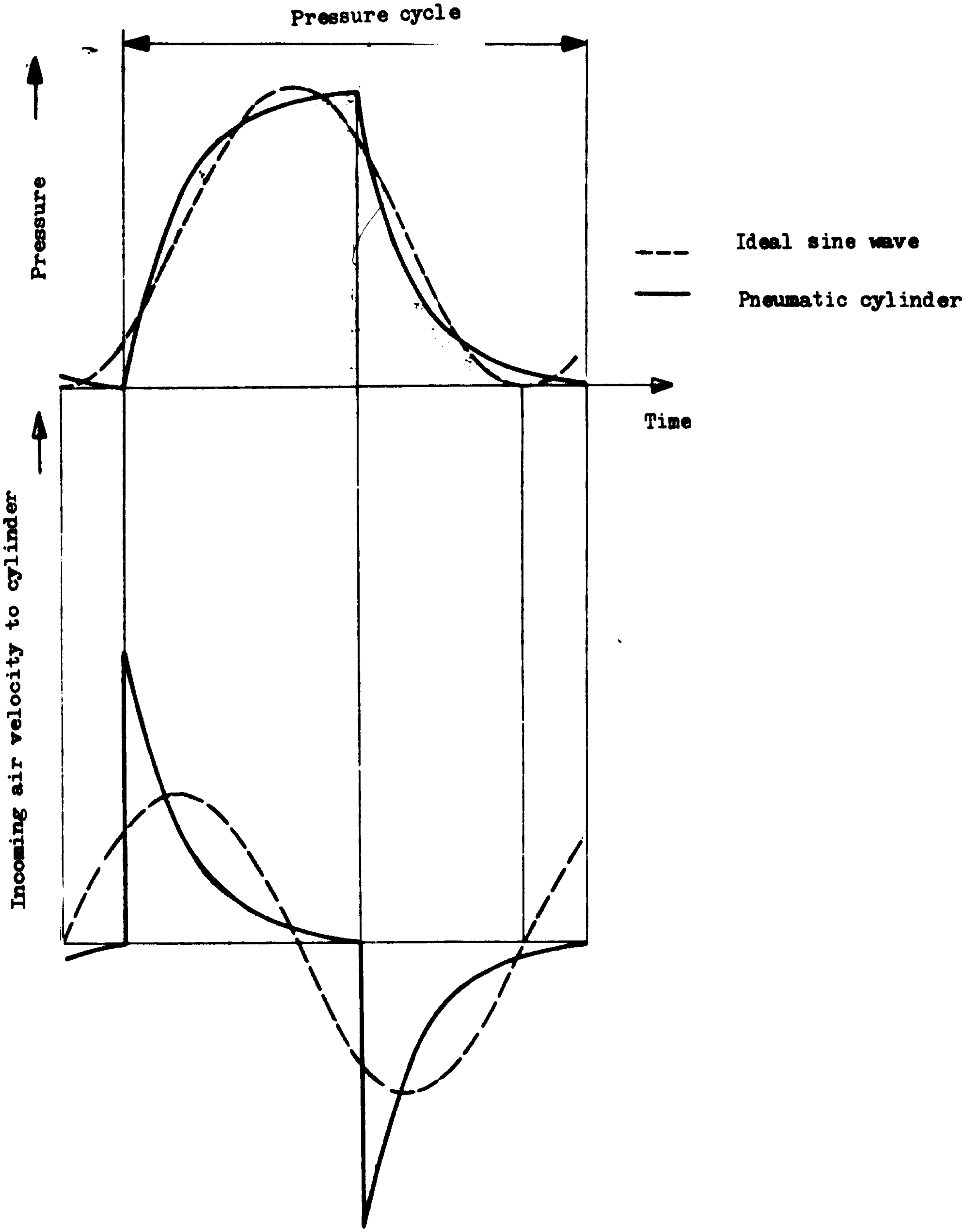


Fig.48 - Cylinder Velocity and Pressure Graph

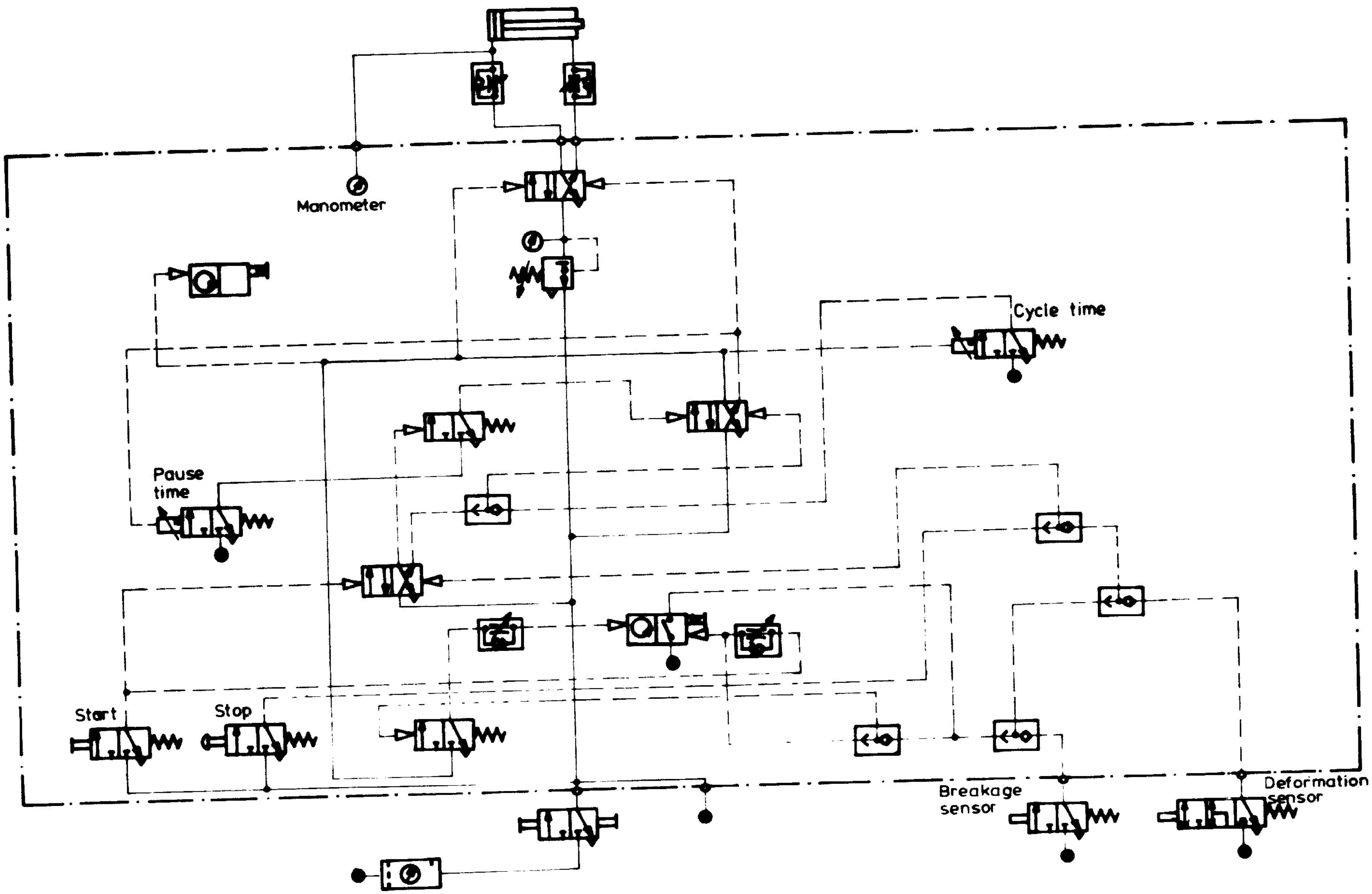


Fig. 48a. Schematic diagram of control system for corner joint tester.

Further notes on test jig construction

All moving parts should be light in construction so as to reduce power lost in acceleration and de-acceleration. Normal factory compressed air line supply is suitable for operating the tester.

Facilities

Piston speed of operation

This can be continuously adjusted by the 2 speed regulator valves provided.

Testing pressure (load)

Continuously adjustable by means of air pressure regulator provided from approximately 1 bar to maximum 8 bar.

Time

Operation and wait interval can both be adjusted individually and independently from one another.

From 0.5 - 10 sec.

Total number of cycles

Can be set on a counter so as to automatically terminate test when number of cycles achieved.

4.2 Furniture testing equipment

Test equipment for testing and research institutes as well as manufacturers have been built with a variable profile adjustable frame work so as to be adaptable to test any sizes of tables, chairs, cupboards arm chairs etc. Pneumatic elements can also be moved to appropriate positions to suit the particular test conditions wanted. Life wear strength tests can be performed on all types of furniture. The fifty cycle electrical mains frequency was used in this tester to provide a cheap and convenient timing cycling frequency and control elements are electro pneumatic. Cycles or time to failure or preset counts can be measured. Normal factory air supply is required.

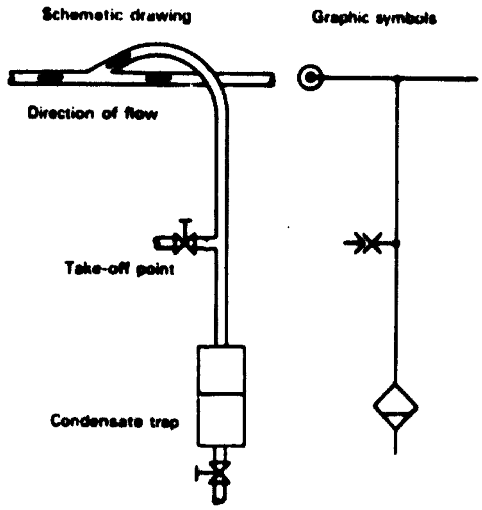


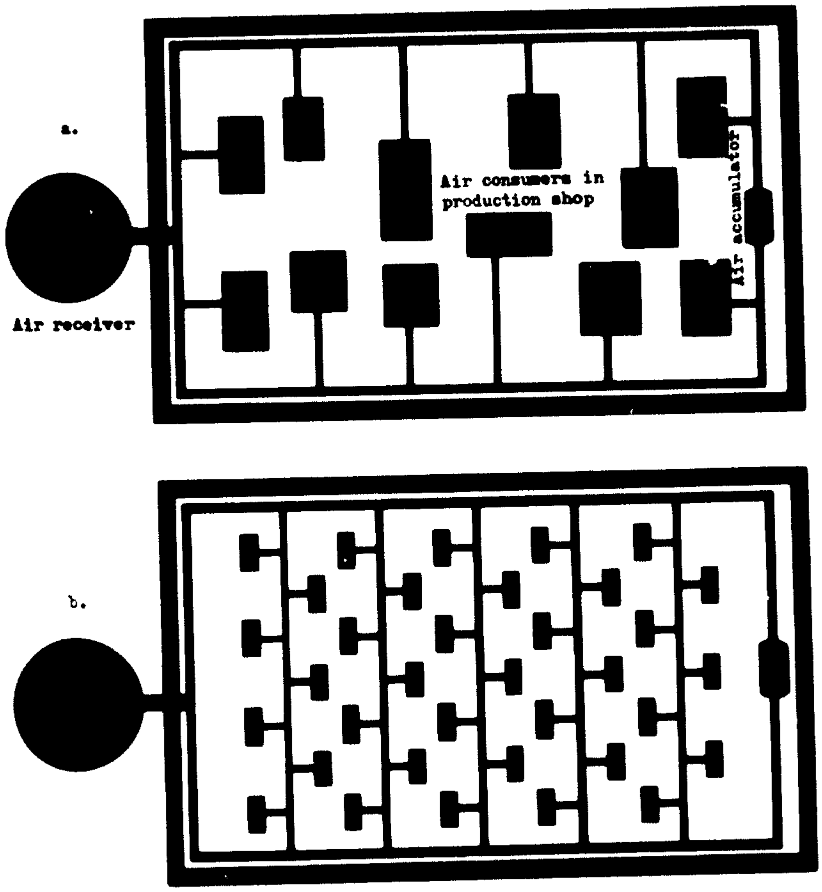
Fig. 49 - Branch line leading off from air main. Branch line should not terminate at air take-off point but should be extended further and end in a condensate trap.

5. Didactic and maintenance of pneumatic systems

5.1 Didactic

It has been found useful to provide special courses to users, larger factories, machine producers and others to instruct various levels of design engineers, maintenance operators etc. from these beginnings has grown-up a complete range of courses, articles, books and special didactics models and equipment. Some extracts from such a course may be of interest here.

Compressed air piping should preferably be installed so as to be accessible for inspection to ensure it is air tight, and in good condition. Horizontal spans should be sloped so as to provide a fall of some 1 - 2 % in the air flow direction. Main down feed supplies should lead direct to a machine user point and the pipe continue down further so as to ensure that any condensate or dirt particles are not fed to the user point but collect below from where they can be occasionally discharged. (Fig. 49).



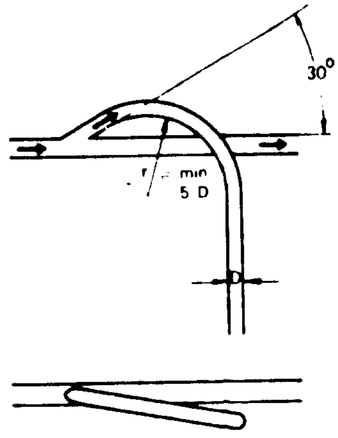


Fig. 50 - Parameters for joining branch line to air main

Fig. 51 - Ring air main incorporating air accumulator
a) Branch lines joined to ring main
b) Branch lines joined to cross lines.

Special collectors are available for mounting at the lower ends of supply points for the condensate water some of which empty automatically when the water reaches a certain level. User point piping from the supply should be carried upwards with bends not sharper then R = 2 D (inner radius of bend 2 times pipe outer diameter). A branch from the main supply pipe feeding several high consumption outlets should preferably be connected to the main supply pipe as shown in Fig. 50. Supplies to a complete workshop or room where several machines are supplied are best installed as a ring supply line as shown in Fig. 51. Ideally an additional compressed air reservoir should also be provided. Piping for a ring supply can be some 1/3 the diameter of a similar single pipe supply for the same conditions of pressure loss. Pressure changes in the supply are minimised with a ring supply and the pressures at outlets more even.

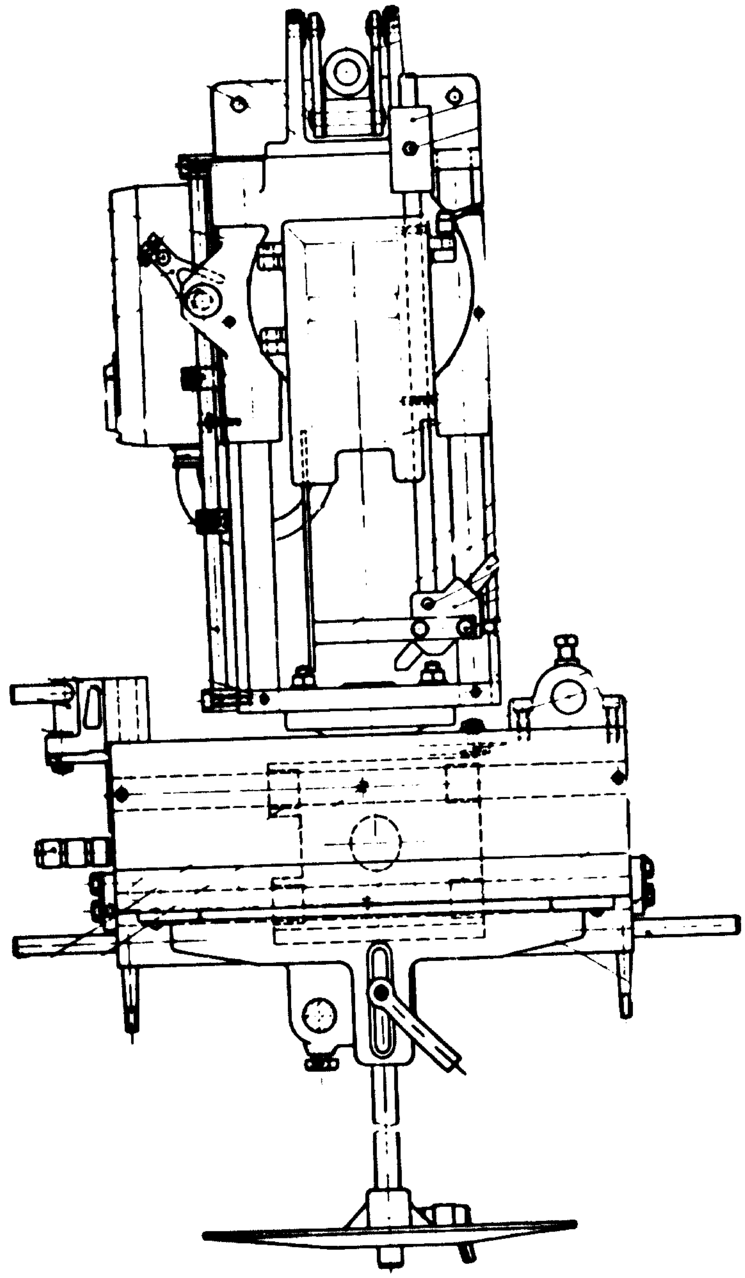


Fig. 1

The idea being to use the existing chain mortising machine and by adding pneumatic automation to produce a purpose built machine capable of handling special production runs and small scale production runs.

Planning a compressed air supply line:

Pipe diameter requirements are determined by the compressed air consumption whioh should allow for a reasonable reserve (bearing in mind additional equipment requirements that invariably follow soon afterwards). Empirioal values have been established for acoeptable limits of air flow velocity and pressure drop for optimum cost operation over the years. The determining factors for pipe diameter are:

Permitted air flow velocity

Permitted pressure drop

Working air pressure

Number of built in restriotions

Pipe lengths

Consumption volume 1 min is a readly established value. The air velocity and pressure drop are closely related. Pressure drop is in addition affected by the smoothness of the inner pipe wall and any intermediate connectors. Pressure increases with velocity and length of piping.

Velocity should be chosen to be between 6 and 10 m/s. Design should aim at below 10 m/s as invariably various parts of the systems will have higher velocities due to built in obstacles, restrictions, reducing couplings or temporary consumption surges.

Pressure drop should be kept to under 1 KP/cm^2 up to the user outlets. In practice up to 5 per cent pressure drop is often found. With a design operational pressure of 6 Kp/cm^2 a drop of 0.3 Kp/cm^2 is thus acceptable.

Throttling: connectors, couplings, bends, valves in the piping all tend to throttle the air supply. To aalculate the required piping diameter it is normal to allow for the effective throttling by adding a factor to the value of piping length.

Designing a pipeline: example and graphs taken from **the Festo text book "Introduction to Pneumatics".**

The air consumption ia a factory is 400 1/min = 4 m^3/min = 240 m^3/h. The increase over a period of about three years will be 300 per cent. This results in 12 m^3/min (720 m^3/h). The total consumption is 16 m^3/min (960 m^3/h). The pipeline will have a length of 280 m, and it contains 6 T-pieces, 5 normal elbow pieces, 1 two-way valve. The permissible pressure drop is $\Delta p = 0.1 \times 10^5$ Pa. Working pressure 8×10^5 Pa.

To be calculated : pipe diameter

The provisional pipe diameter is determined in the nomogram using the available data (Fig. 52).

Use nomogram (pipe diameter)

Line A (pipe length) is joined with B (take-in volume) and extended to C (axis 1). Line E (working pressure) is joined with G (pressure loss) and one then obtains an intersection at F (axis 2). The intersections of axis 1 and axis 2 are joined togehter. One obtains an intersection at line D (inside pipe width) and this specifies the pipe diameter. The pipe diameter was designed with 90 mm (chart).

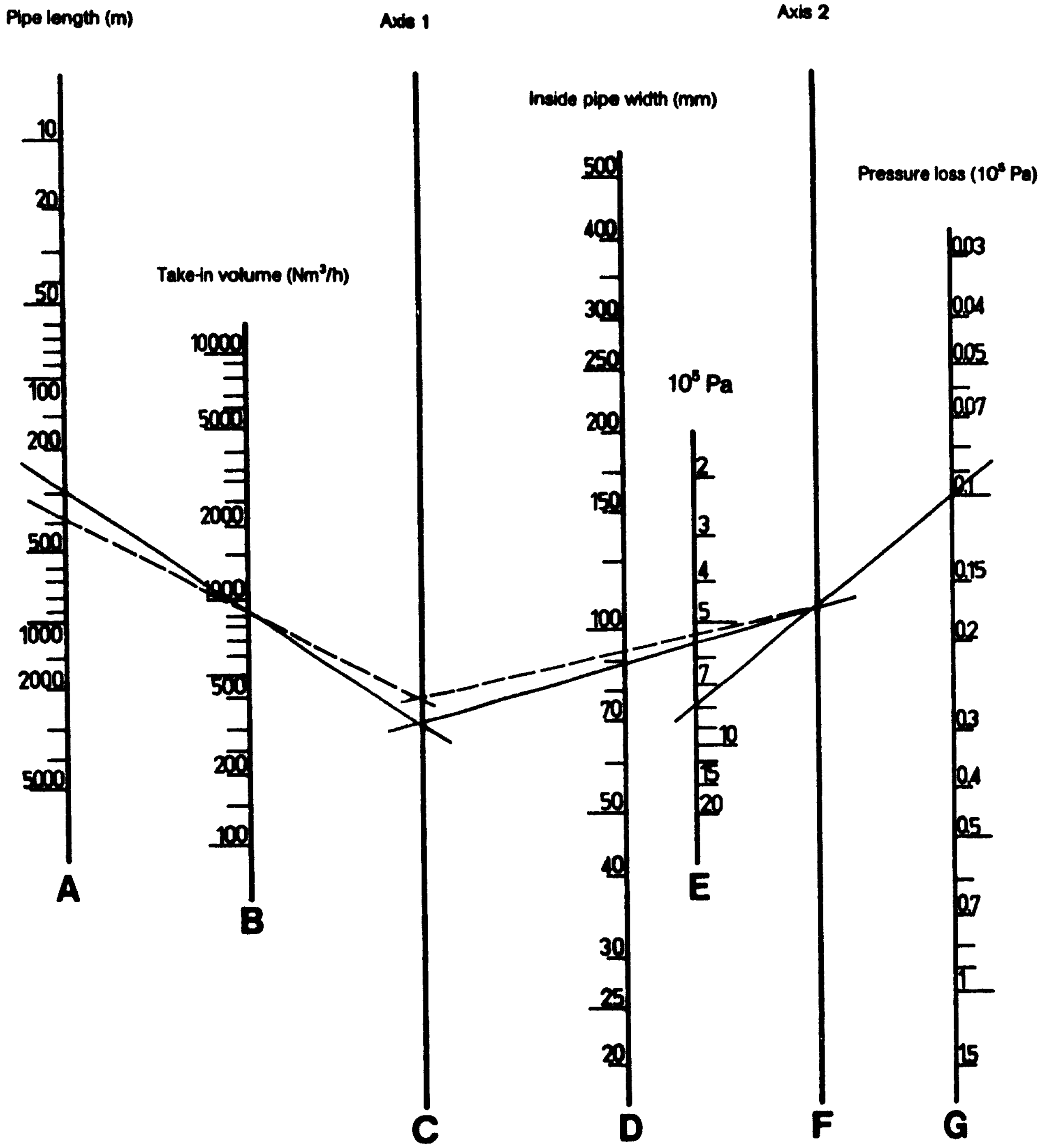


Fig. 52
Calculation of pipe diameter

For the restrictive elements (two-way valve, corner valve, T-piece, slide-valve, normal elbow piece) the resistances are specified in equivalent lengths. Equivalent length is understood to mean the length of a straight pipe having the same resistance to flow as the restrictive element or the point of restriction. The flow cross section of the "equivalent length pipe" is the same as that of the pipe. By means of a second nomogram the equivalent lengths can be established quickly.

Nomogram (equivalent lengths)

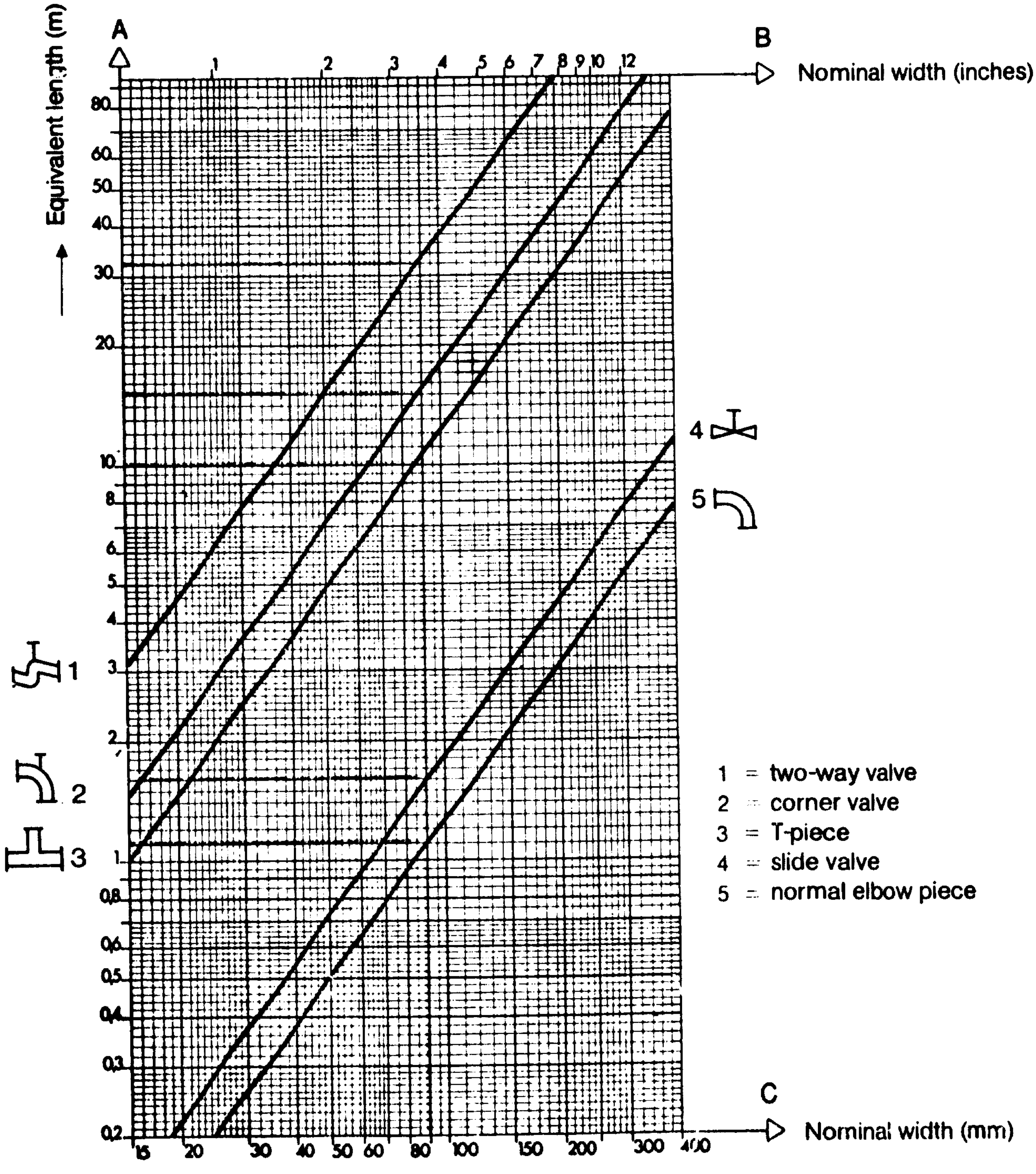


Fig. 53. Calculation of equivalent pipe length

Automatio condensate water separator (Fig. 54)

Air supply lines and related equipment should not be ignored as permanent fixed fittings once installed but regularly serviced, air filters oleaned or replaoed, oilers where fitted refilled pipe line ends regularly opened to empty out accumulated dirt partioles and oondensate eto.

In addition to regular servicing, however, and particularly where high moisture levels prevail, automatio condensate drains installed at various strategic points in an installation are a must.

Funotion: The condensate collects in a collector and when a given level is reached, a float mechanism automatically opens a drain outlet and the air blows the condensate out where upon the float once again seals off the drain outlet.

The condensate in the air filter passes through hole 6 into the piston chamber between the sealing washers 1 and 2. As the condensate increases, the float 3 moves upwards.

When a certain condensate level is reached, nozzle 7 opens. The compressed air from the filter bowl flows through the hole and presses the control piston 5 towards the right. This results in sealing washer 1 opening the flow passage for the condensate. Through nozzle 4, the compressed air oan flow out at only a slow rate and the through passage is kept open for a longer period of time.

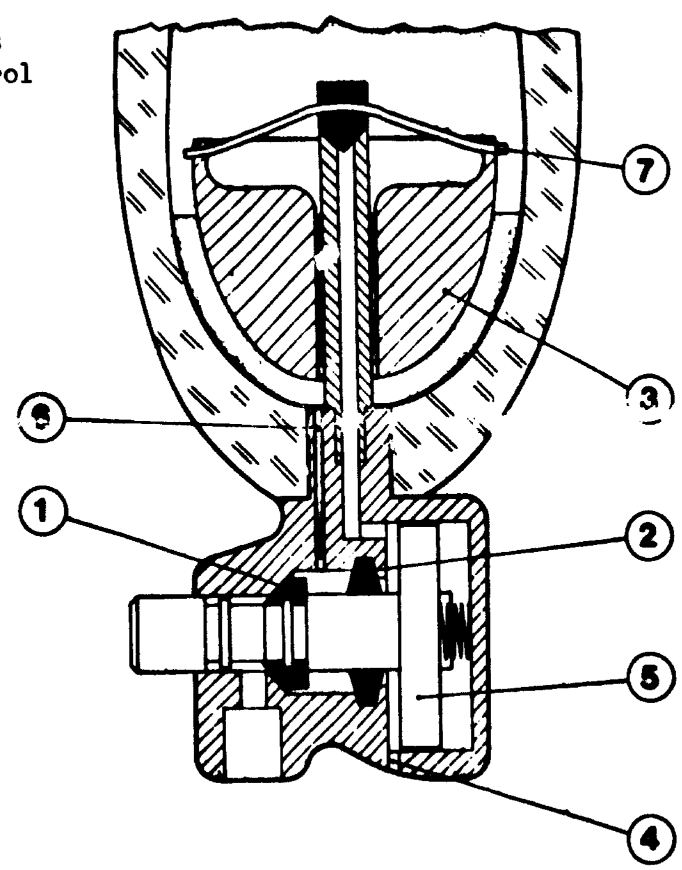
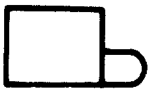
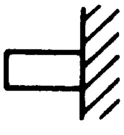


Fig.54. Water separator

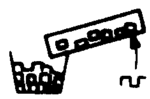
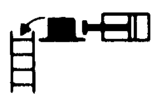
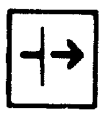
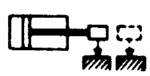
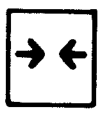
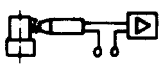
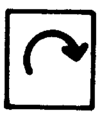
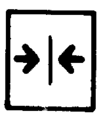
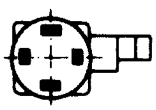
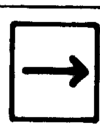
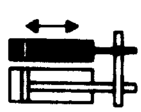
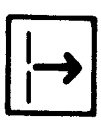
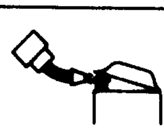
5.2 **Application of pneumatics to the woodworking industry**

Machine	**Work Piece** Criteria 2 = full 1 = limited 0 = nil			**Work Piece** Pneumatic control 0-2 = nil 3 = limited 4-6 = full	**Tool Drive** Criteria 2 = full 1 = limited 0 = nil			**Tool Drive** Pneumatic control 0-2 = nil 3 = limited 4-6 = full
	Power	Accuracy	Speed		Power	Accuracy	Speed	
Sawing machines								
Framesaw		1	1	2				
Log band saw	1	1	1	3				
Table band saw	1	1	1	3				
Circular saw	2	2	1	5	2	2	1	5
Cross-cut saw	2	2	2	6	1	2	2	5
Radial arm saw	2	2	2	6	1	2	2	5
Panel circular saw	1	1	1	3	1	1	1	3
Milling machines								
Moulder	1	2	2	5	1	1	2	4
Spindle moulder	1	2	2	5	1	1	2	4
Router	2	2	2	6	1	1	2	4
Shaper	2	2	2	6	1	1	2	4
Corner locking + profiling machine	1	2	2	5	1	1	2	4
Tenoner	1	2	2	5	1	2	2	4
Slot mortisising machine	2	2	2	6	1	1	2	4
Chain mortiser	1	2	2	5	1	1	2	4
Copying machine	1	2	2	5	1	1	2	4
Thicknesser	1	1	2	4	1		1	2
Moulder/Matcher	1	1	2	4	2	2	2	6
Boring machines								
Drill press	2	2	2	6	2	2	2	6
Multi-spindle boring machine	2	2	2	6	1	2	2	5
Dowel hole boring machine	2	2	2	6	1	2	2	5
Vertical boring machine	2	2	2	6	2	2	2	6
Knot hole boring machine	2	2	2	6	2	2	2	6
Lathes								
Turning lathe	1	2	2	5	2	1	2	5
Copying lathe	1	2	2	5	1	1	2	4
Sanders								
Stroke belt sander	2	2	2	6	2	1	2	5
Pressure bar belt sander	1	2	2	5	1	1	2	4
Wide belt sander	1	2	2	5	1	1	2	
Disc sander	1	2	2	5	2	1	2	5
Copying sander	1	1	2	4	2	2	2	6
Contour sander	1	2	2	5	2	1	2	5

5.3 Recognition of shape size and position by pneumatics

Example	Parameter Sensed	Pneumatic Element
	Length Width Limits	1 mm end stop 3/2 roler actuated valve 1 mm air barrier reflex sensors
	Length Width Limits	1 mm 3/2 roler valve 1 mm air barrier reflex sensors
	Thickness Height	3/2 roler actuated valve air barrier reflex sensor
	Cut-away	Back pressure nozzle reflex sensor air barrier
	Bore	air barrier cylinder (stroke position)
	Flag Cam	Back pressure nozzle Air barrier
	Recess	0.1 mm reflex sensor
	End position	3/2 roler actuated valve back pressure nozzle
	Cut-away	Reflex sensor

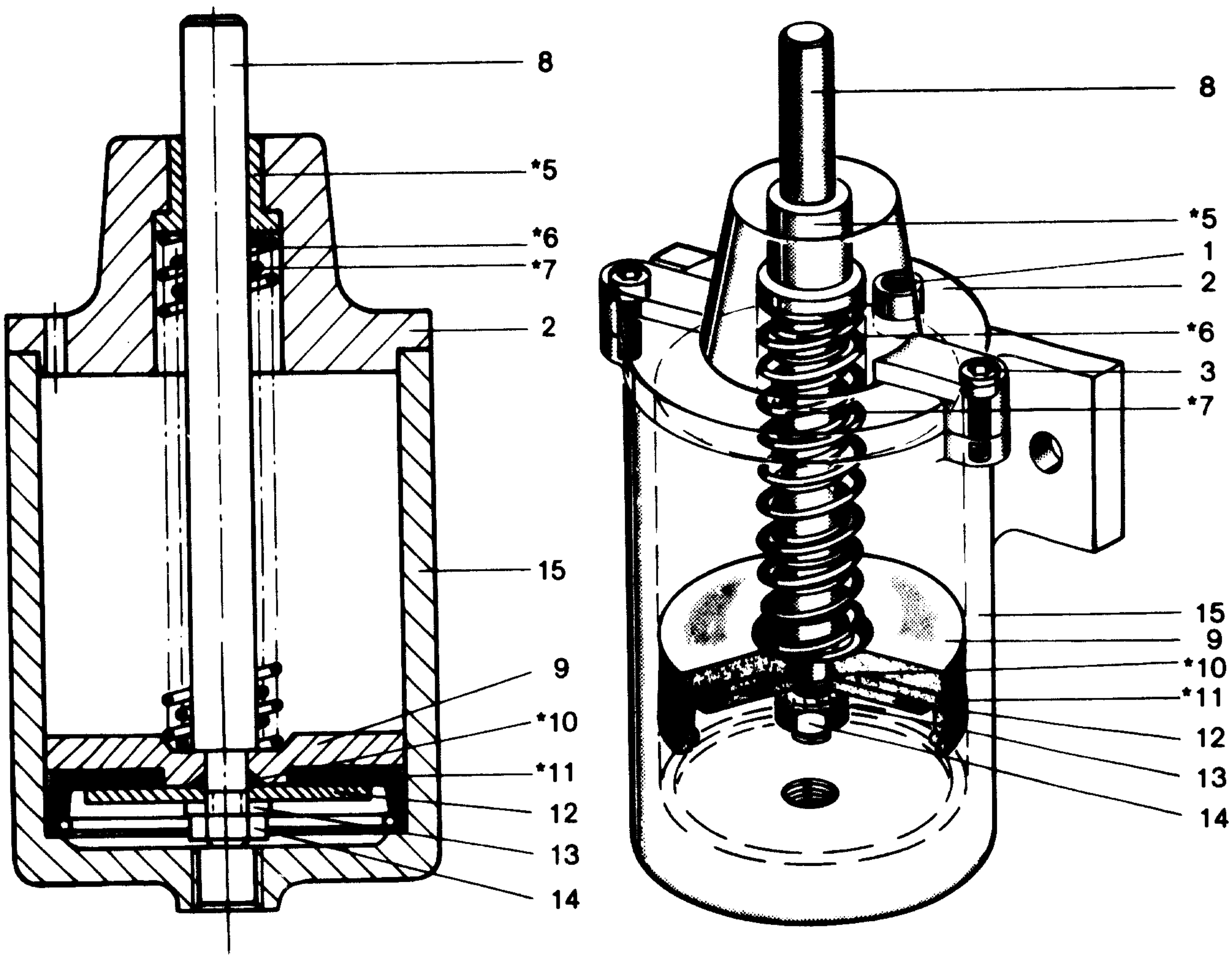
5.4 Typical applications of pneumatic components and assemblies for specific work and tool handling functions

Function	Symbol	Principle	Functional elements	Operating characteristics
Bin loading			Multivibrator	E.g., cylinder with 12 mm piston diameter, frequency 7 c/s (adjustable)
Magazine loading			Single- and double-acting cylinders	1 to 100 parts/min
Advance (Material feed)			Single- and double-acting cylinders	1 to 100 parts/min 60 cm/min to 60 m/min 1 to 2000 mm piston stroke
Position control			Impact nozzle Reflex nozzle Interruptible jet	Maximum spacing 3, 4.5, 6.5, 15 or 100 mm
Turning			Rotary cylinder	Max. 90 or 290 degrees (adjustable)
Positive or non-positive clamping			Single- and double-acting cylinders Vise	1 to 1000 mm, 1 to 2500 kgf 2000 to 7000 kgf
Transfer (Rotary indexing)			Rotary indexing table	Divisions 15, 30, 45, 60, 90 or 120 degrees
Transfer (Linear indexing)			Strip feeder Single- and double-acting cylinders	Progression adjustable up to 250 mm Material thickness up to 2 mm
Machining (Tool feed)			Pneumatic and air-hydraulic feed units	Feed rate 30 to 6000 mm/min
Ejection			Impulse ejector Single- and double-acting cylinders	Up to 480 blasts/min 1 to 100 parts/min

5.2

A didactics course to instruct personnel in the art of pneumatics is desireable not only for design and machine building engineers but also for service and maintenance personnel. The following are some descriptive drawings for explaining the inner construction and workings of some parts from a text book (Festo didactic) for just such a course.

Single acting cylinder

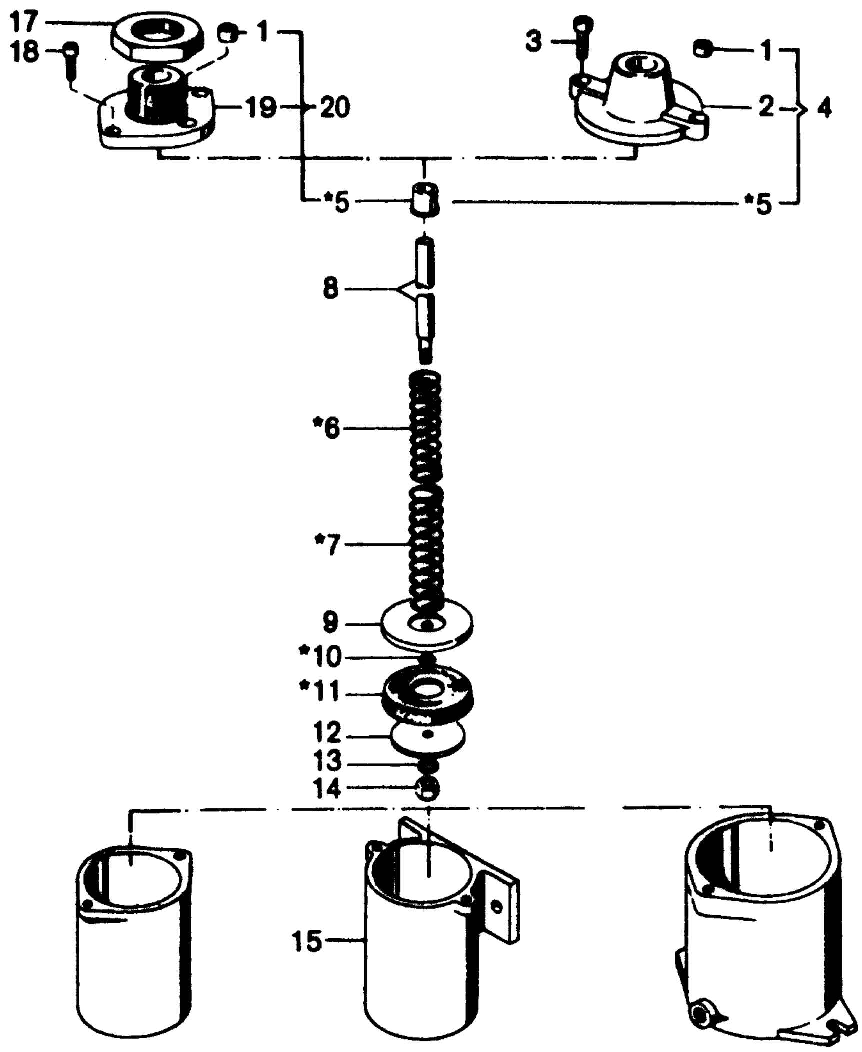


58. Parts of the single acting cylinder

Item	Name	Item	Name
1	Filter element	9	Piston disc
2	Bearing cap	*10	O-ring
3	Cheese-head screw	*11	Cup packing
4	Bearing cap, complete	12	Tightening disc
*5	Bearing bushing	13	Serrated spring washer
*6	Compression spring	14	Hexagon nut
*7	Compression spring	15	Cylinder barrel
8	Piston rod		

Functional description

Air enters through cylinder barrel (15), air is applied to the cup packing (11). Piston rod travels out. When the cylinder is exhausted, springs (6) and (7) push the piston and piston rod back into the initial position.



Wearing parts

Bearing bushing	5
Compression spring	6
Compression spring	7
O-ring	10
Cup packing	11

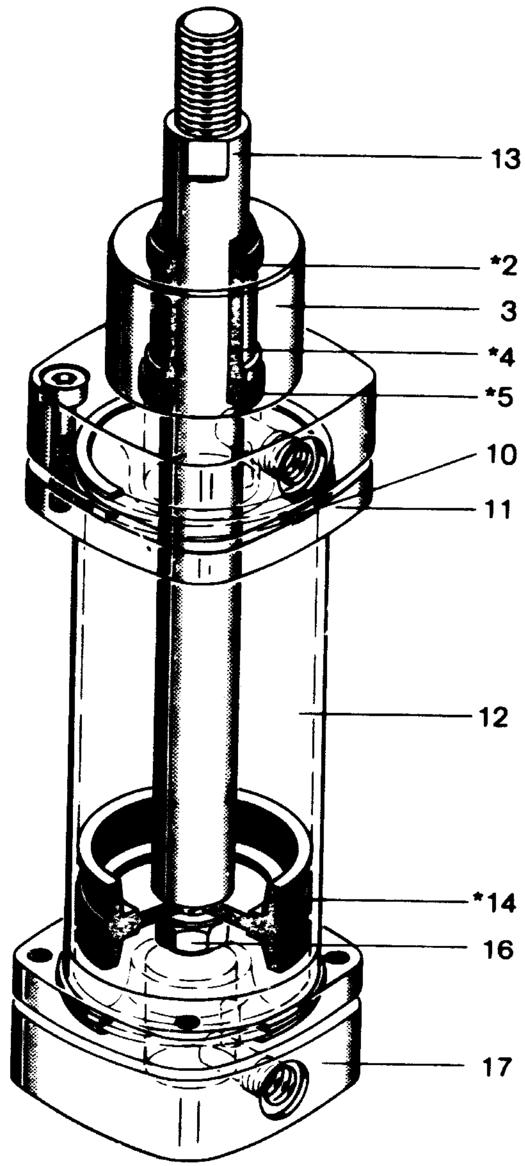
Contamination

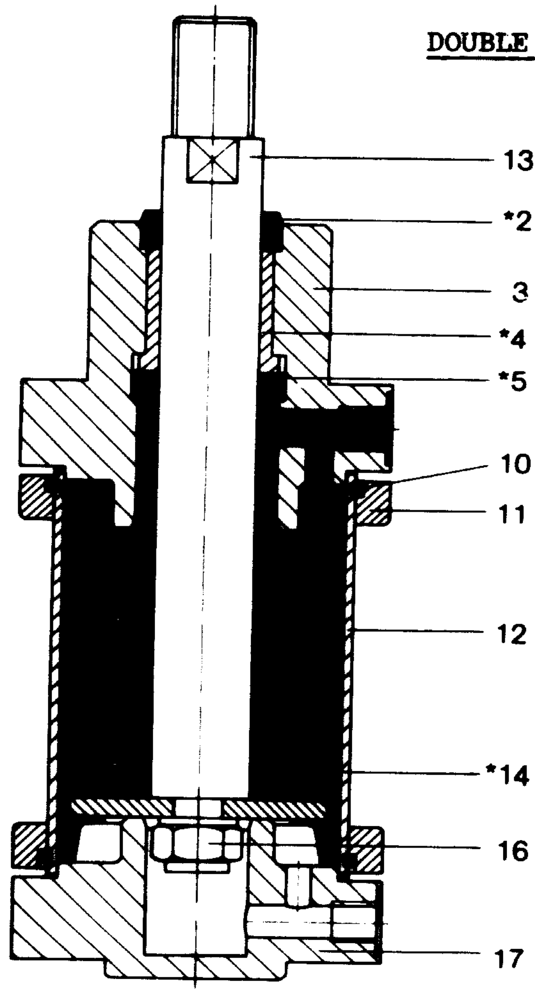
Too much oil in the cylinder barrel, the piston travels out slowly.

List of faults

Type of disturbance	Possible cause	Rectification
Piston rod (8) does not return to the end position	Compression spring (6) and (7) damaged	Fit new spring
	Air filter is blinded	Clean air filter
The air escapes to atmosphere at the bearing bushing (5)	Cup packing (11) not tight, worn	Replace the cup packing (11)
	Cup packing (11) mounted the wrong way round	Reverse the cup packing (11)
Piston rod (7) is not guided smoothly	Bearing bushing (5) worn	Replace the bearing bushing (5)

DOUBLE ACTING CYLINDER





Item	Name
1	Cheese-head screw
*2	Scraper ring
3	Bearing cap
*4	Flange bushing
*5	Groove ring
6	Flange
7	Cheese-head screw
*9	Sealing ring
10	Spring washer
11	Clamping ring
12	Cylinder barrel
13	Piston rod
*14	Double cup packing
15	Washer
16	Hexagon nut
17	End cap
18	Cheese-head screw
19	Swivel flange
20	Cheese-head screw
21	Clamping foot

Functional description

The air is supplied to the piston through the end cap (17). The piston rod (13) travels out. The return stroke is effected by pressure being applied to the piston rod side of the piston through the bearing cap (3).

The following details show how this particular problem was solved:

Chain mortiser for machining ladder runners (Fig. 2)
For step-ladders (right angled tread)
For step-ladders (angled tread)

The runners are clamped in a **fixed** position for machining and the chain mortising attachment is moved in steps from **mortise to mortise**. In this way the space requirement of the machine is kept to a minimum. Should the runners be moved step by step under a stationary mortising attachment, the space taken up by the machine would be doubled.

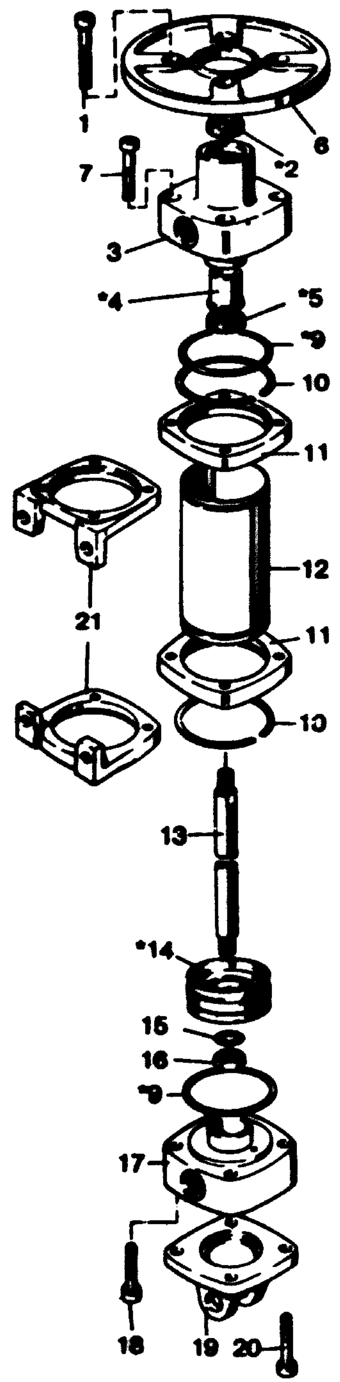
A machine capacity of 1000 **mortised holes/hour was achieved with fully** automatic operation. The installation consists of five essential parts:

a) Machine pedestal mortising guide;
b) Chain mortising head with pneumatic feed facility;
c) **Sliding table and intermitent feed unit:**
d) Work piece clamp;
e) **Slide stop;**
f) Control console with pneumatic control system for external end sensors and cylinders.

a. The machine pedestal is of welded construction and consists of the frame, the tool head, guide rails and the step spacing for setting the distance between mortises. A wooden insert is provided on the machine bed to avoid fraying at the slot edges. The pedestal can be dismantled for ease to transport.

b. The chain mortising attachment is a standard production item with hydro-pneumatic feed. It has in addition a swivel mount attachment which allows mortising of right angled mortises for ladders, as well as angled slots for step ladders.

c. The sliding table with pneumatic feed unit consists of two moving **sliding tables, mounted on rollers. On the larger of the two sliding tables is mounted the mortising head. Precise positioning is controlled and determined by the step spacing and stop cylinder.**



Parts of double-acting cylinder

Wearing parts

Scraper ring	2
Flange bushing	4
Groove ring	5
Seal ring	9
Double cup packing	14

Contamination

Too much oil or water in the cylinder, the cylinder becomes slower. Wear is increased.

List of faults

Type of disturbance	Possible cause	Rectification
The connected valve vents air through the vent hole	The double cup packing (14) leaks or is loose	Fit new packing
		Tighten packing
Air escapes at the piston rod	Groove ring (5) is defective	Fit a new groove ring
Special-purpose cylinder: End position cushioning In a cylinder with end position cushioning, the cushioning does not respond.	Lip seal on the cushioning plunger leaks or has been fitted the wrong way round	Fit a new lip seal
		Refit the lip seal

5.6 Maintenance

Trained maintenance personnel cost money but proper maintenance is very important and will always pay in the long run. Pneumatic equipment and systems also need appropriate periodic maintenance even though it can be said they just work on air.

For any larger pneumatic installation a separate check list should be prepared for maintenance which should include a functional and schematic diagram. This should facilitate maintenance and trouble shooting in case of faulty operation. Various elements or machine parts as well as the compressed air lines can also develop leakages and regular checks are desirable. Components can develop leaks that in extreme cases can cause damage well in excess of the value of the component itself.

A common problem in the woodworking industry is of course the continuously accumulating dust everywhere. This dust can destroy machine and air cylinder bearings, block vents and cause other misfunctioning when it accumulates in the wrong places.

Points for a maintenance plan are listed below:

Daily maintenance checks

- Empty condensate in filters
- Check, top-up oil level in oilers
- Oil grease points
- Special points (where applicable)

Weekly maintenance

- Clean, check and test signal valves, cams, rollers - replace if faulty
- Check for frays, wear, leaks on piping, tubing
- Check tightness, leakage on tubing, couplings
- Check manometer on pressure reducer
- Test oiler functioning
- Check oiler rate drops minute, reset if necessary
- Special points on some machines

Monthly maintenanoe

- Inspeotion of all parts of the installation for leaks, loose oouplings
- Check all valves, cylinders and their vents
- Clean, wash out filter in petrol or clean in air blast
- Cheok air supplies to cylinders and cylinder seals, replace if necessary
- Check operation of automatic condensate drains, no air leakage
- Special points as required

Half-yearly maintenance

- Inspect cylinder shafts for wear or leakage, replace bushes seals or complete unit if required
- Cheok all units for correct operation
- Replace silencer elements where dirty
- Special points as required

The maintenance plan for a complete installation will of course not only be for the pneumatic installation but should encompass all aspects and equipment, mechanical, electrical, pneumatic water sewage services, etc. Naturally one expects to have trained electricians to look after the electrical equipment and one should also expect to have trained people for pneumatic maintenance and repairs. The inner construotion details of some pneumatic cylinders valves and elements can look just as oomplicated as the innards of an electrical unit to the uninitiated. Didactic courses books and information are available for training such personnel today.

Trouble shooting

In a small, simple pneumatic control system trouble shooting can be quite simple but in a more complex installation with many interdependent machine funotions, it oould be like looking for a needle in a haystack unless systematically approached. It is, therefore, very important to keep accurate schematic and detailed drawings of all installations and partioularly to record any changes, modifications or improvements and additions to the system.

System for detecting faults

If one considers the pneumatic controls on simple or complicated machinery in factories in various branches, servicing and maintenance appear to be very difficult and call for a variety of skills. If one considers the matter more closely, however, one finds that many of these pneumatic controls have a lot in common.

Signal output elements

Working elements (cylinders, motors)

Signal processing elements

Actuating elements (3/2, 4/2, 5/2 way valves)
Control elements (shuttle valves, 2-pressure valves, etc.)

Signal input elements

Signal elements (3/2, 4/2, 5/2 way valves)

One recognizes the same components and control groups time and again in the controls, and these are found in different combinations in the machines.

If damage (faults) occur in the systems, systematic fault tracing is most helpful. Repair (servicing) become much easier by systematic fault tracing, and above all the repair time is reduced.

6. Conclusion

Low cost automation possibilities in the wood working industries are virtually unlimited and this short paper can only hope to have touched upon some perhaps more general applications. As individual workshop requirements are likely to vary we can but trust that some of the examples described or the references listed will help guide any interested party towards an appropriate solution or choice for his particular problem.

7. Literature

Pneumatic Control,[1] ISBN 3-8023-0102-1;
Pneumatik in der Holzverarbeitung,[1] ISBN 3-8023-0143-9;
Pneumatic Tips,[2],[3];
Pneumatic Application,[1] ISBN 3-8023-0112-9;
Low Cost Automation for the Furniture and Joinery Industry, UNIDO ID/154;
Maintenance of Pneumatic Equipment and Systems,[2] ISBN 3-8127-0841-8;
Introduction to Pneumatics,[2] ISBN 3-8127-0811-6.

1) Vogel Verlag, 8700 Würzburg, Max Planck Strasse 8, Postfach 8000, W. Germany.
2) Festo Didactic, D-73 Esslingen I. Berkheim, Postfach 6040, W. Germany.
3) Festo Didactic, A-1171 Wien, Haslingergasse 11, Austria.

ANNEX I

Air consumption

The air consumption of a plant is very important for the supply of compressed air and for the determination of energy costs. The air consumption can be simply calculated by means of the air consumption chart.

Chart of air consumption for pneumatic cylinders

cyl. Ø mm	operating pressure . . . atm														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	air consumption in L/cm (liters/cm) stroke of the cylinders														
6	0,0005	0,0008	0,0011	0,0014	0,0016	0,0019	0,0022	0,0025	0,0027	0,0030	0,0033	0,0036	0,0038	0,0041	0,0044
12	0,002	0,003	0,004	0,006	0,007	0,008	0,009	0,010	0,011	0,012	0,013	0,014	0,015	0,016	0,018
16	0,004	0,006	0,008	0,010	0,011	0,014	0,016	0,018	0,020	0,022	0,024	0,026	0,028	0,029	0,032
25	0,010	0,014	0,019	0,024	0,029	0,033	0,038	0,043	0,048	0,052	0,057	0,062	0,067	0,071	0,076
35	0,019	0,028	0,038	0,047	0,056	0,066	0,075	0,084	0,093	0,103	0,112	0,121	0,131	0,140	0,149
40	0,025	0,037	0,049	0,061	0,073	0,085	0,097	0,110	0,122	0,135	0,146	0,157	0,171	0,183	0,195
50	0,039	0,058	0,077	0,096	0,115	0,134	0,153	0,172	0,191	0,210	0,229	0,248	0,267	0,296	0,305
70	0,076	0,113	0,150	0,187	0,225	0,262	0,299	0,335	0,374	0,411	0,448	0,485	0,523	0,560	0,597
100	0,155	0,231	0,307	0,383	0,459	0,535	0,611	0,687	0,763	0,839	0,915	0,991	1,067	1,143	1,219
140	0,303	0,452	0,601	0,750	0,899	1,048	1,197	1,346	1,495	1,644	1,793	1,942	2,091	2,240	2,389
200	0,618	0,923	1,227	1,531	1,835	2,139	2,443	2,747	3,052	3,356	3,660	3,964	4,268	4,572	4,876
250	0,966	1,441	1,916	2,392	2,867	3,342	3,817	4,292	4,768	5,243	5,718	6,193	6,668	7,144	7,619

These should be considered especially for determining the air consumption when long lines are in use.

Calculation of the air consumption

Q = total air consumption L/MM
q = air consumption per stroke in L
s = cm stroke
n = numbers of stroke per min.

a) single acting cylinder
air consumption $Q = s \cdot n \cdot q$ (L/min.)

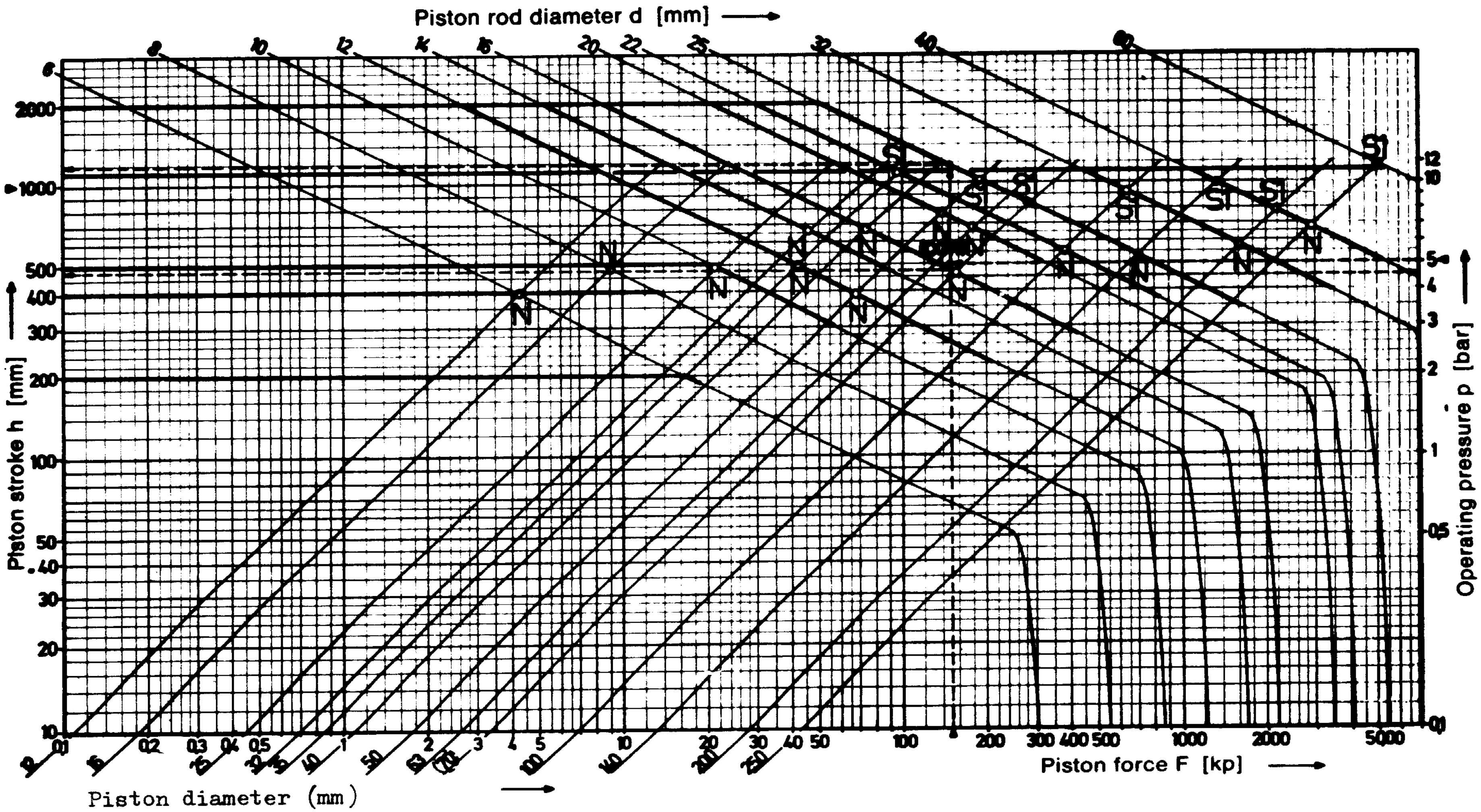
b) double acting cylinder
air consumption $Q = 2 (s \cdot n \cdot q)$ (L/min.)

Example: A double acting cylinder with a diameter of 50 mm and 140 mm stroke must be operated at 6 atm. The number of switching cycles amounts to 50 strokes per minute. How much air is required in L (swept volume) per minute?

$Q = 2 (s \cdot n \cdot q)$
s = 14 cm
n = 50 strokes/min
q = 0,134 L/cm per stroke (after table)
Q = 2 (14 cm · 50 strokes/min. · 0,134 L/cm stroke)
Q = 187,6 L/min

ANNEX II

Calculation of piston force



Example

Given: Load 150 kp
Max. available supply pressure 5 bar
Required piston stroke 1000 mm

Required: Order designation for DC-cylinder, piston diameter, type (normal or reinforced piston rod) and regulated supply pressure.

Solution

1. Locate intersection point between 150 kp force line and 5 bar supply pressure line. Read off the piston diameter of the next higher value = 70 mm diameter.
2. Locate intersection point between 150 kp line and the selected piston diameter. Regulated operating pressure = 4.5 bar.
3. The inter-related intersecting-lines for piston and piston rod diameters are indicated, N = Normal rating, S 1 = reinforced piston rod.

From the intersection point for 150 kp with a piston rod diameter of 16 mm (N Rating for 70 mm diameter) gives a maximum permissible stroke of 470 mm.

Conclusion: The rod is too thin and a danger of buckling exists.

4. Locate the S1 marking on the 70 mm diameter line. Read off the piston rod diameter = 25 mm. Locate the intersection between the 150 kp line and the 25 mm diameter line. Read off the maximum piston stroke = 1150 mm.

Conclusion

Piston rod of 25 mm diameter is appropriate for a 1000 mm stroke with no danger of buckling.

Required order designation:
DC-70-1000-S1

Thick lines indicate the pneumatic load capacity of the piston rods. They terminate at the maximum piston force (N-piston X maximum permissible (operating pressure) and the longest available stroke. A factor of safety of five is assumed and trunnion mounting considered (unfavourable loading method).

For front flange mounted cylinders the permitted maximum stroke may be increased by 50%.

ANNEX III/1

OPERATING METHODS

MECHANICAL COMPONENTS	
	SHAFT: ROTATING IN ONE DIRECTION ROTATING IN TWO DIRECTIONS
	DETENT: ADDED TO INDICATE CERTAIN OPERATING POSITION OF DEVICE IS RETAINED ON ACTUATION
	BLOCK: ADDED TO INDICATE DEVICE IS BLOCKED IN CERTAIN POSITION AND DIRECTION * SYMBOL FOR ACTUATING MEANS
	JUMP: DEVICE JUMPS OVER DEAD POINT INTO ONE OR ANOTHER POSITION
	ARTICULATED JOINTS

ENERGY CONVERSION

	COMPRESSOR
	VACUUM PUMP
AIR MOTOR	
	NON-REVERSING (SINGLE DIRECTION)
	REVERSING (TWO DIRECTIONS)
	LIMITED ROTATION

OPERATORS

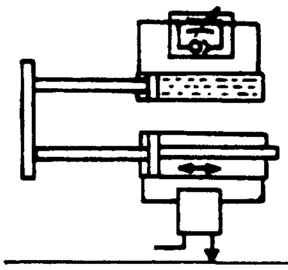
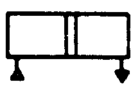
MANUAL		MECHANICAL	
	GENERAL		PLUNGER
	BUTTON		ROLLER
	LEVER		IDLE-RETURN ROLLER
	PEDAL		SPRING
ELECTRICAL		PNEUMATIC	
	SOLENOID		PRESSURE
			BLEED
	SOLENOID AND PNEUMATIC PILOT VALVE		DIFFERENTIAL PRESSURE

CYLINDERS

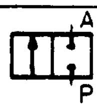
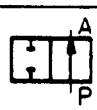
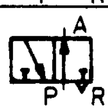
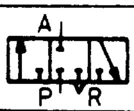
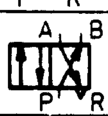
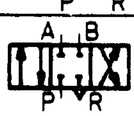
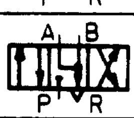
	SINGLE-ACTING RETURN BY EXTERNAL FORCE
	SPRING RETURN
	DOUBLE-ACTING SINGLE PISTON ROD
	DOUBLE PISTON ROD
	ADJUSTABLE CUSHIONING E.G. BOTH SIDES
	CONTINUOUS DRIVE (RECIPROCATING)

Summary of common pneumatic graphical signals (standardized in DIN 24300)

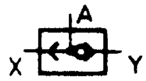
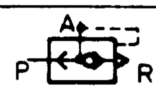
ANNEX III/2

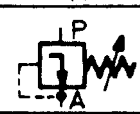
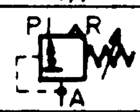
	FEED UNIT WITH CONTINUOUS DRIVE AND HYDRAULIC CHECK CYLINDER
	INTENSIFIER (AIR-HYDRAULIC)
	AIR OIL RESERVOIR

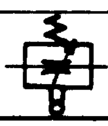
ENERGY CONTROL AND REGULATION

DIRECTIONAL VALVE	
	2/2 WAY VALVE FLOW P TO A CLOSED IN NORMAL POSITION
	2/2 WAY VALVE FLOW P TO A OPEN IN NORMAL POSITION
	3/2 WAY VALVE FLOW P TO A CLOSED IN NORMAL POSITION
	3/2 WAY VALVE FLOW P TO A OPEN IN NORMAL POSITION
	3/3 WAY VALVE CLOSED CENTRE (ALL PORTS CLOSED IN NORMAL POSITION)
	4/2 WAY VALVE
	4/3 WAY VALVE CLOSED CENTRE (ALL PORTS CLOSED IN NORMAL POSITION)
	4/3 WAY VALVE OPEN CENTRE (OPERATING OUTLETS B AND A OPEN TO EXHAUSE. INLET P CLOSED IN NORMAL POSITION)

NON-RETURN VALVES	
	CHECK VALVE

	SHUTTLE VALVE
	RESTRICTOR CHECK VALVE ADJUSTABLE RESTRICTOR (SPEED CONTROL VALVE)
	QUICK-EXHAUST VALVE
	TWO-PRESSURE VALVE

PRESSURE CONTROL VALVES	
	PRESSURE LIMITING VALVE
	SEQUENCE VALVE
	PRESSURE REGULATOR, NO RELIEF PORT
	PRESSURE REGULATOR, WITH RELIEF PORT

FLOW CONTROL VALVES	
	RESTRICTOR VALVES
	ORIFICE VALVE
	ADJUSTABLE RESTICTOR VALVE
	RESTICTOR VALVE, MECHANICALLY ADJUSTABLE BY LEVER ACTUATOR SPRING RETURN

SHUTOFF VALVE	
	SIMPLIFIED SYMBOL

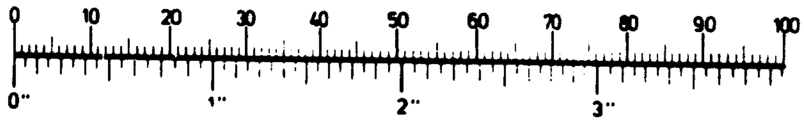
IDENTIFICATION OF PARTS:

Working Outlets	A, B, C ....
Air inlet, air main connection	P
Exhaust, relief	R, S, T ....
Leakage liquid	L
Control or pilot lines	Z, Y, X ....

ANNEX IV/1

Length

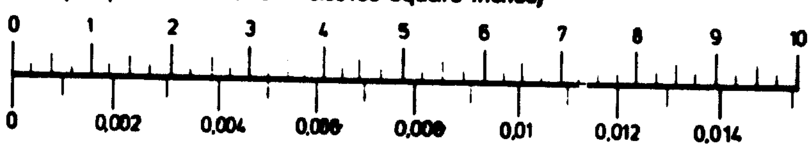
mm (1 millimetre = 0.0394 inches)



in. (1 inch = 25.400 millimetres)

Area

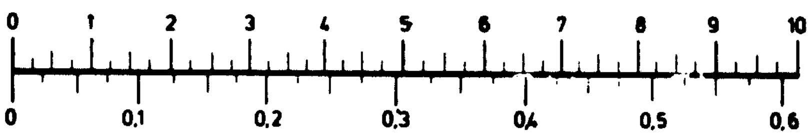
mm² (1 square millimetre = 0.00155 square inches)



sq. in. (1 square inch = 645.2 square millimetres)

Volume

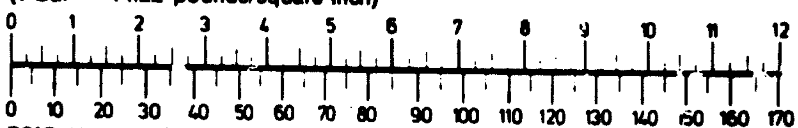
cm³ (1 cubic centimetre = 0.061 cubic inches)



cu. in. (1 cubic inch = 16.387 cubic centimetres)

Pressure

bar = 10⁵ Pa = 0.1 MPa (1 Bar = 100 000 Pascal)
(1 Bar = 14.22 pounds/square inch)

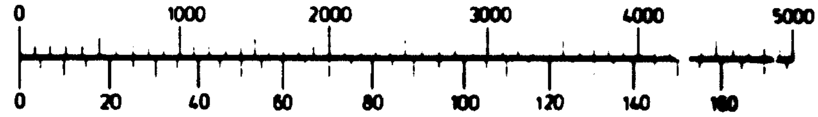


PSIG (1 pound/square inch = 0.070 Bar = 7030 Pascal)

ANNEX IV/2

Flow capacity

l/min (1 litre/minute = 0.0353 standard cubic feet/minute)
(1 cubic centimetre/second [cm³/s] = 0.002 standard cubic feet/minute)



SCFM (1 standard cubic foot/minute 28.316 litre/minute)

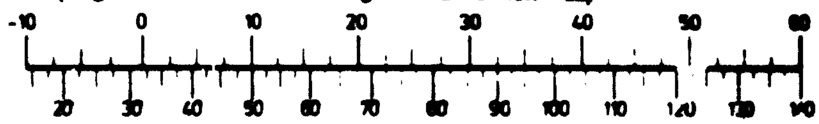
Weight

kg (1 kilogram = 2.202 pounds)

lb. (1 pound = 0.454 kilograms)

Temperature

°C (degrees Celcius = 0.556 degrees Fahrenheit −32)



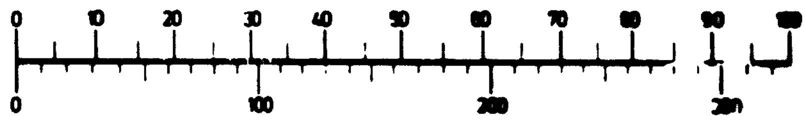
° F (degrees Fahrenheit = 1.8 degrees Celsius +32)

Force

kp (1 kilopond = 9.81 kilogrammetre/square second)

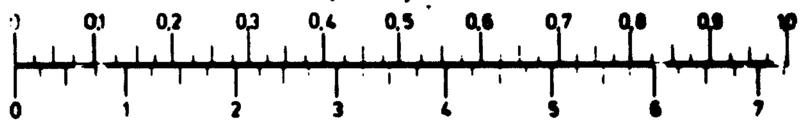
Miscellaneous

m/s (1 metre/second = 3.278 feet/second)

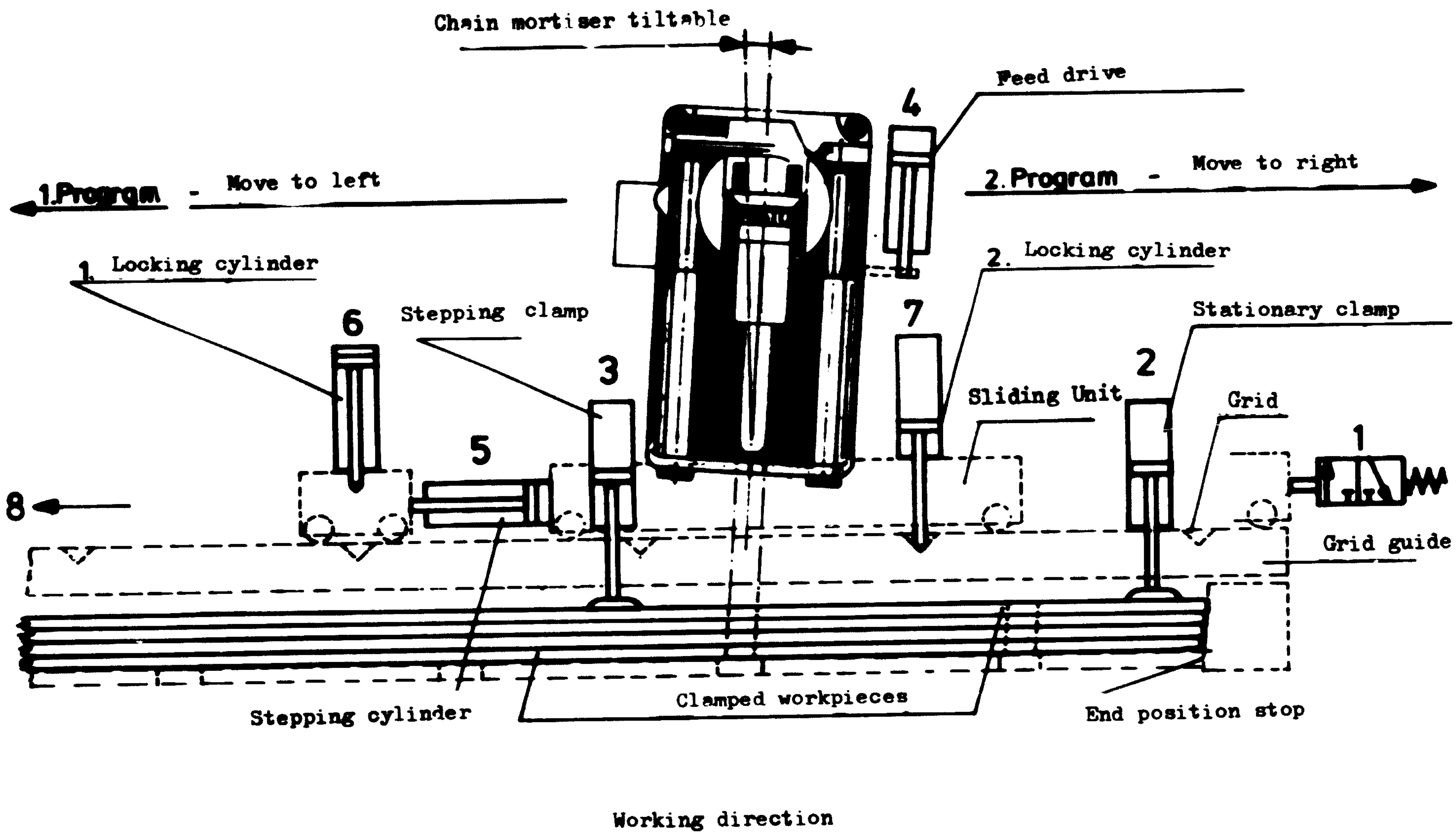


ft./s. (1 foot/second = 0.305 metres/second)

kpm (1 kilopondmetre = 9.81 Joule = 9.81 Newtonmetre)
(1 kilopondmetre = 7.230 feet pounds)



ft.lb. (1 foot pound = 0.1383 kilopondmetre)
AW = width over flats of hexagonal nut (hex)



Note: Numbers 1–8 correspond to those on Schematic

Fig. 2

I - 594

81.09.29

d. The work piece clamp consists of two parts. The stationary part is activated for the whole operational cycle. Whereas the movable part mounted on the larger sliding table is activated during the forward feed to the next step position of work piece. Workpieces are clamped with pressure pads from the front and from above to ensure firm anchoring during machining.

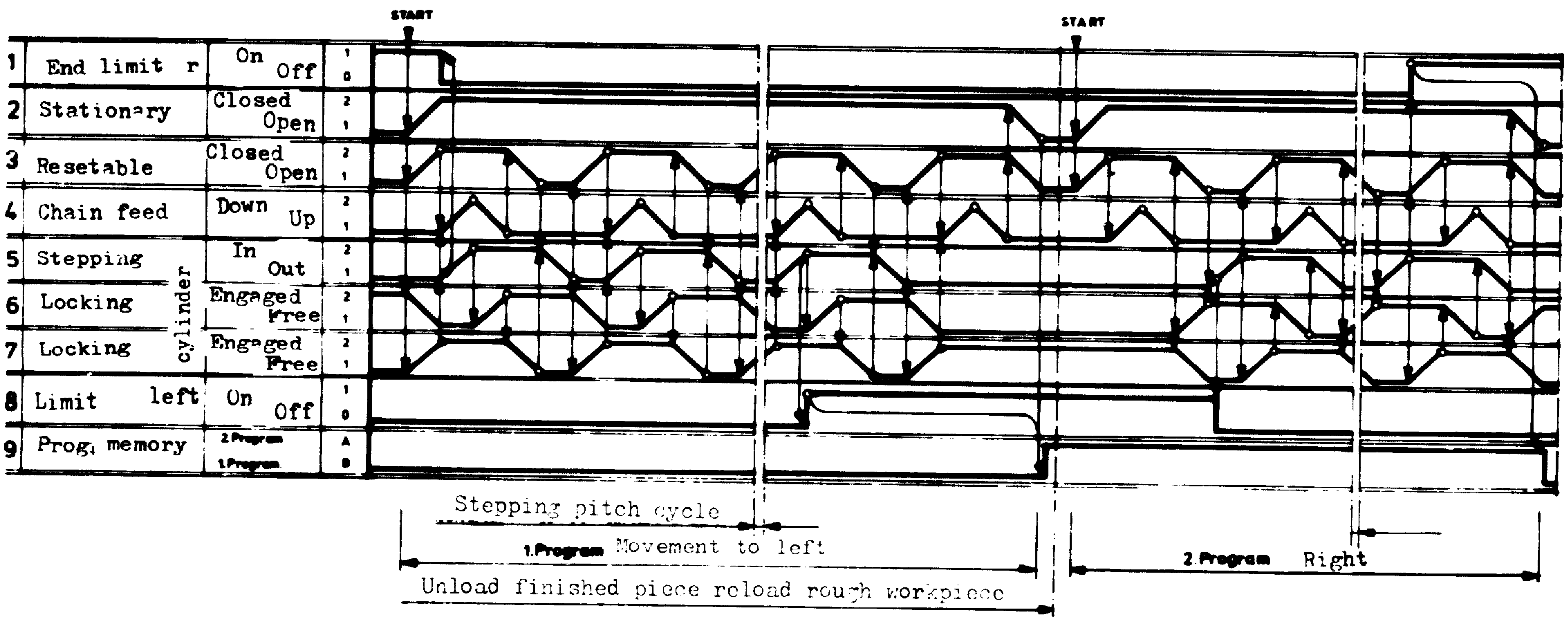
e. Slide stop holds the sliding table firm in the step positions during machining. The sliding table feed cylinder coupling will accomodate various step pitches which can be chosen to suit different requirements.

f. Control console contains all pneumatic elements and the front panel has command controls which consist of a stop button and two start buttons. Start button 1 is used to start a normal operation cycle whilst start button 2 allows one to restart the machine after an emergency interruption of operation. The emergency stop button interrupts operation and the mortising attachment is withdrawn.

Compressed air supply to the whole equipment is supplied through a hand operated stopcock. The sequential operational cycle is shown in a schematic form in fig. 3.

Technical data:

Air supply	6 bar
Mortise width	4 - 25 mm
Mortise length	20 - 60 mm
Mortising depth	max. 175 mm
Mortise pitch	according to requirement
Adjustable angle	max. 10°
Work piece length	max. 6000 mm
Mortising drive	AC motor, 2.2 KW capacity
Cycle time	8 - 12 seconds, dependent on feeder drive speed by milling 4 work pieces together, time per slot is reduced to 2 - 3 seconds per slot.
Air consumption	approx. 200 l/min
Weight	approx. 1000 kg



Operational cycle diagram

Fig. 3