OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

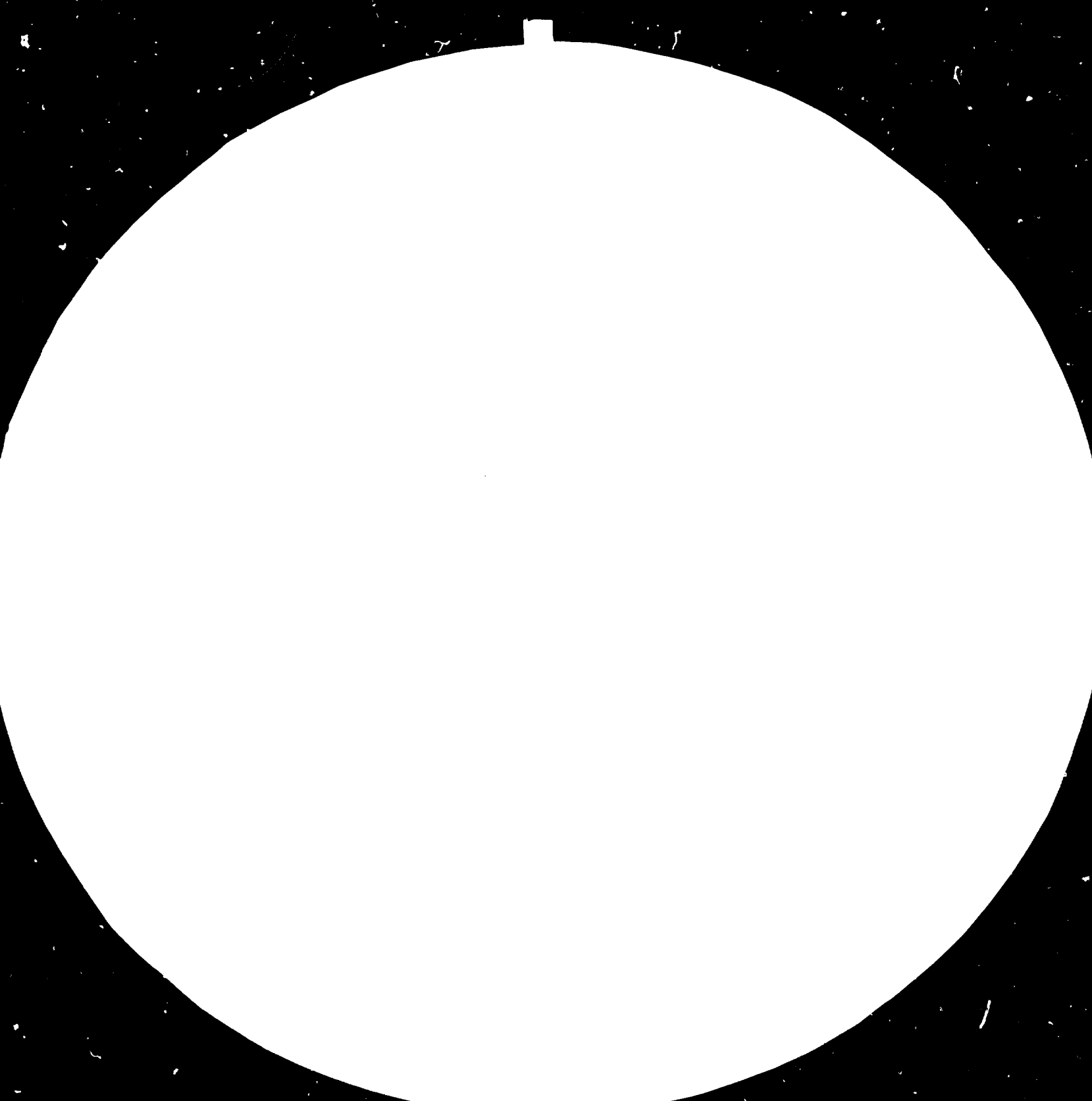
FAIR USE POLICY

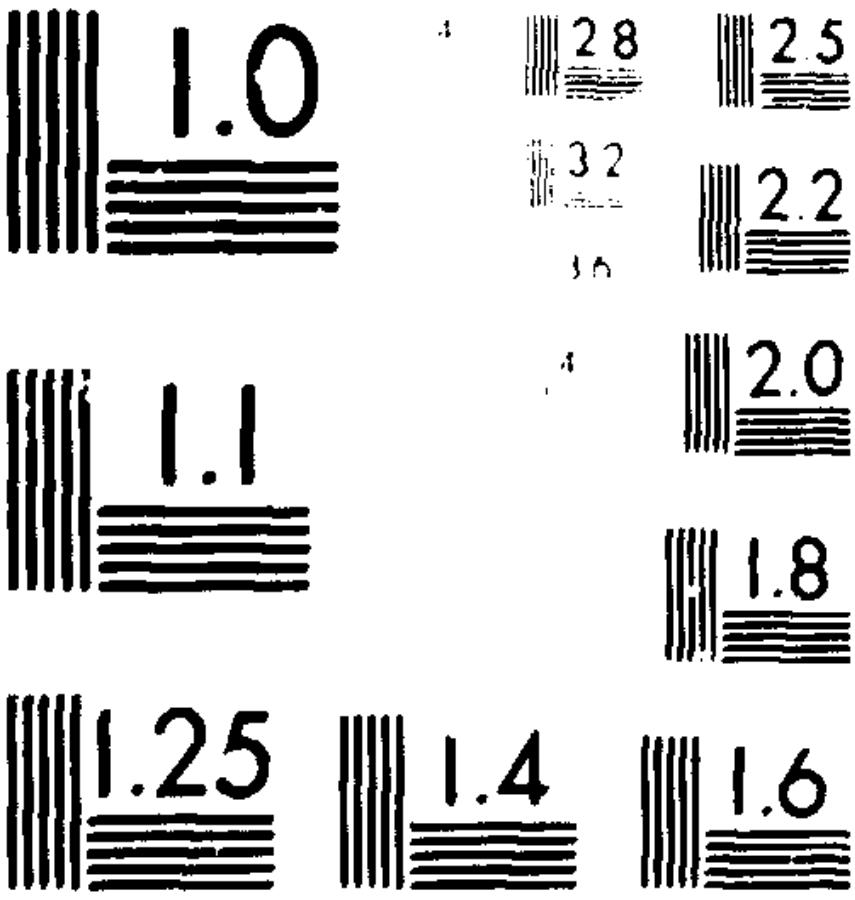
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org





12876

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.369/8
2 September 1983

ENGLISH

Technical Course on Criteria for the
Selection of Woodworking Machines

Milan, Italy, 10 - 26 May 1982

ECONOMIC PRODUCTION OF DOORS AND WINDOWS*

by

I. R. Traversa **

1069

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

** Engineer, SCM Engineering.

V.83-61642

TABLE OF CONTENTS

INTRODUCTION

Volume manufacturing calls for building equipment around product, rather than manufacturing product around equipment.

The many factors governing the choice between standard (traditional or basic) and special (automatic) machines involved in this concept. The following factors which enter into the picture are included: production rate, volume, man-hours, floor space, depreciation and degree of adaptability of standard machines. Much thought and planning is required to determine when it is profitable to operate with adapted traditional machinery, and when to utilize the advantages of automatic machinery particularly suited to the production schedule. When the products present unusual situations, as is the case of windows and doors manufacture, it is sound engineering practice to compare, at the outset, the advantages of both automatic and traditional machines. From these findings decisions can be made, resulting in fewer difficulties and greater profits.

It is true that the concept of adapting standard machines to volume production is outmoded; however, there is no side-stepping the fact that the standard machines cost less when, and if, its application is practical in the setup.

Investigation shows, however, that a vast number of jobs could be more profitably handled with specially built equipment, when all cost factors are taken into account. In many cases the use of specialized machinery has resulted in lower initial investment and process cost than the use of standard machinery. In the woodworking industry, and especially in the manufacturing of doors and windows, there is more tendency to adapt unsuited machinery than to utilize equipment that is "right for the job"; this is probably due to a certain skepticism on the part of enterpreneurs towards special equipment and, also, to the fact that (especially in developing countries) labour is cheaper than automatic equipment; although,

in the last decade, the dramatic increases in labour costs, and unstable labour-management relations have resulted in an inversion of trends.

Manufacturers should realize that, in competitive market conditions, production, sales and profit are dependent on utilizing efficient production methods which will ensure proper quality at low unit cost.

Further, they should realize that short pay-off and return on investment theories must be recognized for what they are and, therefore, that the idea that a machinery purchase is justified only if it saves its cost in direct labour in some relatively short period of time, generally tends to work against the replacement of equipment that is costly to operate.

Economic production of doors and windows, means, above all, the most economic choice of equipment and the successful blending of all the human and material resources of production. However, there is another important aspect of manufacturing which should be considered, that is: work planning or to put it more simply, what has to be done, where and by whom in order to transform, say, a piece of timber into a window or door component, before one could even think of purchasing plant equipment. This paper should provide manufacturers of doors and windows the technical information for selecting machinery and equipment.

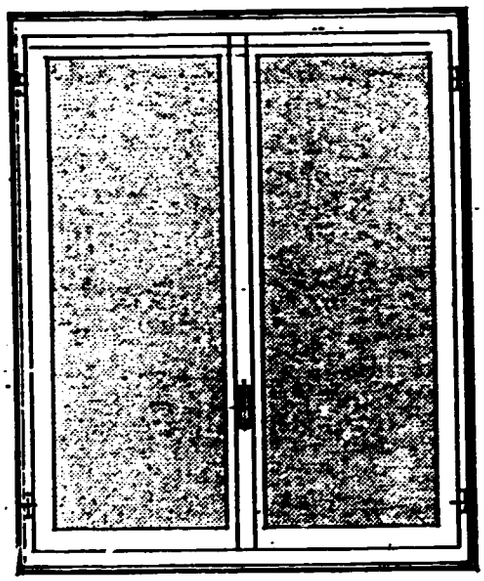
The work is divided in three parts:

(1) Definition of technical terms used in current doors and windows manufacturing practice.
(2) Manufacturing methods for doors and windows, hence the work sequence of the various production processes involved.
(3) Outlines of a medium-sized doors and windows factory.

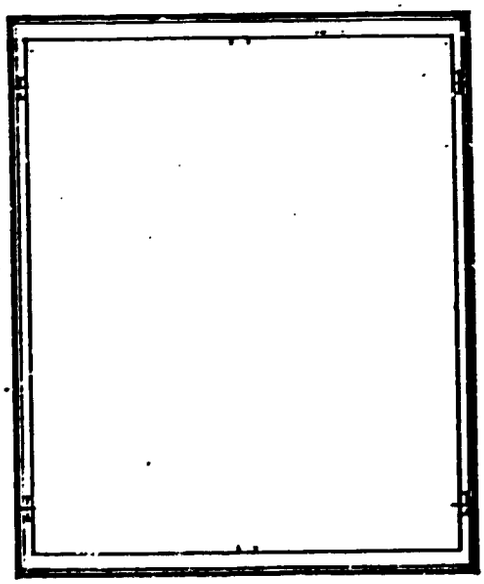
1.0 - DEFINITIONS

Before specifying the subject, we believe it would be useful to define the meaning of the most recurrent technical terms used in doors and windows manufacturing practice.

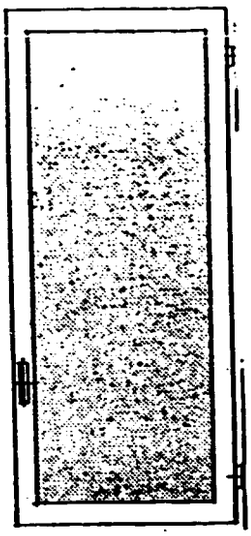
1.1 - Definition of Window Components



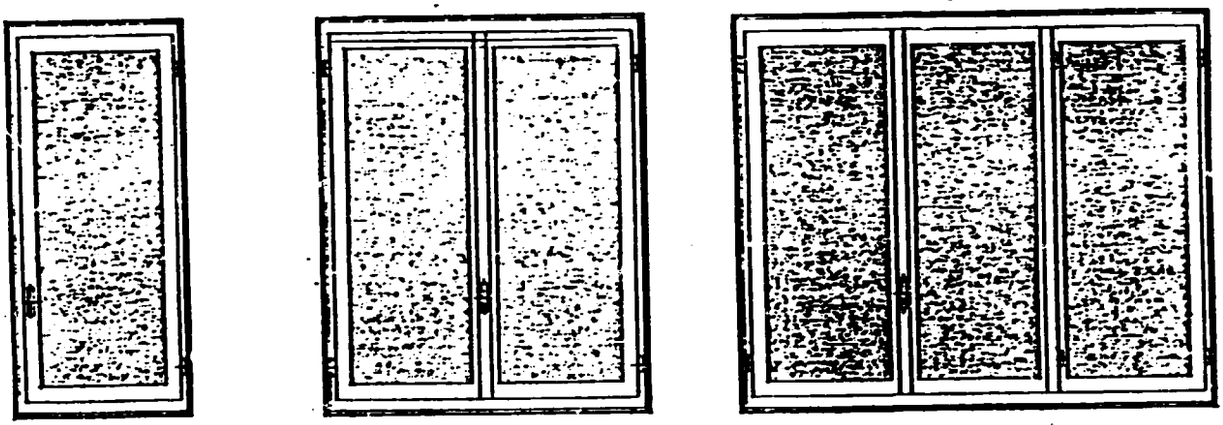
(a) Window - The assembly made-up of the casement (fixed frame) the shutters (movable), the glasses, the accessory fittings (hinges, handles, locking devices).

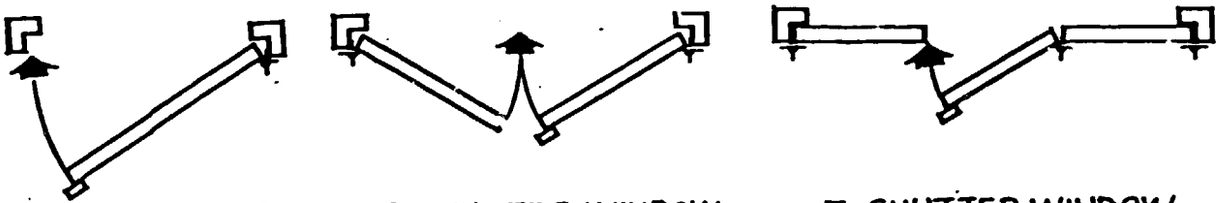


(b) Casement - Part of the window which is fixed to the building's wall. It is the shutters bearing structure, otherwise called "master frame".

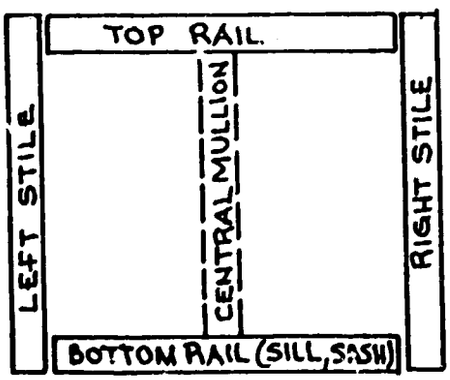


(c) Shutters - Movable (opening) parts of the window which flap against the casement: they support the glasses and part of the window fittings. Shutters distinguish in left hand side and right side wings (for a 2-shutter window) or single wing (for single shutter window).

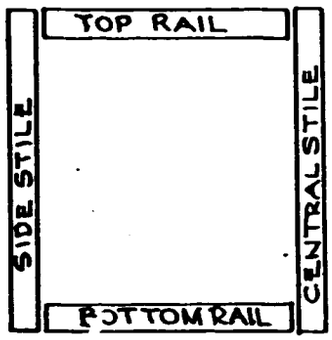




Each CASEMENT is composed of the following elements :

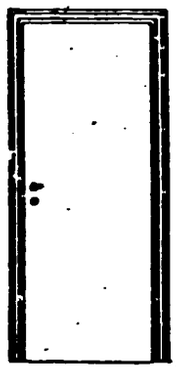


Each shutter is composed of the following elements:

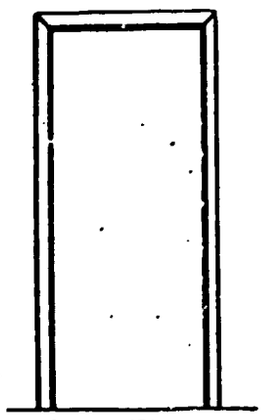


-- Top rail
-- Side stile
-- Central stile
-- Bottom rail

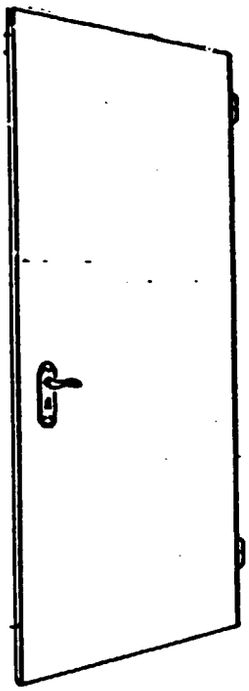
1.2 Definition of door components:



(a) Door - The assembly made-up of casement (fixed frame), the decorative casings, the door panel (movable), the accessory fittings (hinges, handle, lock).

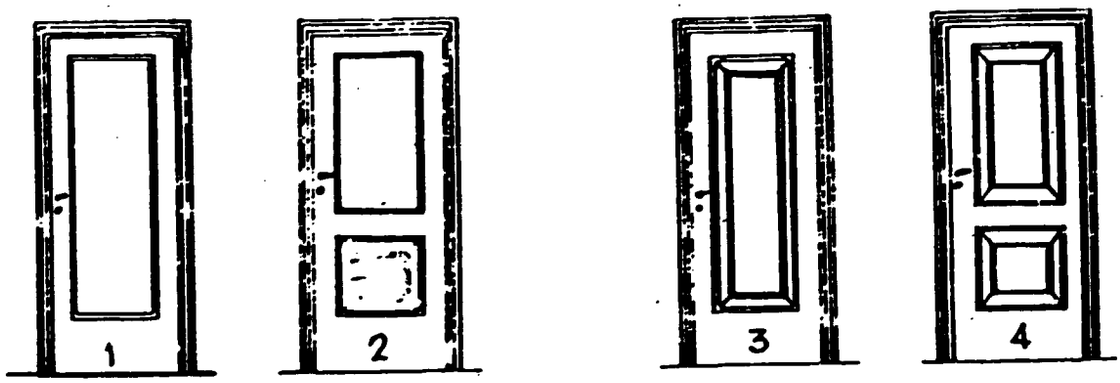


(b) Casement - It is the door's bearing frame which is fixed to the walls; it is complete of lock face plate, hinges and casings.



(c) Door Panel - It is the moving part of the door proper, complete with hinges, lock and latch, handle. There are several types of door panels; the main types which are of interest to us are the institutional doors with wood or plastic laminated skins. These may be subdivided into two broad classes: (i) Full core flush doors, (ii) Cut-out doors. Both classes may be lipped and unlipped. Furthermore, cut-out doors may be characterized by: glazed panels and/or raised panels.

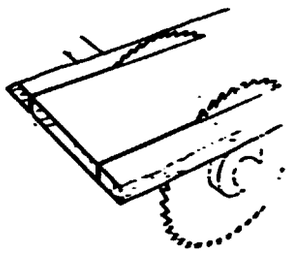
Some Common Types of Cut-Out Doors



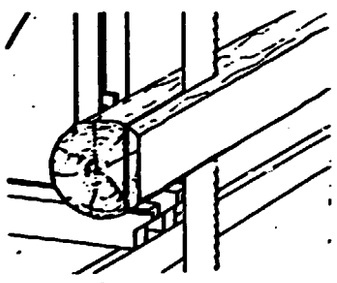
Legend: 1 - Single Aperture Glazed Panel
2 - Double Aperture Glazed Panel
3 - Single Aperture Raised Panel
4 - Double Aperture Raised Panel

1.3 - DEFINITION OF BASIC MACHINING OPERATIONS IN DOORS AND WINDOWS MANUFACTURING PRACTICE

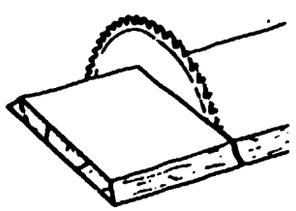
1.3.1- **RIPPING** - is the operation of making a lengthwise cut through a board.



1.3.2- **RESAWING** - is the operation of ripping a thick board to make a thin board.



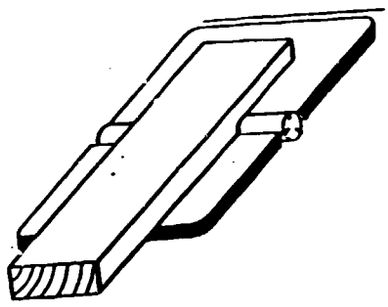
1.3.3- **CROSSCUTTING** - is the operation of sawing through (across the grain) a piece of stock or cutting across the narrowest dimensions of a piece of stock.



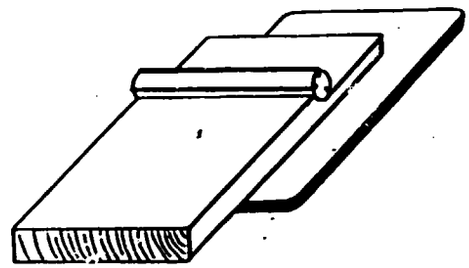
1.3.4 - Planing: is the operation of trueing-up the faces of a board or a piece of stock along the wood-grain. There are two distinct planing operations:

(a) Surface Planing - it is the first operation which is usually performed in machining the sawn timbers. It has the scope of obtaining a plane surface cut of a roughly sawn surface.

(b) Thickness Planing - it is an operation whereby an almost perfect parallel board surface can be obtained with reference to a surface previously obtained by the surface planing operation.

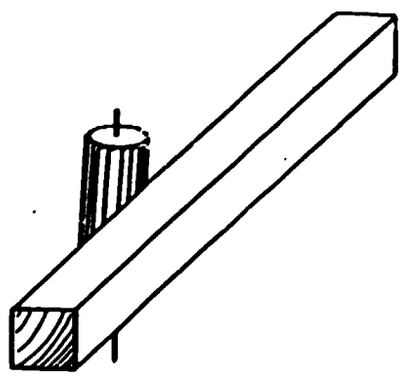


SURFACE PLANING

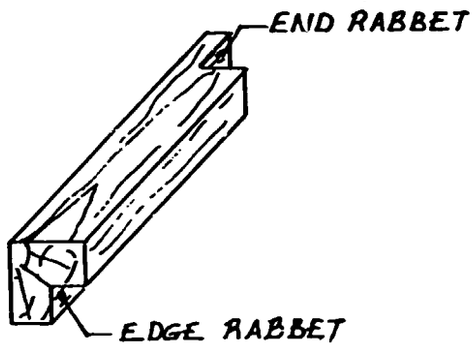


THICKNESS PLANING

1.3.5 - Jointing: is the operation of trueing-up or straightening a board or a piece of stock edgewise.



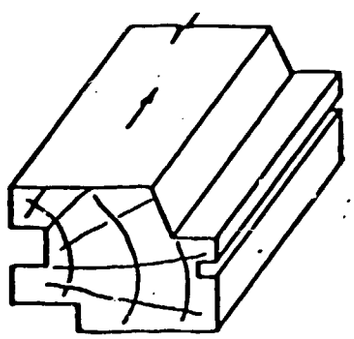
1.3.6 - RABBETING - is the operation of cutting along the edge of a board or of a piece of stock so as to remove a corner down the length of the stock.

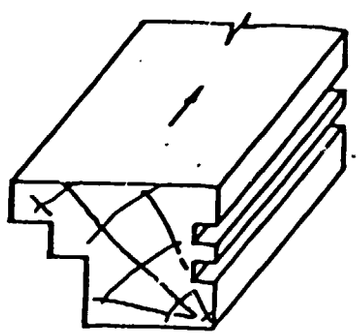


1.3.7 - MOULDING - is the operation of cutting a shape on the edge or face of a workpiece.

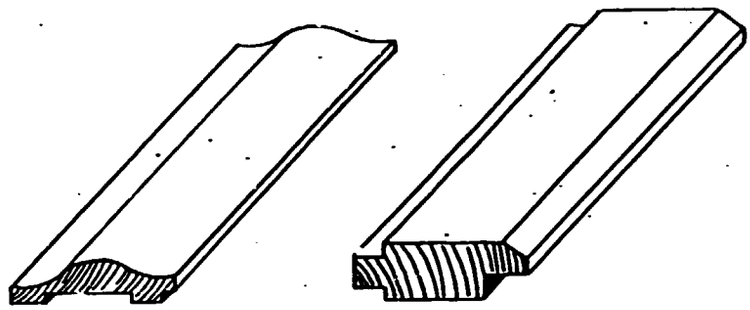
Typical moulding operations most frequently encoun tered in doors and windows manufacturing practice are :

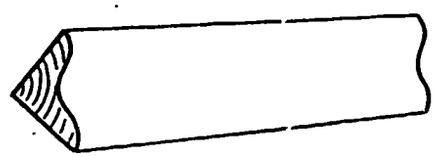
a) those performed on the inside profiles of the windows components such as : top rails, sashes sills, stiles, etc.





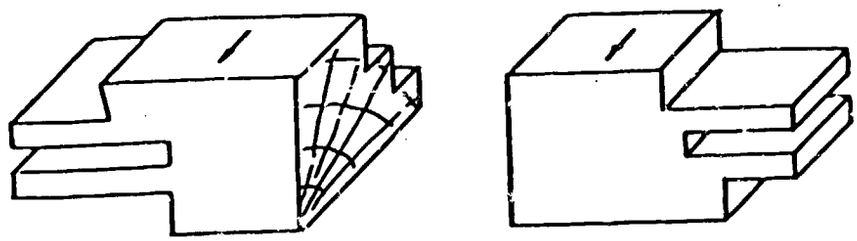
b) those performed on the door components such as : lipping, astragals, ornamental casings, back bands, wainscots, raised panel lips, jambs, heads (as illustrated below).



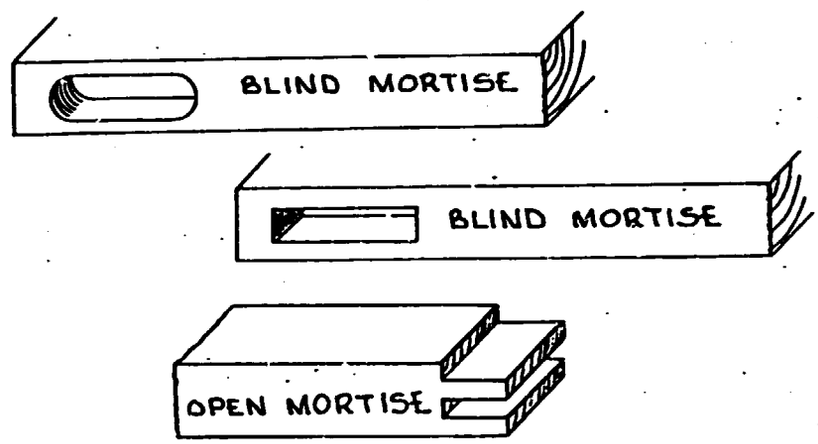


1.3.8 - TENONING - is an operation which aims at reducing the thickness of a piece at stock's ends, in order that these may be fitted into the corresponding mortises to form thus mortise and tenon joint assemblies.

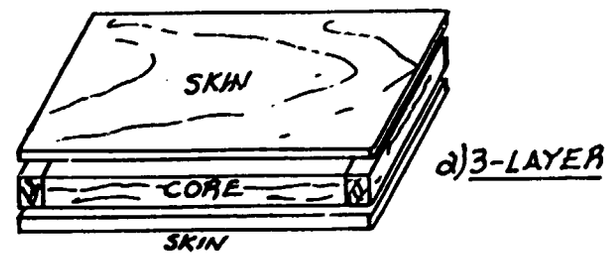
Typical examples of tenons mostly used in door and windows manufacturing practice are :

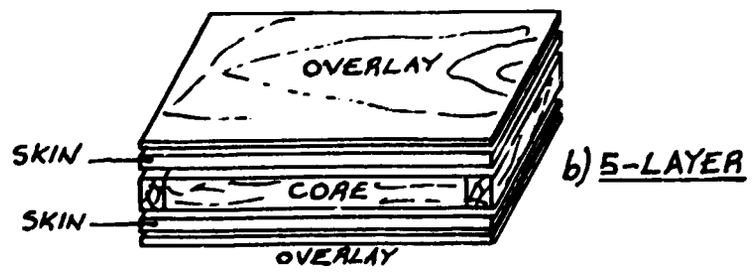


1.3.9 - MORTISING - is an operation which consists in removing material from the ends or the faces of a piece of stock, in order to create a seating or a slot for a corresponding tenon.
Typical mortises used in door and windows manufacture are :



1.3.10 - PRESSING- is the operation whereby, by means of pressure and glue, a cored door panel is formed.
The pressing operation is thus the formation of a "sandwich panel".
Sandwich panels may be of two kinds :
a) 3-layer
b) 5-layer





The pressing operation is usually carried out by means of machines called "presses". There are several types of presses, but the most commonly employed may be divided into two main categories:

I - Hydraulically operated hot platen presses

These may be further subdivided into automatic or semi-automatic, multiplaten or single-platen presses.

The selection of one or the other type of press depends on the quantity of doors one wishes to produce in a given time. Furthermore, the pressing cycle depends, amongst other factors, on the thickness of skins, the temperature of the hot platens and on the kind of glue used.

Orientatively, the following parameters may be used as guide:

-- Glue: Urea Formaldehyde molasses, viscosity 30 to 40 poises, 100 parts by weight charged with 30 parts of flour (starch, rye, etc.), mixed with 25 parts of water and 10 parts of hardener solution. The quantity of glue to be spread over each skin varies between 160 and 220 g/m^2 depending on the nature of the skin material as well as on the skeleton wood species.

-- Time/Temperature: in practice it is considered that, at a press platen temperature of $95^{\circ}C$, the pressing time should be calculated at 1 minute per each millimeter of skin thickness; obviously, a veneering cycle, employing 0,7 mm veneer overlays, would take around 40 to 45 seconds.

-- Pressure: the press gauge pressure should be set between 2 to 30 Kg/cm^2 for a 3-layer sandwich, and between 4 to 6 Kg/cm^2 for a veneering cycle.

II - Cold Platen Presses

These are usually "single daylight presses" featuring a top platen and an iron girder; the top platen is movable and may be operated either hydraulically or mechanically by jack-screws. The number of doors which can be pressed depends on the press' daylight clearance; standard presses do usually have a clearance ranging between 400 to 800 mm.

The pressing times are relatively high; the glue most commonly used has the following formulation: Urea Formaldehyde Molasses, 100 parts by weight charged with 5 parts of starch or rye flour mixed with 5 parts of Kaolin.

Cold pressing is particularly indicated when door skins are of PVC, PVA or other materials which are susceptible to temperature or when a suitable heat source is not available or, at any rate, when energy saving may be a predominant economic factor.

1.3.11 - ASSEMBLY: In the present context, assembly means joining all the elements of shutters or of casements by means of clamps or frame presses for window construction together; whereas, for door panels, assembly means joining all the elements of the door skeletons together: stiles, rails, hinges blocks, lock blocks, core material (expandable honeycomb or rigid core) by staples, nails, etc.

1.3.12 - DIMENSIONING: Is the operation of trimming off and/or moulding, rabbeting, dadoeing, edging, etc. all four edges of shutters and doors in order to obtain perfect parallelism, hence squarenness, of the manufactured edges.

1.3.13 - EDGEBANDING: Is the operation whereby the edges of a door panel, usually the longitudinal edges, are covered with a lipping strip of solid wood, veneer or other laminating material with the purpose of hiding the exposed edges of door skins.

1.3.14 - SANDING: Sanding operations have the purpose of reducing products to correct gauge thickness (thickness or gauge sanding) or to remove any surface defects prior to the veneering operation (for doors) or to the surface finishing operations (finish sanding). Sanding is "plening by abrasives". There are a lot of sanding machines, but the most common ones are: portable tools, belt sanders, disc sanders, drum sanders.

1.3.15 - SURFACE FINISHING: Is the process of applying stains or paints on finished products with the purpose of preserving their surfaces from weathering effects and of imparting them pleasant appearance. The characteristics of the finishing products and of their application techniques are beyond the scope of the present work.

1.3.16 - HARDWARE FITTING: Includes all operations, manual or mechanical, which involve the application of hardware and accessories such as: hinges, knobs, handles, locks, glasses, etc. onto the products with the purpose of making them functional and ready for use.

2.0 - MANUFACTURING METHODS FOR WINDOWS AND DOORS

2.1 - WINDOWS

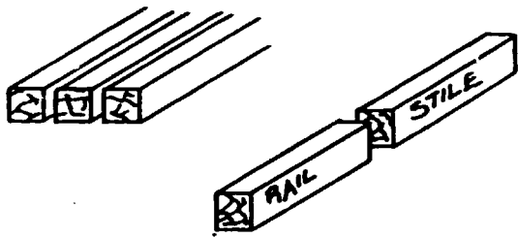
The manufacturing methods, hence the work sequence to be adopted, vary in accordance with the types of machines installed within the factory. We distinguish two classes of machines:

I) **Traditional or Basic Machines**
II) **Automatic Machines**

We will now describe the various manufacturing steps involved in the construction of typical windows.
For both traditional and automatic machines operation, it is assumed that the timber to be employed for the construction of windows has a moisture content ranging between 12 and 14 per cent, that it is free from relevant defects, and that it does not need particular preservation treatments.
Thus the machining sequences are as follows :

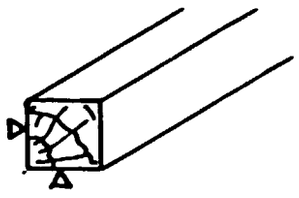
I) **Window Production Employing Traditional or Basic Machines**

STEP 1 - **Board Ripping (a)**
Cross Cutting (b)



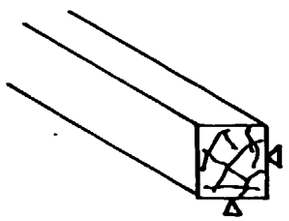
MACHINE : BANDSAW OR CIRCULAR SAW

STEP 2 - SURFACE PLANING ON TWO ORTHOGONAL FACES



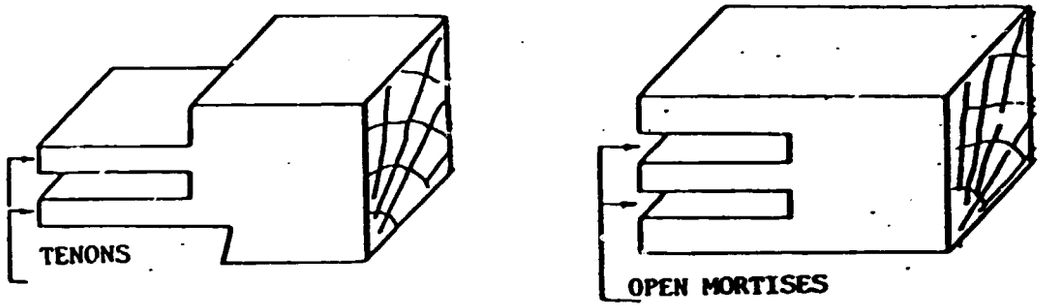
MACHINE : SURFACE PLANER WITH JOINTER ATTACHMENT

STEP 3 : THICKNESS PLANING ON OTHER TWO SURFACES



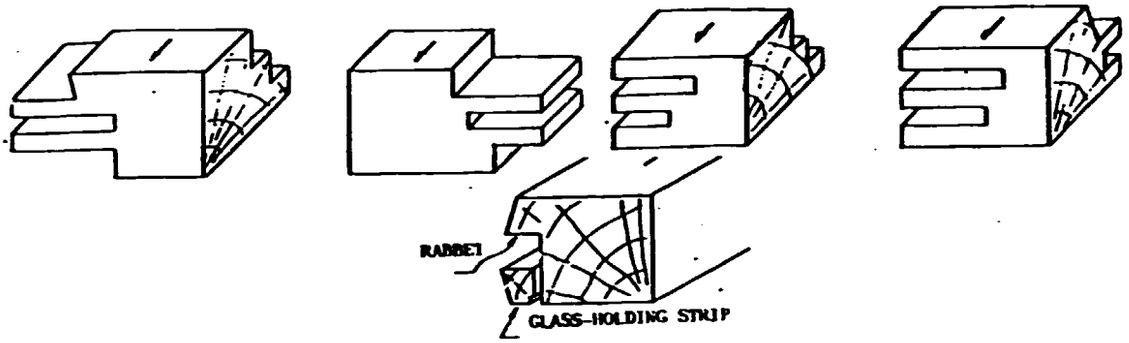
MACHINE : THICKNESS PLANER

STEP 4 : TENONING OF CASEMENT AND SHUTTERS' STILES AND RAILS



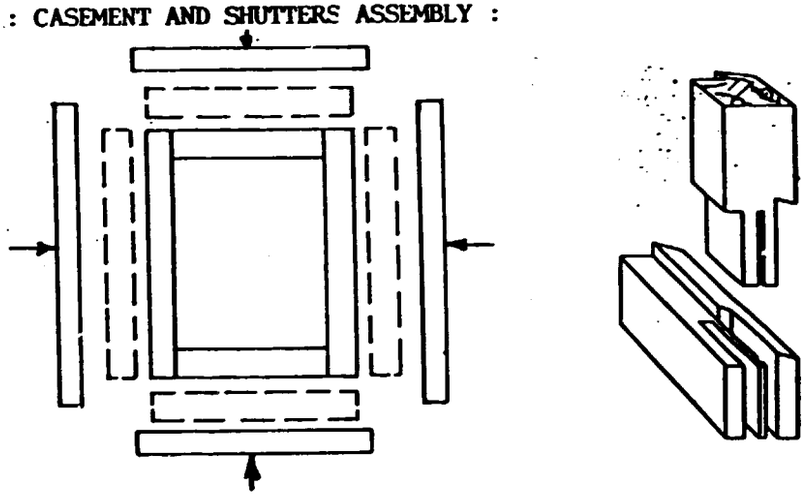
MACHINE : SPINDLE MOULDER TENONER COMBINATION MOULDER/ CIRCULAR SAW

STEP 5 : MOULDING INSIDE PROFILES OF CASEMENT AND SHUTTERS'STILES AND RAILS



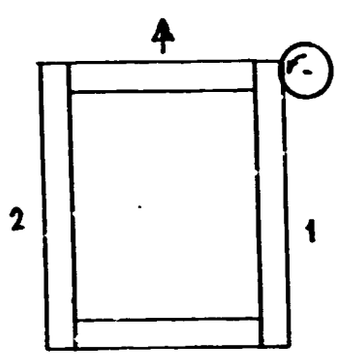
MACHINE : SPINDLE MOULDER COMBINATION MOULDER/CIRCULAR SAW

STEP 6 : CASEMENT AND SHUTTERS ASSEMBLY :

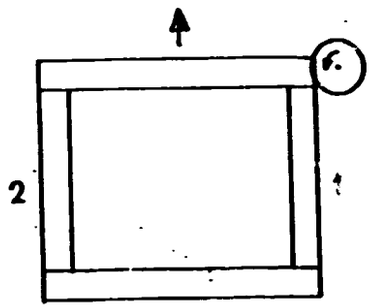


MACHINE : FRAME CLAMP (PRESS)

STEP 7 : DIMENSIONING OF ASSEMBLED SHUTTERS :



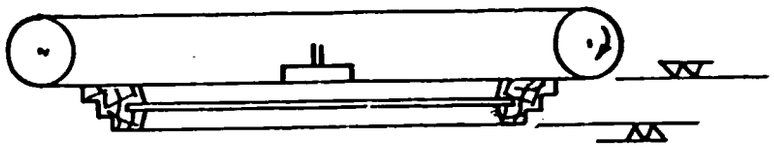
LONG-SIDE FIRST



BROAD-SIDE AFTER

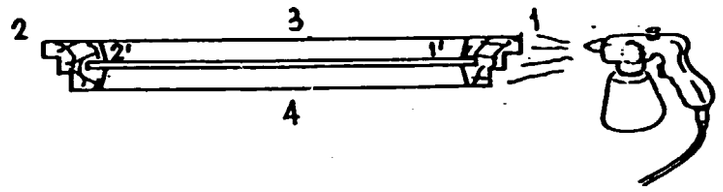
MACHINE : SPINDLE MOULDER COMBINATION MOULDER/CIRCULAR SAW

STEP 8 : SURFACE SANDING OF DIMENSIONED SHUTTERS



MACHINE : BELT SANDER DRUM SANDER PORTABLE SANDER

STEP 9 : SURFACE FINISHING OF DIMENSIONED SHUTTERS



MACHINE : SPRAYING GUN

STEP 10: Hardware Fitting on Shutters and Casements

The operation consists in drilling and driving hinge pivots onto casement stiles, drilling and driving hinge sockets onto wings, driving and screwing locking mechanisms and handles onto wings, drilling and driving eye-bolts or sockets onto casement head rails and sills, then in testing window assembly for good matching and performance.

The window glasses are generally fitted at customer's site, after window casement has been fixed to building's walls.

Machine: Portable Power or Pneumatic Tools
Such as drills, nailing guns, hinge drilling and sinking attachments, screwdrivers.

II WINDOW PRODUCTION EMPLOYING AUTOMATIC MACHINES

The manufacturing sequence does not change; what does change, instead, is the factory productivity in that, the use of automatic machines diminishes the number of operations and increases production output, thus:

Step 1 - Ripsawing

Is carried out on a multiple ripsaw (or gang ripsaw) which can cut dimension stock in multiples up to four staves can be ripped-off in one single machine pass from a board, on 50 HP multiple ripsaw with 300 mm cutting width capacity, at an effective machine feed of around 8 metres per minute, attended by two operators. This means, of course that, due allowance being made for machine setting-ups, tooling-up and operators idle time, it is possible to produce around 14,000 lineal meteres per day of stavings or, in the case of a standard 2-shutter-window (1400 x 1500 mm) a multiple ripsaw may produce sufficient stock pieces for about 1000 windows per 8 hours day, and could comfortably feed two to three multispindle moulders.

Step 2 - Length Cross Cutting of Stiles and Rails

In order to fully exploit the capacity of both the multiple ripsaw and the machines downstream of it (for example the multi-spindle moulding machines, the double end tenoners, etc.) it is advisable to perform the cross-cutting operations (stiles and rails cross-cut to correct lengths), in multiples prior to the ripping operation; this procedure will, also, eliminate the need to install costly high-capacity cut-off saws between the multiple ripsaw and the multi-spindle moulders in that a heavy-duty, good quality cross-cut saw, placed before the multiple ripsaw, should be able to easily keep pace with the latter machine's capacity.

Step 3 - Moulding Inside Profiles of Casement and Shutters Stiles and Rails

Whereas the use of traditional or basic machines demands that prior to profiling two machining operations be carried out, namely surface planing on two orthogonal faces (see Step I-2) and thickness planing (see Step I-3), the installation of a suitable multi-spindle throughfeed moulder, for instance, would enable to perform the profiling job in one single operation. The main advantages to be gained by the use of such machine are: higher production volume, higher work quality and long range economies in labour and overheads. In fact, a good automatic moulder, suitably equipped, can machine a sufficient number of rails and stiles for about 200 standard 2-shutter windows (1400 x 1500 mm) per day of 8 working hours with only two semi-skilled machine operators.

Step 4 - Double End Tenoning of Casement and Shutters' Stiles and Rails

The tenoning and mortising operations on the two extremities of rails and stiles, respectively, must be performed in two steps when using basic machines that is: first, we must machine one end, then turn the piece around and machine the other end. This is rather awkward way of doing things and does require pretty skilled operators. But, if we could pass our piece of work through a machine which does work both extremities simultaneously and without need for the operator to worry about work jigs or any other attachment, then not only would we reduce machining times, hence increase productivity, but a higher work precision would be obtained. There is such a machine and it is called an "automatic double end tenoner"; as the name will imply, the machines does work both ends of the stocks with extremely high precision and rate of execution. All the machine operators have to do, is to keep feeding the work to the machine on one end and catch it on the other, once the machine has been set-up and tooled-up. A double end tenoner may machine up to 4000 pieces per day, or a sufficient number of rails

and stiles for 500 standard 2-shutter windows per day of 8 working hours with only two semi-skilled machine operators.

Step 5 - Assembly of Shutters

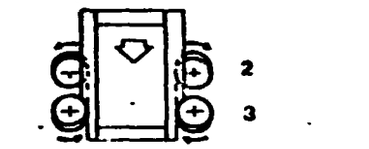
In a modern window factory the assembly operation may represent a serious bottleneck if adequate assembly facilities are not provided for. There are two ways of speeding-up the assembly process:

(a) by installing a suitable number of frame clamps, thus employing lots of people to do the job, or
(b) by installing a hydraulically operated automatic frame press assisted by automatic glue spreading equipment in order to speed-up operations and maintain the number of labour to a minimum.

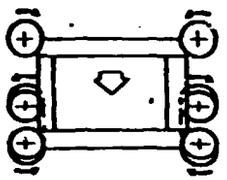
Step 6 - Dimensioning of Assembled Shutters

A properly tooled-up automatic double end tenoner serves also the purpose of dimensioning the shutters that is, it will trim and rabbet the wings of shutters in only two machine operations: long sides and broad sides. Apart from the advantage of halving the amount of machine operations - two on the double end tenoners as against four on the basic machines - other advantages are:

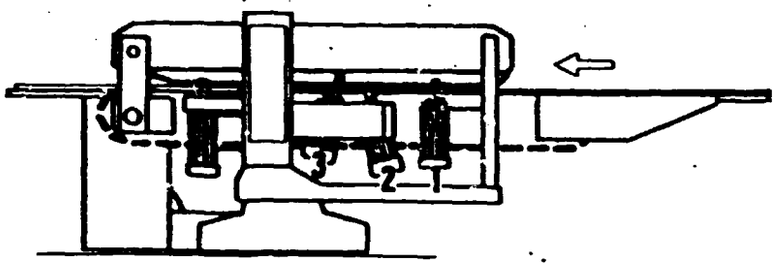
-- greater dimensional control;
-- good and splinter-free surface finishes, owing to the possibility of equipping the machine with several work stations and with automatic relishing tool heads;
-- elevated production capacity; up to 600 standard shutters per 8 hours shift - equivalent to 300 standard 2-shutter windows - can be dimensioned on an automatic double end tenoner attended by only two operators.



LONG-SIDE DIMENSIONING

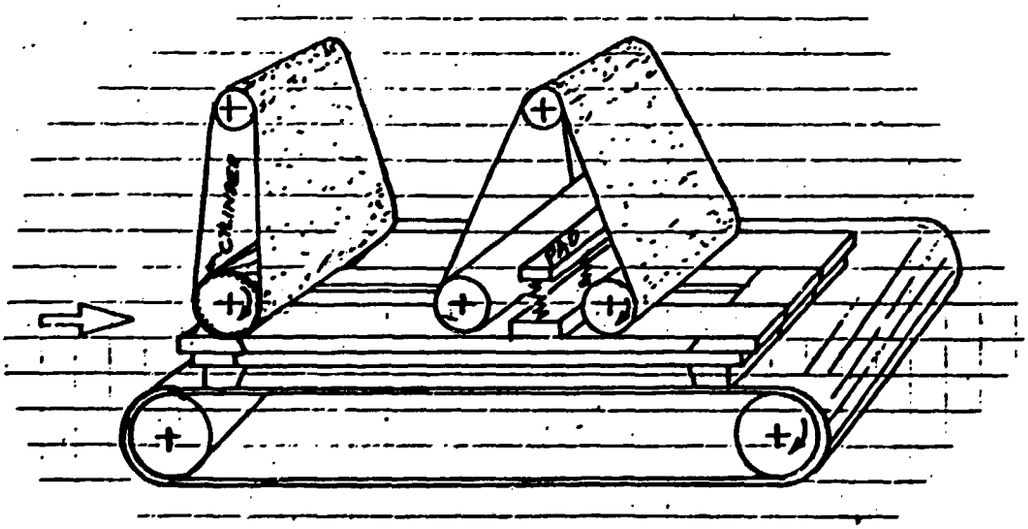


BROAD-SIDE DIMENSIONING



Step 7 - Surface Sanding of Dimensioned Shutters

Owing to the high productive capacity of the machines upstream, it is logical to assume that the traditional manual sanding operations performed in workshops equipped with basic machines, would constitute a serious bottleneck in a modern factory. So, in order to get a balanced production process, it is necessary to install a surface sanding unit capable to cope with the situation: this is usually an "automatic overhead wide belt sanding machine" which can perform, in two steps, the sanding operations needed prior to the surface finishing of the shutters.



The sanding machine may be equipped with two sanding units: a sanding cylinder and a pad, thus enabling to perform both the abrasive planing and the pre-painting surface preparation operations.

The automatic wide belt sander may surface-sand two faces anything up to 600 standard shutters in 8-hour shift (that is, 300 standard 2-shutter windows per day) and requires only two semi-skilled workers to do the job.

Step 8 - Surface Finishing of Shutters and Casement Components

In Step 5, the assembly of casements has not been mentioned at all: this has been done on purpose; there are special reasons behind this:

- hinge fitting will be done by automatic machines, hence, it is not practical (if not difficult) to lay-in the hinges on cumbersome frames; therefore the hinges should be driven-in after the painting operation,
- it is much easier and more paint-saving to finish a single component than the whole casement assembly,
- it is much easier to carry around the factory, say, four unassembled stock pieces, than a cumbersome casement frame.

Thus, the surface finishing equipment should be characterized by a moulds' painting line and by a shutters' painting line, suitably dimensioned and sufficiently mechanized to meet the factory production requirements. Typical finishing equipment may be:

- a stain dipping tank,
- an overhead transporting conveyor,
- a water-wash spraying booth with spraying guns,
- a paint curing oven,
- some sanding benches,
- a moulds automatic spraying machine,

-- a profile automatic sanding machine,

-- a moulds paint curing oven.

Step 9 - Hardware Fitting on Casement Components and on Shutters

The hinge fitting operations on both casement components and on shutters, are usually carried out by an automatic universal hinge boring and inserting machine. A great variety of such machines exist on the market depending on the type of hinges, on size of windows and on production quantities to be achieved, we may select one, two, three or four-aggregate hinge inserting machines whose capacity may vary from two up to six hinges being inserted per minute.

The fitting of hardware accessories other than hinges, such as shutters locking mechanisms, handles, eye-bolts, glasses and any other accessory that may be required, is usually performed manually on special assembly benches equipped with suitable jigs and fixtures.

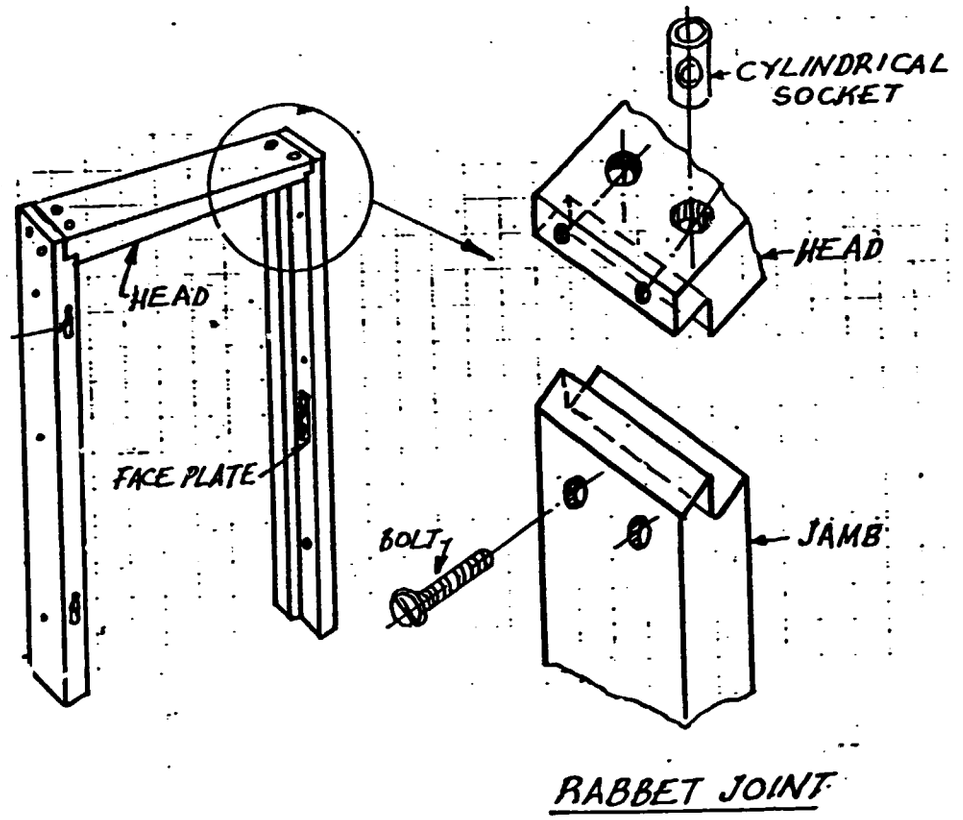
Step 10 - Casements Assembly

This is usually carried out by means of hydraulically operated horizontal frame presses equipped with glue-spreading facilities and suitable tools for the assembly of hardware accessories characteristic to the product.

2.2 - DOORS

As mentioned earlier (section 1.2 - q.v.) a door assembly is composed basically of a casement, decorative casings, door panel and some accessory fittings. In this section we will briefly illustrate and describe the construction details and the manufacturing sequence of each door component , employing both basic and automatic machines. In both cases, it will be assumed that the timber species to be used have a moisture content ranging from 8 to 10 per cent and are free from relevant defects.

2.2.1 - DOOR CASEMENT CONSTRUCTION

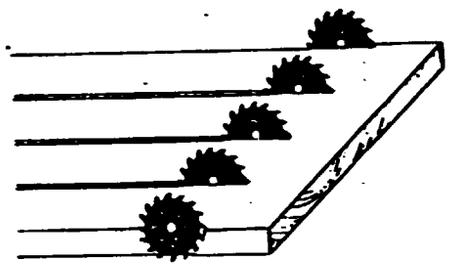


RABBET JOINT

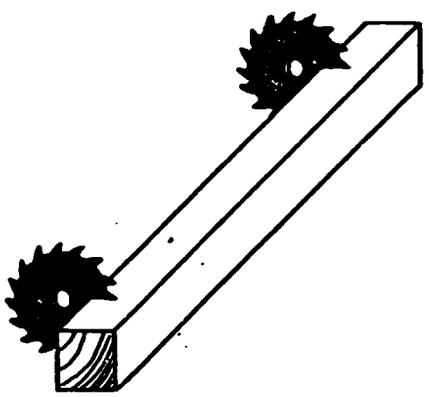
The important features of the rabbet-joint in combination with bolt and socket are:

- ease of machining,
- ease of assembly,
- the casement can be delivered in knock-down form to the customer, which results in considerable savings in transport costs.

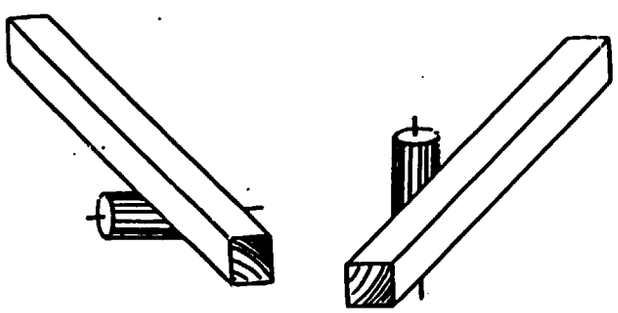
I - MACHINING SEQUENCE FOR DOOR CASEMENT EMPLOYING BASIC MACHINES



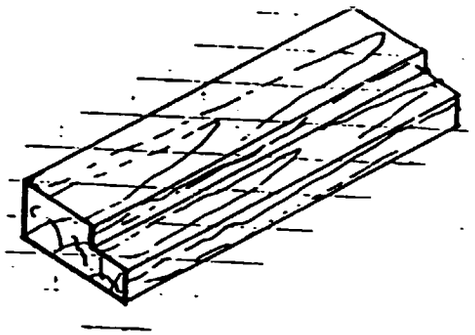
a) Rip rough sawn timber, kiln dried, at bandsaw or circular saw.



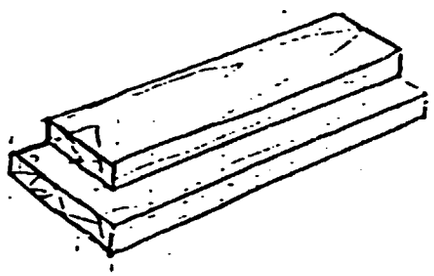
b) Cross-cut to correct length at bandsaw or circular saw (defective ends trimmed off).



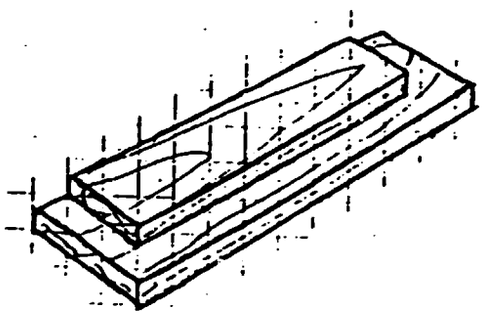
c) Plane four faces to correct cross-section at surface planer with jointer attachment and thickness planer.



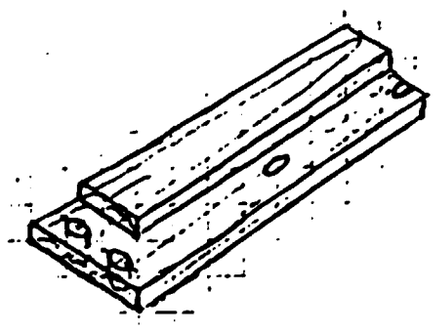
d) Machine with rabbet at spindle moulder or combination moulder/ circular saw.



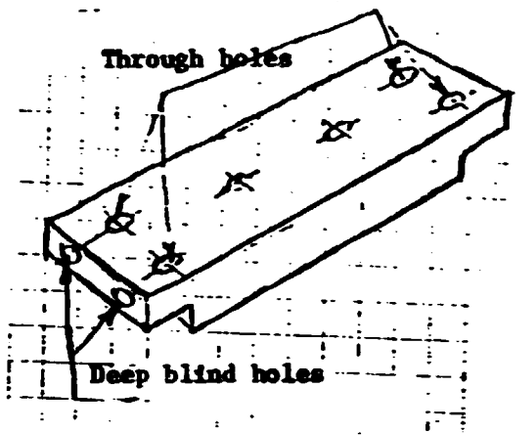
e) Machine end rabbet on one end of jamb only (i.e. the end which joins casement head) at spindle moulder, combination moulder/ circular saw, tenoner.



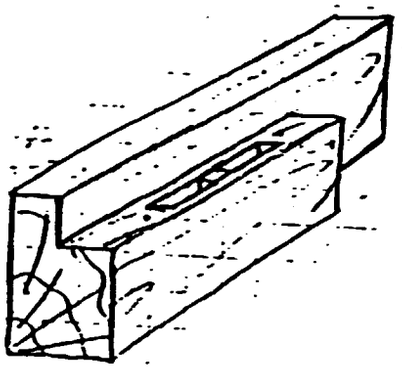
f) Machine end rabbet on both ends of head :
spindle moulder, combination moulder circular saw, tenoner.



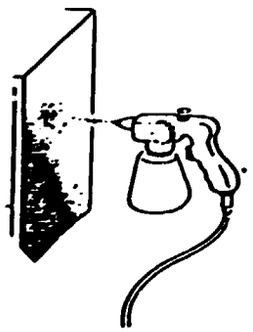
g) Drill two through holes on jamb end for joining with head, and three on rabbeted face for fixing casement to building: drill press, portable dowel, bench drill.



h) Drill two deep blind holes and two through holes on each end of head for joining with jambs, and two through holes on rabbeted face for fixing to building : drill press, portable drill , bench drill.



l) Machine face-plate slots on one jamb (right or left, depending on sense the door opens) : portable router, drill press, chain and chisel mortiser.



m) Paint visible surfaces of jambs and head (edges and rabbets) : manual spraying gun.

n) Insert hinges on jamb opposite to jamb fitted with face-plate. Fit face plate on other jamb. Fit cylindrical socket and relative bolts to ends of head: portable drill, portable screwdriver with hinge driving attachment, hand screwdriver.

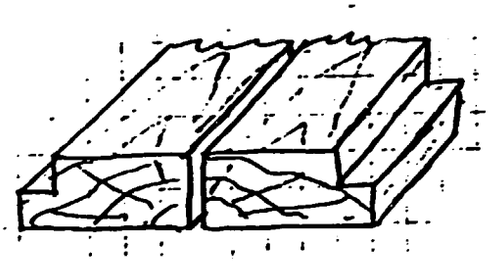
II - MACHINING SEQUENCE FOR DOOR CASEMENT EMPLOYING AUTOMATIC MACHINES

The great advantages in using automatic machines are:

- operations (c) and (d) can be performed simultaneously on one machine pass; if the width of jambs and heads allows it, then in many instances even operation (a) can be performed simultaneously with (c) and (d);
- operations (e), (f), (g), (h) and (i) can be performed on one single machine in one pass;
- operation (m) can be performed very quickly on an automatic moulds spraying machine

The machines employed on automatic operation are the following, in chronological order of process :

- **Automatic Cross-Cut Saw:** it cross-cuts stock to correct jamb and head length **and trims off defective ends.**
- **Automatic Multi-Spindle Throughfeed Moulder:** it machines the jambs and heads to correct finished cross sections and, if a universal spindle is available, it is possible to work two pieces at a time, then split-up on the end, thus :

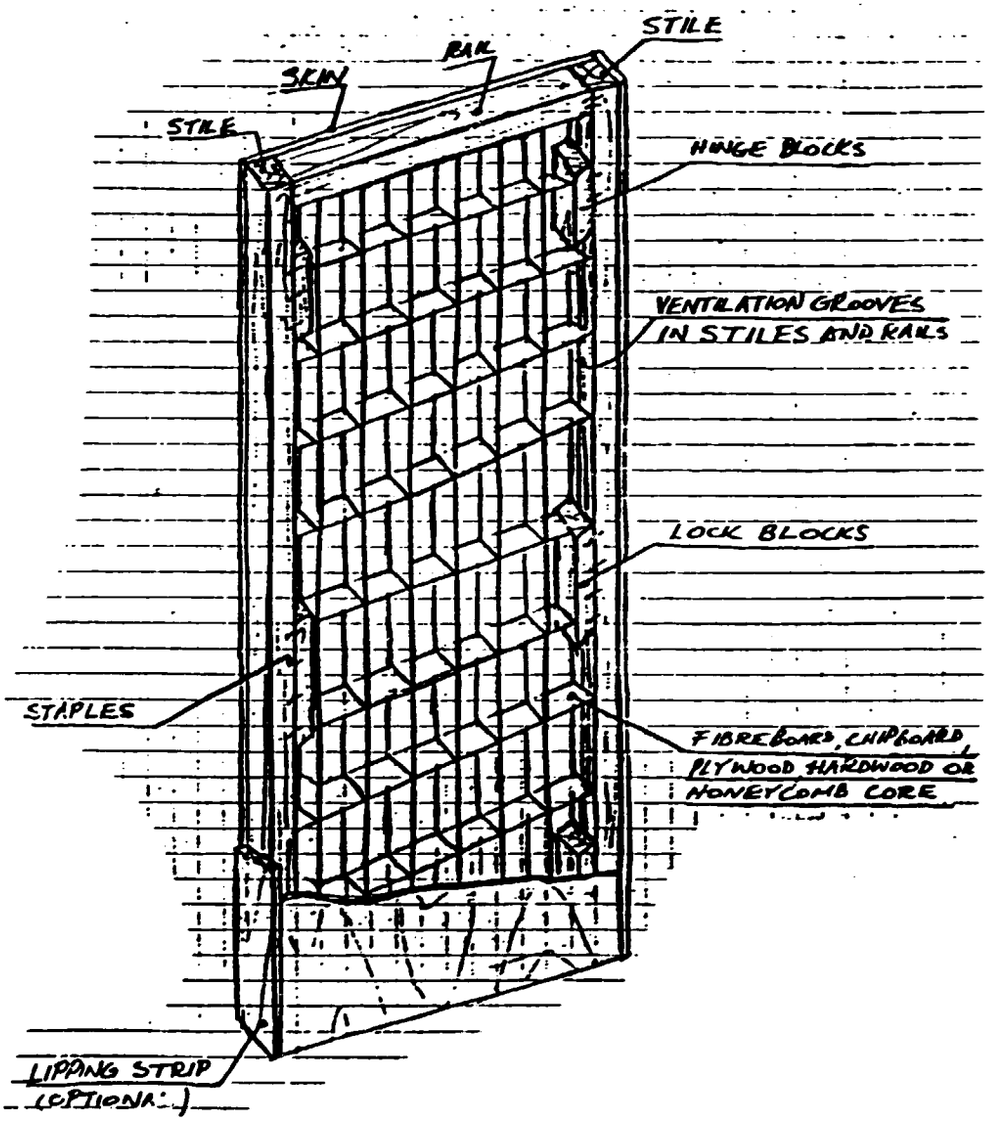


- **Automatic Double End Tenoning and Boring Machine:** it simultaneously trims-off the ends of jambs and heads to correct finished length, it machines the end rabbets, drills holes on ends and on faces, automatically drives-in cylindrical sockets (optional aggregate -but not always advisable before painting operations), routes face-plate slots.

- **Automatic Profiles Spray Painting and Varnishing Machine:** it automatically paints jambs and heads on edges and rabbets. This machine has a high production capacity : typical machine feeds range from 0 to 80 ml/minute. This operation, of course,presupposes the installation of a paint curing oven for mouldings down-stream of it and, depending on degree of surface finishing,sometimes an "automatic profile sanding machine" is installed upstream of the spray painting machine.

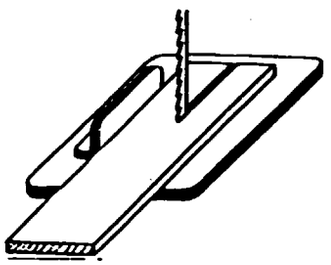
- **Automatic Hinge Inserting Machine:** the hinge fitting operation on door carrying jamb is performed automatically by the hinge drilling-inserting machine. Depending on production volume, such a machine can be equipped with one or more drilling aggregates with relative hinge feeding magazines so that, all the operator has to do is load-and-unload the workpieces.
The face plate fitting operations on the other jamb is usually performed manually by the operator.

2.2.2. - FLUSH DOOR CONSTRUCTION

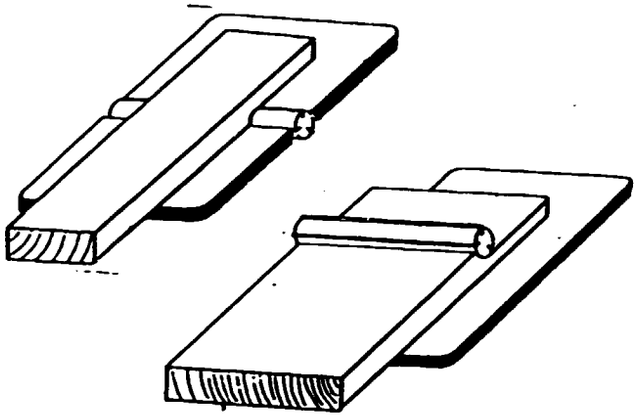


N.B. - An alternative core material would be expandeable Honeycomb core; however, despite its many advantages, this kind of material is not available everywhere. Hence the choice of using rigid core.

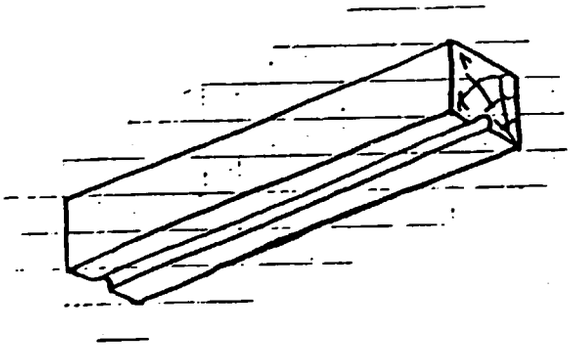
I - MACHINING SEQUENCE FOR FLUSH DOORS EMPLOYING BASIC MACHINES



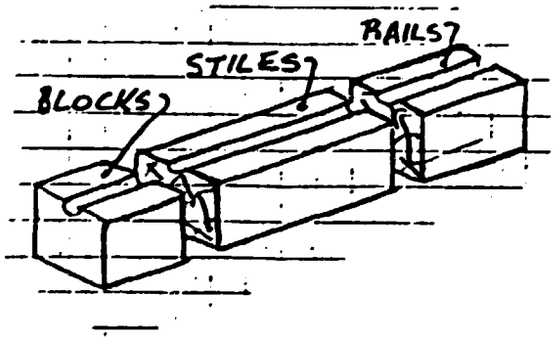
a) Rip rough sawn timber kiln dried at 8-10% humidity: **bandsaw or circular saws.**



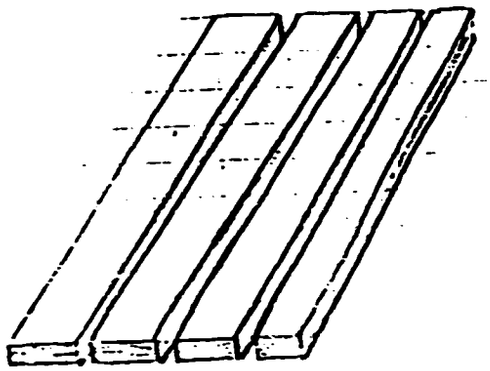
b) Plane and strighten ripped staves on three faces : **surface planer with jointer attachment, thicknessing planer.**



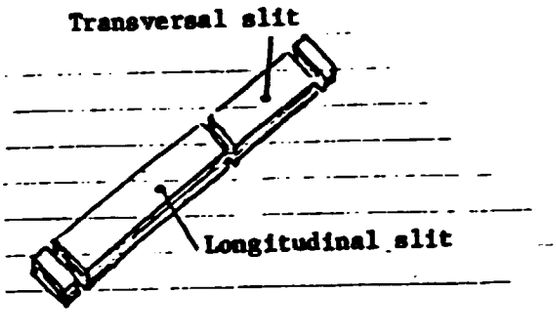
c) Machine ventilation grooves on fourth face of planed **staves: spindle moulder.**



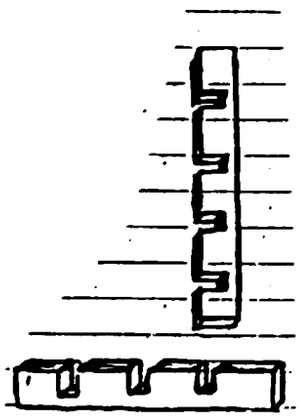
d) Cross-cut staves to correct lengths of stiles, rails, hinge blocks and lock blocks : **bandsaw or circular saw.**



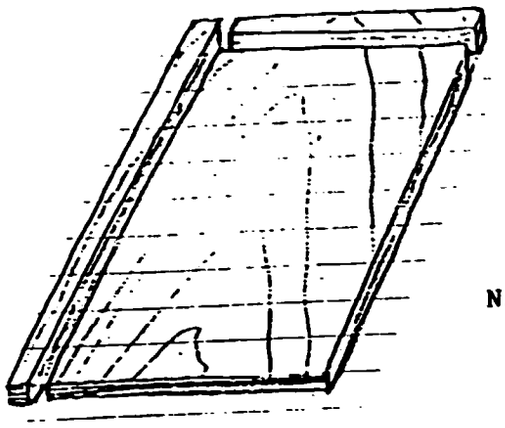
e) Rip fibreboard, or chipboard, or plywood (or hardwood strips previously planed) to correct width (equivalent to core frame thickness): **circular saw.**



f) Cross-cut core slits to correct length:
bandsaw, circular saw.

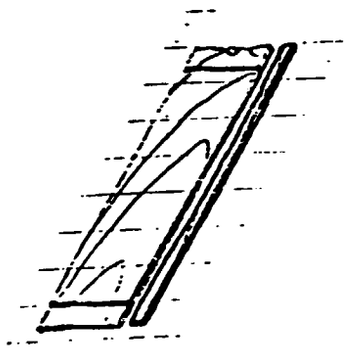


g) Machine kerf on longitudinal and transversal core slits :
circular saw (radial arm saw with kerf spacing attachment).

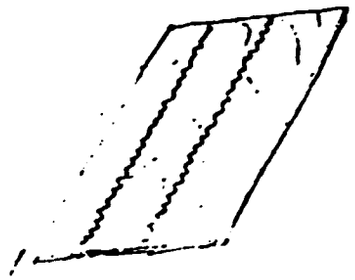


h) Cut skin panels to size (length-wise and cross-wise) of door allowing some excess material: **dimension circular saw, double end saw.**

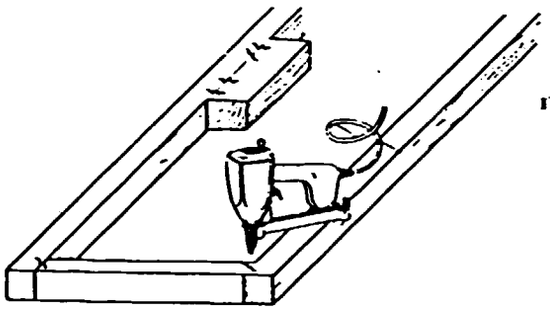
N.B. In case of cut-out doors, it is advisable to ROUTE apertures on skins prior to the pressing operation.



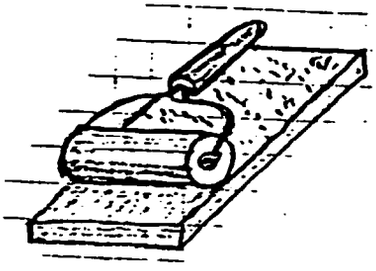
l) Clip veneer overlays to size : **knife guillotine.**
(Optional operation to be performed in case of veneer upgraded door panels)



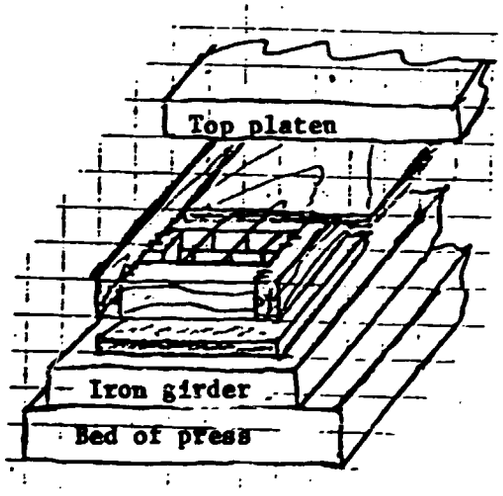
m) Splice veneer overlays together to size little over door size: **portable tape veneer splicer or portable thread veneer splicer.**



n) Assemble door skeleton,i.e. fit together stiles, rails, hinge blocks, lock blocks and core slits by staples: **assembly bench and portable stapling gun.**



p) Spread glue over skin panels: **glue bench plus brush or squeegee roller.**



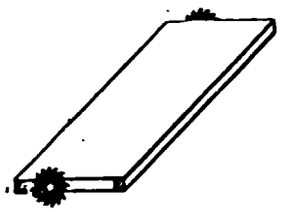
q) Assemble door sandwich on workbench and load into press, in following order :

- Place first door skin on bench ensuring that glued surface of skin is facing upwards.
- Place assembled door skeleton on skin.
- Place second door skin over door skeleton, ensuring that glued surface of skin is facing downwards.
- Load assembled sandwich into press.

Cold Press - Hydraulically or

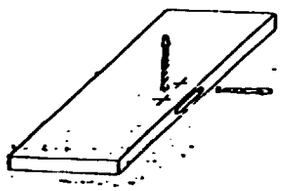
Hot Press - Mechanically Operated

N.B. - After pressing operation, allow door panel to cure, prior to performing next operation, for at least 8-hours (depending on type of glue). In case of veneer upgraded door panels, prior to perform the veneering operation at the press, it is advisable to gauge-sand both surfaces of door panel just formed by using either **portable sander, belt sander or drum sander.** Then, lay first veneer skin on workbench, apply glue on first surface of door skin; lay door panel over veneer skin (glued surface should be placed facing first veneer skin. Hence, spread glue over second door skin (now facing upwards) place second veneer skin over door surface just glued-up and load the lot into press. Allow glue to cure before commencing next operation.

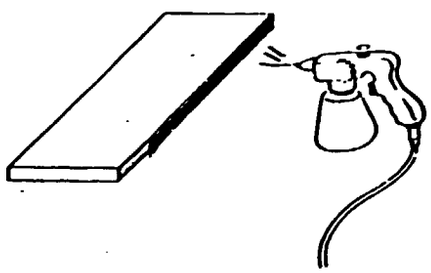


r) Dimension door panel lengthwise and crosswise (machine eventual rabbets on long edges) :
dimension saw with scoring saw unit, combination spindle moulder/ circular saw with scoring unit.

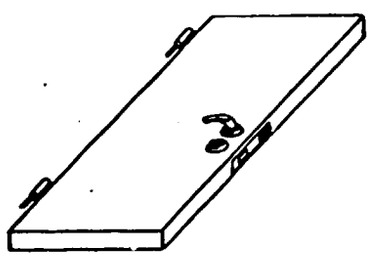
N.B. - If lippings are required fit them on after dimensioning then trim horns off at **circular saw with scoring unit.**



s) Mortise lock slot, handle and key holes :
chain and chisel mortiser.



t) Finish edges and surfaces :
brush, spraying gun.



u) Assemble hardware such as :
hinges, lock, handles or knobs, key-plate :
assembly bench, portable drill, screwdriver with hinge inserting attachment.

N.B. - In case of cut-out doors, the apertures should be trimmed-off after the dimensioning operation by means of **portable router, portable saw, fretting saw.**
Then, the hardware assembly operation should also include raised panels (or glasses), fittings, decorative moulds fitting by means of **hammer and tacks or portable tacking gun.**

II - MACHINING SEQUENCE FOR FLUSH DOOR EMPLOYING AUTOMATIC MACHINES

The use of special machines in modern door manufacturing practice does not change substantially the manufacturing sequence: it does, however reduce the number of operations and, consequently, the number of material handling operations in that on a special machine may be performed several sequences simultaneously. Furthermore, since special machines are, broadly speaking, equipped with work-feeding units, it is possible to achieve great savings on labour and production times. The machining sequence, when automatics are installed, is as follows:

Step I: Cross-cut rough sawn timber, kiln dried to 8 ÷ 10% moisture content, to correct stiles and rails length at the automatic cross-cut saw.

Step II: Machine to correct cross-section stiles and rails in multiples, thus obtaining also ventilation groove. This operation may be done on an automatic throughfeed 5-spindle moulder equipped with a gang ripsaw attachment or universal spindle fitted with gang ripsaw arbor.

Step III: Cross-cut to correct lengths hinge blocks in multiples (the lock blocks will be made from multiples of hinge blocks to required sizes); the right cross section of staves for hinge and lock blocks will have been obtained during step II. Suitable cross-cutting machines for this step operation depend on quantities: Multiple cross-cut saw (drum type), automatic cross-cut saw with automatic stock feed, rotating platform cross-cut saw.

Step IV: Size skin panels and core-strips to correct dimensions on automatic panel saw.

Step V: Clip veneer overlays lengthwise and crosswise on automatic veneer guillotine (slicer).

Step VI: Join veneer overlays on automatic veneer splicer.

Step VII: Assemble door skeleton, i. e., fit together stiles, rails, hinge blocks and lock blocks by means of automatic frame composing machine (there are machines of different capacities ranging from 50 to 150 frames per hour, so select one that is most suitable for factory capacity).

Step VIII: Assemble core by means of automatic kerfing and core composing machine. In this case, also, the right capacity machine should be selected as there are various types which may produce from 20 up to 80 cores per hour.

Step IX: Form door sandwich on pressing line. A pressing line may be automatic or semi-automatic. The automatic line installation should be contemplated when daily production exceeds 300 door panels per work shift and veneering of doors is required. Such a line is generally made by means of the following machines all connected together:

- 4-roll glue spreader (automatic feeder, optional),
- powered edge-knife disc conveyor,
- sandwich preparation belt conveyor,
- press feeding conveyor,
- hydraulically operated hot platen press (this may be of the short-cycle type or single daylight, multi-daylight type with 2 to 6 hot platens),
- press outfeed conveyor with automatic stacking unit optional.

A semi-automatic pressing line would be composed of the following machines:

- 4-roll glue spreader,
- idle edge-knife disc conveyor,
- sandwich preparation bench,
- hydraulically operated hot platten press (this should not have more than 6 daylights although presses with only one daylight are also used).

If veneering operation is required, the doors should be thickness sanded or gauge-sanded on both faces before returning to the press, and the sanding operation should be performed at least eight hours after the door panel has been discharged from the press. Depending on quantities, the sanding operation may be done on a top and bottom automatic wide belt sander (over 400 doors per shift) or an overhead wide belt sander (up to 400 doors per shift).

Step X: Door dimensioning is carried out either on single side automatic trimming and edging machine - maximum production capacity about 100-150 doors per shift, depending on operator's skill; or on double end automatic trimming and edging machine - maximum capacity around 300-350 doors per shift; or, lastly, on automatic edging line consisting of 2-double end automatic trimming and edging machines connected by an automatic panel turning device long-to-broad side. Such an edging line may machine about 700-800 doors on four edges per shiftwork. Its machining potential may be further increased up to 1000 - 1200 doors per shiftwork if automatic feeder and stacker are connected to the line.

Step XI: (optional) - When doors have to be fitted with solid wood lippings or with veneer edges to cover up the exposed edges of skins (for high

quality doors) use is made of automatic or semi-automatic Edge banding machines. Then, even for these machines the arguments outlined in step IX are valid. The double end automatic edge-banding machines may be installed in line with the automatic double end trimming and edging machines, thus forming an integrated process line of very high productive capacity.

Step XII: Door finishing can be carried out in several ways, depending on production volume and on degree of surface finish required and, also, on the kind of paints and varnishes required. The choice of surface finishing equipment and facilities should always be carried out by specialists in this field because the quality of the manufact depends principally on good surface finishing. Generally, the machines and equipment required can be thus summarized:

- Lacquer spraying booth and spraying guns
- Automatic lacquer sanding machines
- Automatic roll coating machines
- Paints curing ovens (infrared, ultraviolet, hot air, etc.)

Step XIII: The hardware fitting operations (hinges, locks) are carried out automatically on machines capable to machine mortises, drill holes, insert hinges and locks simultaneously. There are two main calsses of hardware fitting machines: semi-automatic and automatic ones. The semi-automatic machines differ from the automatic ones in that they are not characterized by automatic feed of the workpiece and, consequently they require more manual labour. The choice of one or the

other class of machines depends, of course, on production volume; semi-automatic machines are suitable for a production capacity of up to 200 doors per hour, while automatic machines range from 30 to 120 doors per hour. Downstream of the hardware fitting machines, a suitable number of assembly benches are usually installed for glasses,raised panels, mouldings, door handles; the benches are suitably tooled-up with portable power tools.

3 - OUTLINES OF A MEDIUM-SIZED DOORS AND WINDOWS FACTORY

In the preceding chapter, we have examined the manufacturing methods for windows and doors and in a certain way, we have mentioned the succession of the various operations (routing) necessary to manufacture the end-product. This last chapter of our work shall be devoted entirely to the basic engineering problems associated with the layout of a manufacturing plant for doors and windows, with a particular emphasis on a medium-sized factory.

Before the factory layout for a new installation can be completely developed, the equipment must be selected - type, capacity, number of units, type or make, size, drive and other factors. For this purpose, it is necessary to:

(1) Obtain drawings or sketches, bills of material and specifications of the products and then list and analyse the materials and parts required.

(2) Establish the volume and rate of production to be considered.

(3) Obtain and develop operation sheets for the parts, sub-assemblies, and final assembly or assemblies.

(4) List operations according to the type of equipment on which they will be performed.

(5) Obtain estimates on the unit times of operations, allowing for the use of jigs and fixtures, acceptable methods of processing and the introduction of semi-automatic or automatic machines. Calculate the daily capacities of the kinds and sizes of machines which, it is assumed, will be installed, and determine the amount of each type of machine required.

(6) Select the types or makes of machines which appear the most suitable for the installation.

(7) Develop layouts for the proposed installation; if the equipment has to fit in an existing building, the layouts will have to be adjusted to tie-in with other machines and departments. Floor loads must be calculated for heavy machines and sometimes such machines may have to be taken out of their desired location and placed on the ground floor where separate foundations can be put in.

(8) Investigate the possibility of expanding production which may require certain machines with greater capacity, or may call for a modified layout with excess area available for later occupancy.

(9) Establish manpower and energy requirements.

In the present context, only points (2), (3), (4), (5) and (9) will be examined as point (1) has been already fulfilled in chapters (1) and (2), while points (6), (7) and (8) are beyond the scope of this work.

3.1 - Volume and Rate of Production

The factory we propose to layout should produce the following quantities:

A - 25.000 Casement 2-Shutter windows/year

B - 25.000 Flush Doors/year complete with Casements.

Products will comply to the following specifications:

(a) All windows should be treated against degrading and ageing elements (insects, mold, weathering) and finished with gloss paint.

(b) Fifty per cent (50%) of the doors will be cut-out with a single aperture raised panel, veneered and finished with mat paint. The remaining 50% will be fully cored with plastic pre-laminated skins and hardwood lippings on two long edges. Core material will be obtained out of hardwood strips, and door skeleton will be of softwood; the cut-out doors will be edge-banded with veneer skins on long edges only.

(c) Door casements will be of good quality hardwood, painted like the cut-out doors, and to be delivered in knock-down form.

(d) The raw material for windows will be "Douglas-fir" timber.

(e) Doors and windows will be delivered complete with hardware and accessories, but window panes will not have to be assembled at the factory.

(f) Average window dimensions: 1,4m wide x 1,5m high; finished sections of all components: 68mm wide by 54mm thick, with glass-holding strips.

(g) Average door dimensions: 0,8m wide x 2,1m high by 45mm thick, with finished section of casements 105mm wide x 70mm thick. The factory will work 250 days/year on a single shift of 8 hours/day.

3.2 - Operation Flow Sheet

On the basis of data available from (3.1) above and following the work of chapters (1) and (2), an operation flow sheet can be drawn up, however, for lack of space, we will merely draw up a General Production Flow Diagram, which summarizes and illustrates the content of the operation flow sheet (see fig. 1).

3.3 - Machine Loading and Estimating

Based on data from chapter (2) - Routing - and on General Production Flow Diagram, the following list of operations (machine loading) is drawn up:

I - Cross-Cut Saw: Cuts all solid wood components for windows, door core, door lippings and raised panels, decorative mouldings to length. It also trims off defective ends.

II - Multiple Ripsaw: Machines to correct cross section all solid wood components, in multiples, such as: window casement rails and stiles, shutters' rails and stiles, door skeleton rails, stiles, hinge and lock blocks, door lippings, mouldings, door casements jambs and heads, door core strips.

- Machine capacity . . . . . 10,000 m/day
- Required output . . . . . 7,000 m/day
- Number of machines required . . . 1

III - Multi-spindle Moulder: Machines to correct the cross-section of all solid wood components as follows: window casements' stiles and rails; shutters stiles and rails (also glass holding strip being parted-off); raised panels decorative mouldings (astragals) in multiples; door casement jambs and head (two at a time).

- Machine capacity . . . . . 4,000 m/day
- Required output . . . . . 3,000 m/day
- Number of machines required . . . 1

IV - Double End Tenoner: Machine tenons and open mortises, on windows components, machines rabbet joint on door casement jambs and head, dimensions door panels lengthwise and widthwise, dimensions window shutters lengthwise and widthwise.

- Machine capacity . . . . . 2,800 pcs/day
- Required output . . . . . 2,100 pcs/day
- Number of machines required . . . 1

V - Frame Press: Assembles window shutter components; it is serviced by a workbench and glueing facilities.
- Machine capacity . . . . . 400 pcs/day
- Required output . . . . . 300 pcs/day
- Number of machines required . . . 1

VI - Surface Sander: Sands window shutters on both faces, door panels on both faces prior to veneering operation.
- Machine capacity . . . . . 1,200 m/day
- Required output . . . . . 1,350 m/day
- Number of machines required . . . 1

VII - Profiles Finishing Line: It is composed of the following machines:
- Profile sander,
- Profile painting and varnishing machine,
- Hot air paint curing oven.

The line will completely finish window casement stiles and rails, door jambs and heads, shutters glass holding strips and doors mouldings in two passes.
- Line capacity . . . . . 4,000 m/day
- Required output . . . . . 3,000 m/day
- Number of lines required 1

VIII - Window Shutters and Flush Doors Finishing Line: The line is composed of the following equipment:
- Impregnation dipping tank for window shutters,
- Oscillating guns automatic painting and varnishing machine,
- Hot air curing oven.

The line will completely finish edges and surfaces

of window shutters, flush doors and raised door panels in four passes.

- Line capacity . . . . . 3,200 m/day
- Required output . . . . . 2,600 m/day
- Number of lines required 1

IX - Mitre Saw: Cuts off, to correct length and angles, shutters glass holding strips and raised panels holding strips (astragals).

- Machine capacity . . . . . 1,800 pcs/day
- Required output . . . . . 1,600 pcs/day
- Number of machines required . . . 1

X - Radial Arm Saw: Machines kerfings on doors strip cores.

- Machine capacity . . . . . 1,200 cuts/day
- Required output . . . . . 750 cuts/day
- Number of machines required . . . 1

XI - Double End Panel Saw: Cuts skin panels to size.

- Machine capacity . . . . . $4m^3$/day
- Required output . . . . . $1,5m^3$/day
- Number of machines required . . . 1

XII - Veneer Clipper: Cuts to size sorted veneer skins.

- Machine capacity . . . . . $1,300m^2$/day
- Required output . . . . . $250m^2$/day
- Number of machines required . . . 1

XIII - Veneer Splicer: Joins veneer strips to suitable door sizes.

- Machine capacity . . . . . $650m^2$/day
- Required output . . . . . $250m^2$/day
- Number of machines required . . . 1

XIV - Single Side Edge Bander: Applies lippings and/or veneer edges on doors.

- Machine capacity . . . . . 1,000 m/day
- Required output . . . . . 400 m/day
- Number of machines required . . . 1

XV - Hot Pressing Line: The line is composed of the following machines and equipment:

- two roll glue spreading machine,
- idle edge - knife disc conveyor.
- sandwich preparation bench,
- hydraulically operated 4-daylight hot platten press.
- Line capacity . . . . . $400m^2$/day
- Required output . . . . . $350m^2$/day
- Number of machines required . . . 1

XVI - Automatic Router: Machines door cut-outs and door raised panels.

- Machine capacity . . . . . 200 pcs/day
- Required output . . . . . 100 pcs/day
- Number of machines required . . . 1

XVII - Universal Drilling Machine: Drills holes on door jambs and heads and on window casement rails for water drainage and lock-rod.

- Machine capacity . . . . . 800 pcs/day
- Required output . . . . . 500 pcs/day
- Number of machines required . . . 1

XVIII - Universal Chain and Chisel Lock Mortiser: Machine lock slots, key and handle bores on flush door panels; machines face plate slots on door jambs, machines slots and bores for locking mechanisms on window shutters.

- Machine capacity . . . . . 200 pcs/day
- Required output . . . . . 300 pcs/day
- Number of machines required . . . 2

XIX - Hinge Drilling and Inserting Machine: Prepare holes for and inserts hinges in automatic cycle/sequence on door jambs, door panels, window casements and window shutters.

- Machine capacity . . . . . 400 pcs/day
- Required output . . . . . 600 pcs/day
- Number of machines required . . . 2

XX - Fully Tooled-Up Workbench: Workbench equipped with portable power tools such as: screwdriver, drill, nailing gun, hammer, etc. It is used for performing minor manual assembly operations on doors, windows and casements prior to delivery.

- Number of benches required . . 4

XXI - Material Handling Equipment: Suitable number of pallet trucks, forklifts, containers and roller conveyors and trolleys to move raw materials, semi-finished stock and finished products around the factory floor.

3.4 - Manpower and Factory Services Requirements

Having defined the types and quantities of machines and equipment needed to get estimated factory outputs, tables may be drawn-up to show manpower requirements and factory services requirements (power, lighting, compressed air, heat, dust and chips extraction, water, tool sharpening facilities, maintenance facilities, indirect materials such as abrasives, tools, glues, paints and solvents, etc.). Thus, from (3.3) the following requirements result:

3.4.1 - Manpower Requirements

The labour required to man the factory is thus sub-divided by degree of skills and number:

- Skilled labour	14 workers
- Semi-skilled labour . . .	18 workers
- Unskilled labour	8 workers
T O T A L	40 workers

From the above analysis, we can conclude that the factory is of the "batch-production type". The layout will be based on the process. The main advantages of this factory are:

(1) Extremely flexible.

(2) High machine utilization with correspondingly low capital investment.

(3) Individual operator's efficiency tends to be high, since operators are required to be versatile and have some degree of skill.

The only disadvantages of this type of factory are:

(1) Substantial pre-production planning required if machine loading is to be high.

(2) Control difficult.

3.4.2 - Energy Requirements

From the list of machinery and equipment proposed, the following energy requirements can be calculated:

- Power	250 KW
- Compressed air at 6 - 8 Atm	4,000 Nl/min
- Dust and Chip Extraction . .	35,000 m^3/h
- Heat (hot water at 80 - 100°C)	250,000 Kcal/h

It should be noted that:

(a) Power includes the power to run the production machinery, the air compressors, the dust and chips extraction fans and a small boiler plant for hot water generation.

(b) Power has been calculated using an overall operating factor of 0,6.

3.5 - Conclusions

We have set down the foundations for the design of an economic model factory for doors and windows production of medium physical dimensions, but with a relatively high return on capital investment. In fact, upon examining the productivity of this factory we would see that each worker will produce 2,5 casement windows plus 2,5 flush doors per day. In terms of money (assuming current prices and labour costs situation in Italy), this means that each worker would produce:

- 2,5 Windows x £240.000 = £600.000/day/worker
- 2,5 Doors x £ 90.000 = £225.000/day/worker

T O T A L = £825.000/day/worker

That is, based on the current costing situation in the business of Doors and Windows manufacturing, a worker would yield about 7 times its cost value. Of course, this does not take into full account such factors as machinery and equipment depreciation, interests on invested capital, and other cost items. But we have assumed that these items of cost, as well as raw materials and indirect materials should be pretty well covered by the sales prices of the products and by labour cost.

FIG. 1-GENERAL PRODUCTION-FLOW-DIAGRAM