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PHILIPPINES

Technical report: Manual on Surface Finishing of Furniture*

Prepared for the Government of the Philippines
by the United Nations Industrial Development Organization

Based on the work of Gabriele Varenna
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* Mention of company names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO). This document has not been edited.

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I. ENVIRONMENTAL REQUIREMENTS AND FUNDAMENTAL EQUIPMENT FOR SETTING-UP A FINISHING SHOP

It is fundamental to provide a factory with a proper finishing shop. The finishing shop should be located far from the production area in order to avoid contamination of dust affecting the obtention of good finishes. The shop should be separated from the rest of the factory by walls and the doors should be kept open only for the time strictly necessary to bring in the items for finishing and for delivering the finished products. The finishing area is a big source of fire risk - a fire in a furniture factory normally starts in the finishing shop. For this reason, a valid insulation from the other production areas is important. It is furthermore important to:

- Set-up a valid fire fighting system in the finishing shop;
- Provide the finishing shop with an emergency exit opening in an enclosing factory wall for the workers to escape in case of need.

The risk of fire comes from the heavy utilization of solvents in finishes; these are highly volatile and flammable and are a source of environmental pollution. For these reasons, it is important to keep the finishing area as free as possible from solvent fumes. Most solvents are also a danger to the health of the operators. A poor environment, affected by the heavy smell of solvents and paints, certainly plays against productivity and quality; it is only in a good and comfortable environment that a worker can do his best.

It is very important that the space destined for the finishing department complies with the following fundamental rules:

- A good lighting system allowing the operator perfect visibility;
- A good ventilation to avoid atmosphere saturation of solvent vapours;
- Prevention, as far as possible, of dust invading the finishing environment;
- Minimization of environmental pollution.

All these requirements could be attained with a good ventilation and by using a spray booth (possibly a spray booth with a curtain of water). If the costs of a spray booth cannot be afforded by a small factory, a good ventilation system has to be provided to ensure a good extraction of the over-sprayed materials and evaporated solvents. Fans for the extraction of over-sprayed materials should be placed in front of the spray guns.

Other fans have to be used to blow fresh air into the varnishing areas through filters. The volume of air blown in has to be more than that extracted to have a positive pressure in the room so as to avoid contamination of the environment with dust from outside. (The air injected should be 5-10 percent more than the air sucked out.) If it is not possible to have a spray booth, another system to capture over-spray and to avoid dust contamination could be keeping the floor wet by pouring water on it. A sufficient change of air has to be provided also during the drying process. Dust and cold drafts have to be avoided. To satisfy these conditions the following must be remembered:

- The temperature of the air must not be less than 20°C. Warm air will absorb a substantially greater quantity of solvent and accelerate the chemical reaction in the varnish films.

- Placement of the recently lacquered workpieces too close to each other must be avoided since solvent films or water from stains or from varnishes will not be removed speedily enough due to inadequate circulation of air between the pieces.

- Fresh-air fans have to be placed close to the ceiling, but the extraction ducts must be near the floor, since dust and solvent vapours are heavier than air and tend to settle down near the floor (see Fig. 1).

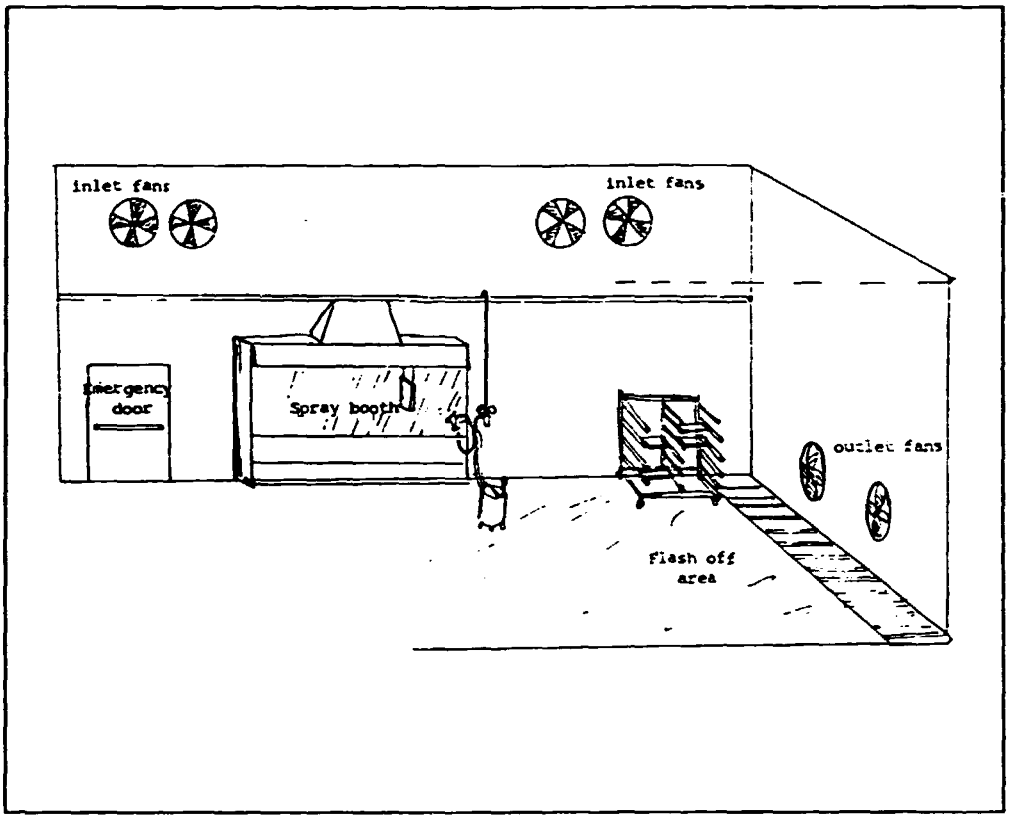


Fig. 1: Spraying room.

- Drying times are reduced by increasing the change of air, e.g. changing the speed of the air across the lacquered work pieces from 0.5m/sec to 1.0m/sec causes a 50 percent reduction of drying time.

- Dust must be prevented from invading the finishing area. The freshly varnished surfaces are very sensitive to dust and get nibbing surfaces easily if the environment is not clean.

- Too high a temperature and too high an air-flow could accelerate the drying of the surface film so much that the solvent would be trapped inside and create blisters on the surface. The temperature should thus not exceed 40°C and the velocity of the air should not exceed 2m/sec.

- The ventilation of the drying room has to be maintained for a few hours after the application of varnishes. A typical layout of a finishing shop is given in Fig. 2.

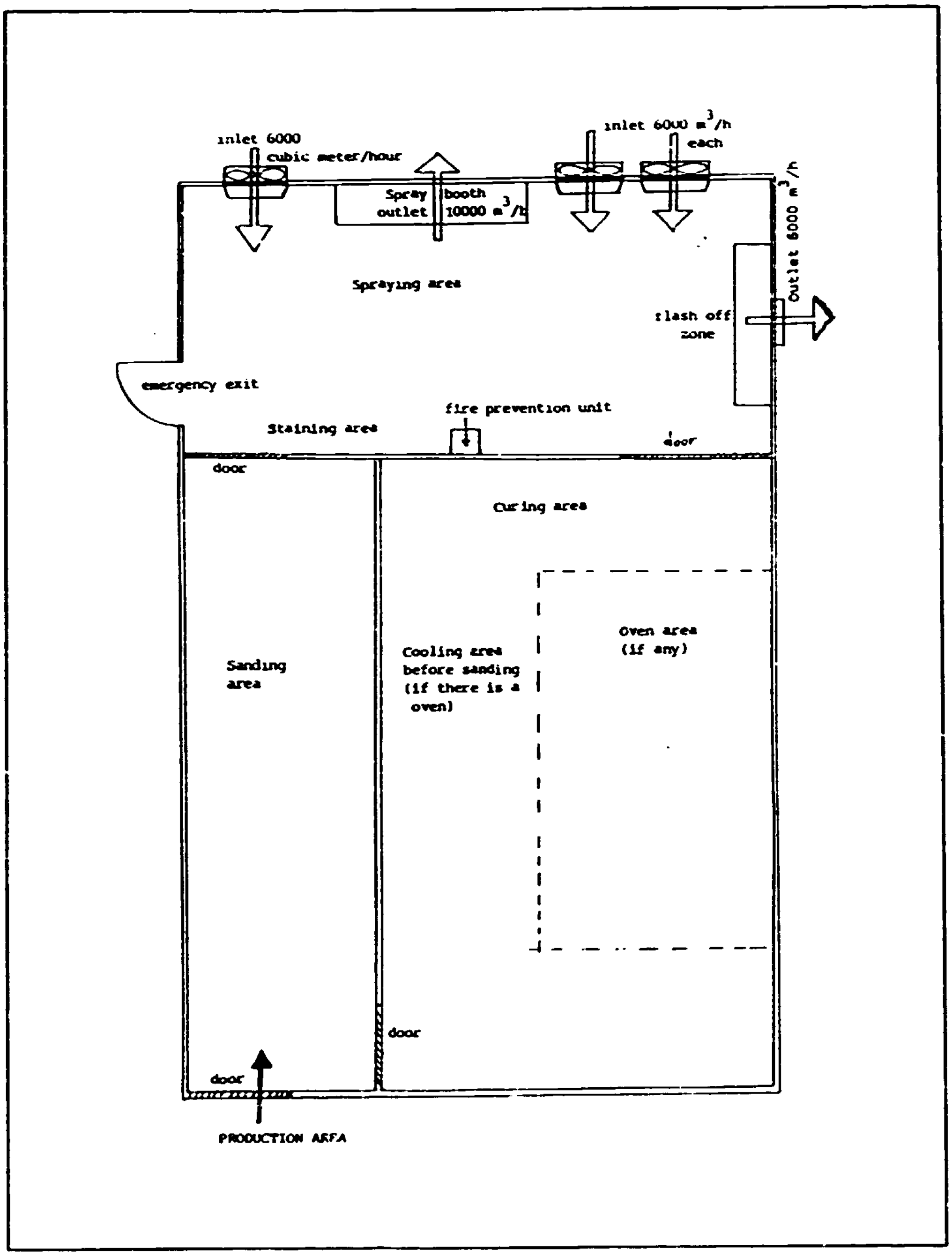


Fig. 2: Simple layout of a finishing shop.

SPRAYING CABINS

To provide the best possible conditions. spraying should be carried out in spraying cabins or in spray booths. The principal purpose of spray cabins is to draw out the particles of lacquer and solvent from the work area and thus improve the working environment. Furthermore, the spraying cabin should eliminate the lacquer particles from the extracted air and thereby protect the environment from pollution. A distinction is made between spraying boxes and spraying cabins or booths - and between dry-filer and wet-filter cabins.

Dry-filter cabins or spray booths

In dry-filter cabins, the extracted air is directed through a dry filter consisting of, e.g. baffles arranged as labyrinths, or trough one-way filters made of cardboard or glass fibre. Dry filters have a separation effect of about 70 percent and the pressure differential is small - about 10 kPa - so the fan can have a relatively low rating. Dry-filter cabins are mostly used for small production volumes where the polluted air can be released without inconvenience (see fig. 3).

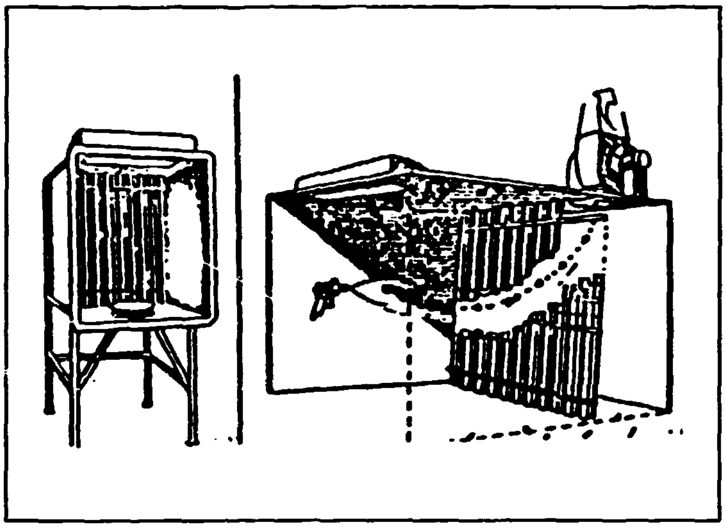


Fig. 3: Dry filter cabin.

Wet-filter cabins or water curtain spray booths

In a wet-filter cabin, the extracted air is washed in a mist of water. Chemicals are added to the water and these allow the lacquer particles either to rise to the surface or to sink to the bottom. The chemical used depends on the type of wet-filter (see Figs. 4 and 5).

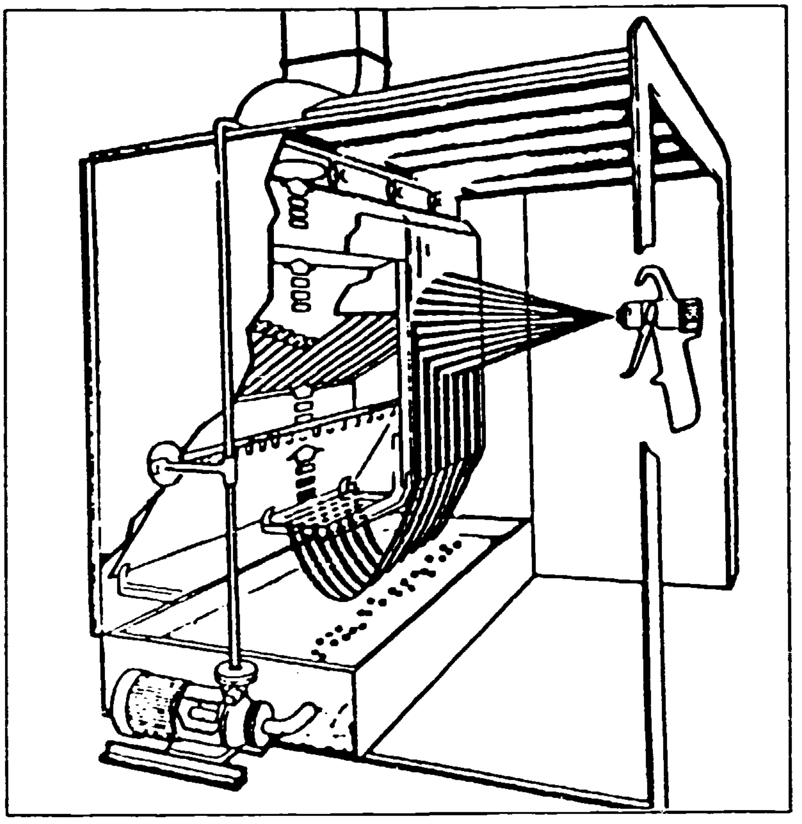


Fig. 4: Spray booth with water curtain or wet spraying cabin.

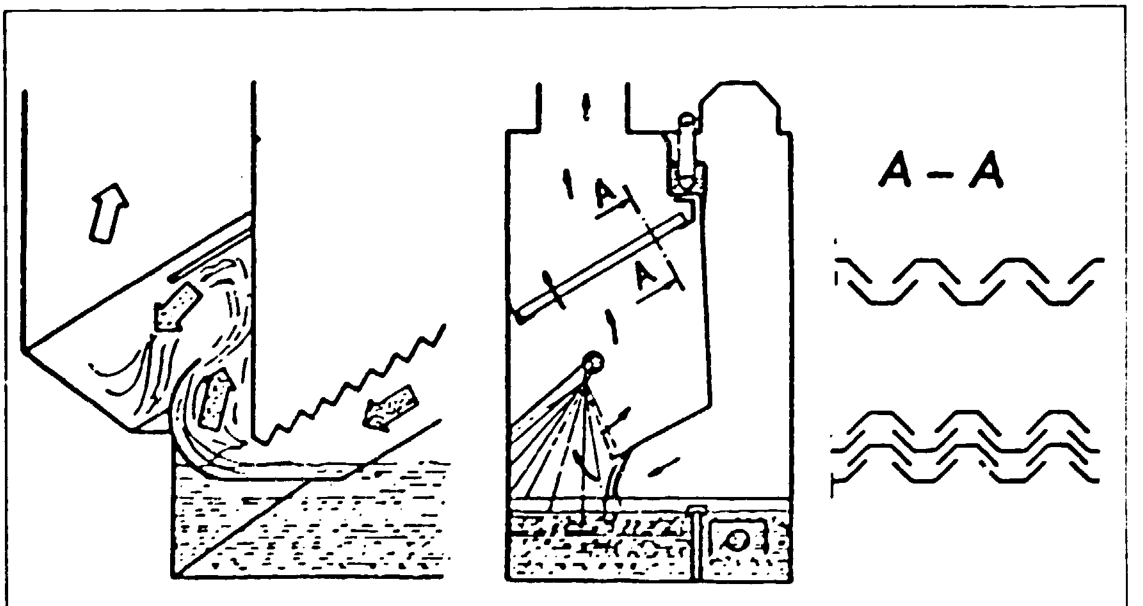


Fig. 5: Different systems for water solvent separation in a water curtain spray booth.

Compressors

A compressor is a device that compresses air to a desired pressure; i.e. a compressor is nothing more than a pump that takes air at atmospheric pressure and delivers it at a higher pressure. In small compressors, the air is compressed in one stage. In medium-sized compressors (the type generally used in the industry) the air is compressed in two stages with a cooling stage in between to obtain greater efficiency. In the most commonly used systems, the pressure varies from 6 to 10 bar (one standard atmosphere = 0.98679 bars).

The temperature of the air rises to approximately 200°C in a one-stage compression and to approximately 100°C in a two-stage compression. During compression, the humidity in the air is also compressed and, when cooled, it condenses to water. The air compressor compresses also the air moisture present in a more significant quantity in tropical countries (see diagram in Fig. 6). This causes a great deal of trouble and it is therefore necessary to plan for the continuous removal of water from the compressed air network.

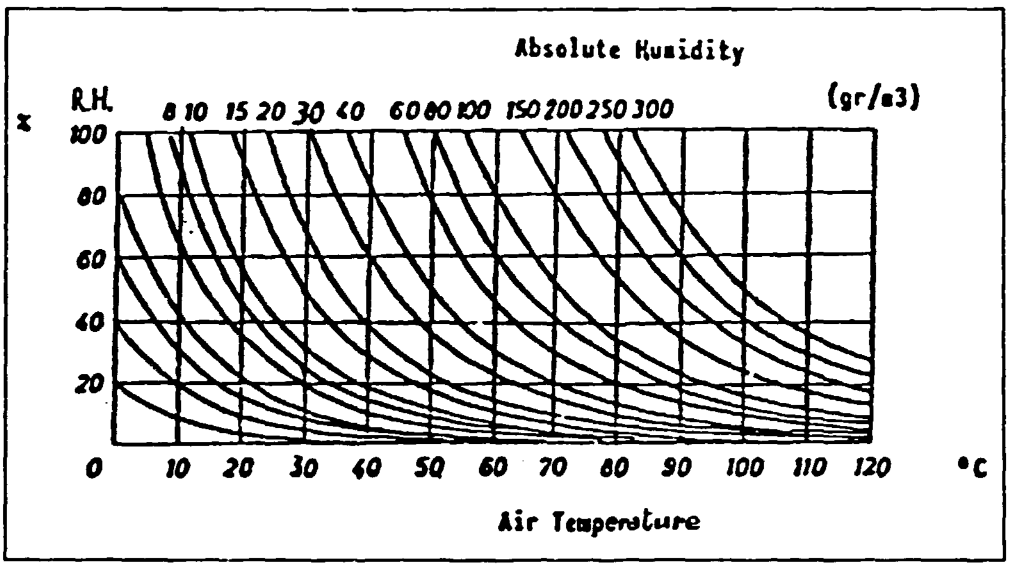


Fig. 6: Graphs showing water content (relative humidity) of air at various temperatures.

In a hot country with a high relative humidity, there is a tendency for excessive water to condense and remain in the compressed air. The water causes operational disturbances, corrosion and wear of the equipment and the quality of the finishes can be largely affected.

There are different types of air compressors, the following are the most commonly used:

Piston compressors (see fig. 7)

In this type of compressor, the piston draws the air into the cylinder and compresses it to the desired pressure. Both the inlet and the outlet of air are controlled by valves. A piston compressor is efficient, and high pressures can be obtained with it. The vibrations due to the reciprocating motion are one of its disadvantages.

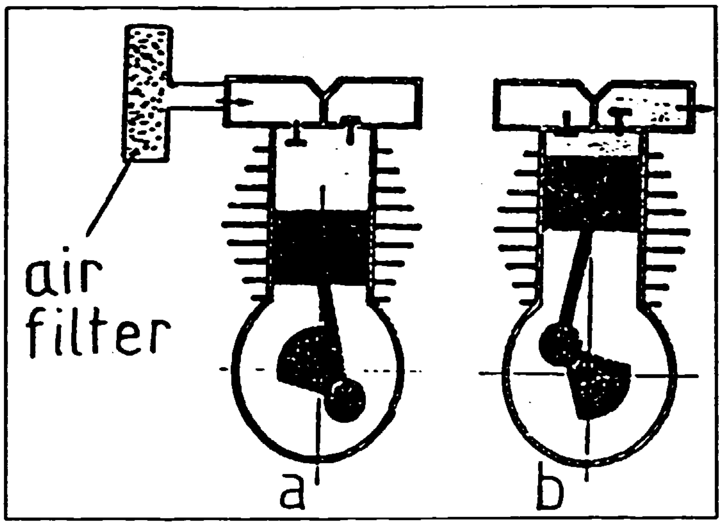


Fig. 7: Piston compressor, where (a) is the suction phase, and (b) the exhaust phase.

<u>Vane compressors</u> (See fig. 8)

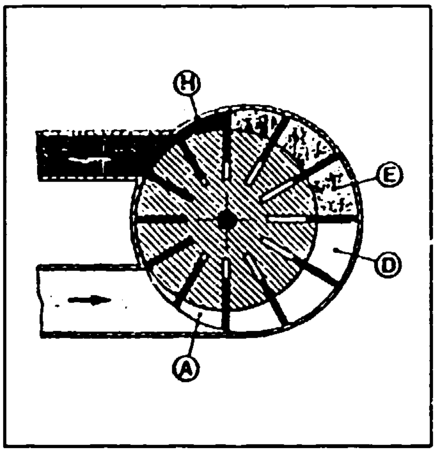


Fig. 8: Vane compressor.

Vane compressors are provided with a rotor with eccentric bearings. The rotor has slots in which the vanes can move freely. The volume of air between the vanes changes, and the air can be compressed. Efficiency is satisfactory and the machine vibrates less and is increasingly popular. A pressure of approximately 10 bars can be obtained with it.

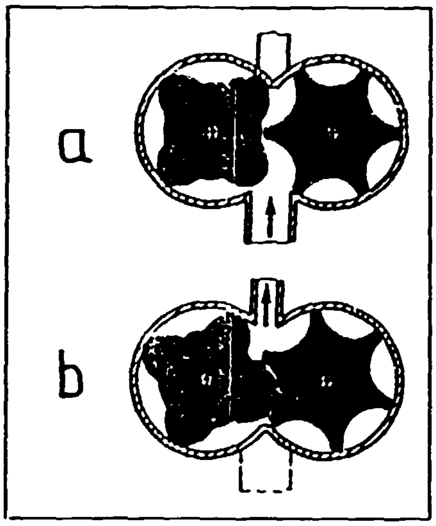


Fig. 9: Screw compressor.

Screw compressors (see Fig. 9)

The screw compressor is the newest type of compressor and is still used relatively seldom. In it, the air is compressed between two screws. The machine does not vibrate and produces air without pulsations. The pressure is approximately 10 bar. It can be used only for medium-sized and large compressors, preferably with outputs over 2m³/min of air.

How to choose an air compressor

The fundamental data is the free air delivery (FAD) measured in cubic meters per minute. This parameter is calculated as follows for a conventional piston air compressor:

$$FAD = K \times V \times N \times 60$$

where K is the volumetric efficiency of a compressor. It varies between 0.75 and 0.88, the balance (12 to 25 percent) are the losses due to temperature, friction, etc.;

V is the volume of the cylinder and

N is the number of cycles of the piston per minute.

The fundamental tasks in choosing an air compressor is to consider the FAD expressed in N m^3/hour. FAD should correspond to the compressed air needs of the shop. To calculate these needs it is important to consider the following things:

- Machines and equipment needing a continuous flow of compressed air;

- Equipment having a discontinuous utilization like all the pneumatic power tools such as drills, orbital sanders, etc. The tools' consumption is indicated by the maker. To take in account the discontinuous use, the consumption is normally multiplied by 0.25 (i.e. the utilization of this equipment is considered to be 25 percent).

- It is further more advisable to add to the total consumption of the above-mentioned machines and equipment 5 percent to take in consideration leaks in the compressed air network and add another 30 percent considered as a reasonable margin for further expansion of the factory and its activities.

Another important parameter is the amount of pressure required for the utilization: normally this is 7 bar. It must be remembered that pressure higher than that requires a bigger investment in the air compressor and also a bigger consumption of power. For these two reasons, it is important to separate the utilization and buy a separate compressor for machines requiring more than 7 bars.

It is possible to refer to the table hereunder which gives an idea of the best solution for the finishing equipment under various conditions. An under-dimensioned compressor will be subject to overload and consequently its life will be shorter; if the air compressor is too small, this can lead to troubles in finishing, resulting in a loss of quality.

Table 1: Compressor requirements for various types of spraying equipment.

Type of spraying equipment	Compressor power required	Losses
Cup gun	3-5 Hp	30-40%
Pressure pot	4-6 Hp	30-40%
Airless	1-2 Hp	30%
Airmix	1-3 Hp	20%

There are two systems to safeguard the air compressor by avoiding a dangerous overload: a pressure switch and a constant speed unloader.

Pressure switch

This is a pneumatically operated electrical switch which stops and starts electric motors at predetermined minimum and maximum pressures. When the maximum pressure in the air receiver is reached, the air pressure on a diaphragm activates the switch, thus breaking the circuit and stopping the motor. When the pressure drops to a minimum setting the circuit is closed again, the motor starts and operates the compressor until the maximum pressure is reached. Any compressor outfit which runs intermittently and less than 60 percent of the time is best controlled with a pressure switch.

Constant speed unloader

This is an automatic device to maintain a supply of air within given pressure limits when it is not practical to stop and start the motor during operations. Where the demand for air is relatively constant at a volume approaching the compressor's rated capacity, a constant speed unloader is recommended. When the maximum pressure in the air receiver is reached, the unloader valve opens to allow air travel through a small tube to the unloader mechanism and holds open the inlet valve on the compressor, allowing it to idle free of load. When pressure drops to a minimum setting, the spring loaded pilot automatically closes, the air to the unloader is shut-off, causing the inlet valve to close and the compressor operates again.

The following requirements should be observed for the good operation of an air compressor:

- It should be located in a place where there is a supply of clean air, in a place spacious enough to allow easy maintenance and service.

- The erection for piston compressors should be on the ground; for other types of compressors there are no requirements.

- The air intake should be from a dust-free place. and it must be protected from rain and dust particles.

- The air intake should be filtered before its arrival in the compressor.

- The air should be cooled for water removal and for air or water cooling.

- The air receiver should be a pressure resistant steel receiver with a volume of at least half the compressor's rated capacity per minute. Its location should preferably be in a shady place outdoors. For a constant demand system, it is better to increase the volume of the receiver to 1.5 times the compressor's production per minute, or even three times this value. For a layout of a large compressed air system, see fig. 10.

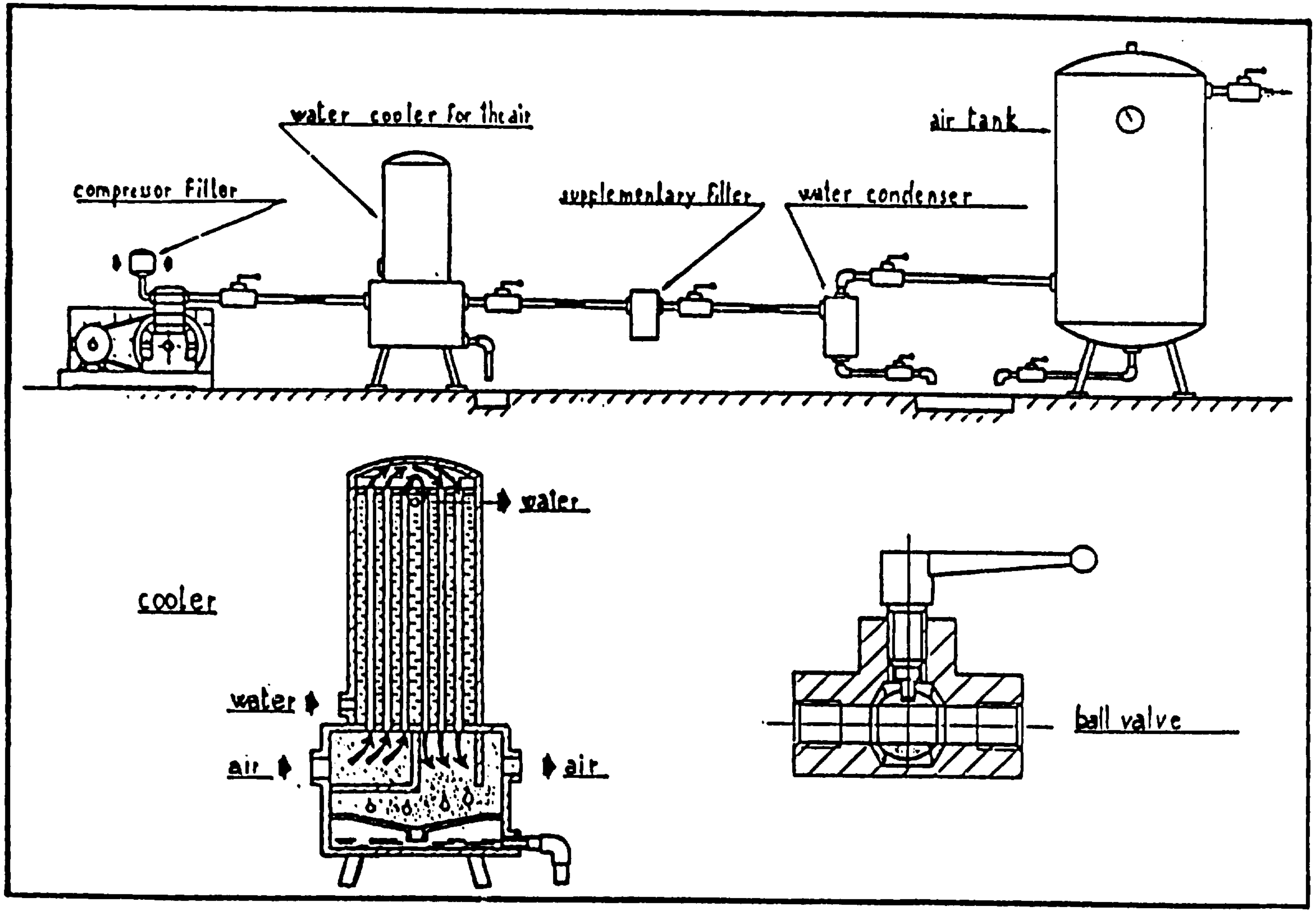


Fig. 10: Large compressed air system.

Compressed air distribution

It is always adviseable, even for a small network of compressed air, to put at least 10 meters of metal piping between the compressor and the first offtake to allow the air to cool and to facilitate the separation of the water from the air. A linear form of distribution is suitable only for very limited use when the main line is short (see Fig. 11.1). A ring is the most common form of network: the piping starts from the compressed air receiver, goes around through the whole factory and comes back to the receiver (see fig. 11.2). This is done to maintain the pressure as constant as possible in all the points of the main network. Another solution is to interlink the main piping to create a lot of rings and this is done when the distribution system covers very big areas (see Fig. 11.3). Since pipes run from the compressor's air-receiver to a system that may be remote, the pipe should be large enough to minimize friction losses. The friction losses are bigger if the diameter of the pipe is smaller; the diameter of piping plays the most essential role in pressure losses. This means that if the piping is long and small in diameter, there is a considerable drop in pressure so if the pressure in the reservoir is 7 bar, the dynamic pressure at the end of the line can be 5 or 4 bar. Exact dimensioning through calculations is not easy, it is thus useful, in practice, to refer to diagrams based on experience (see Fig. 12). The system is normally manufactured by welding or joining steel pipes and sometimes by brazing copper pipes.

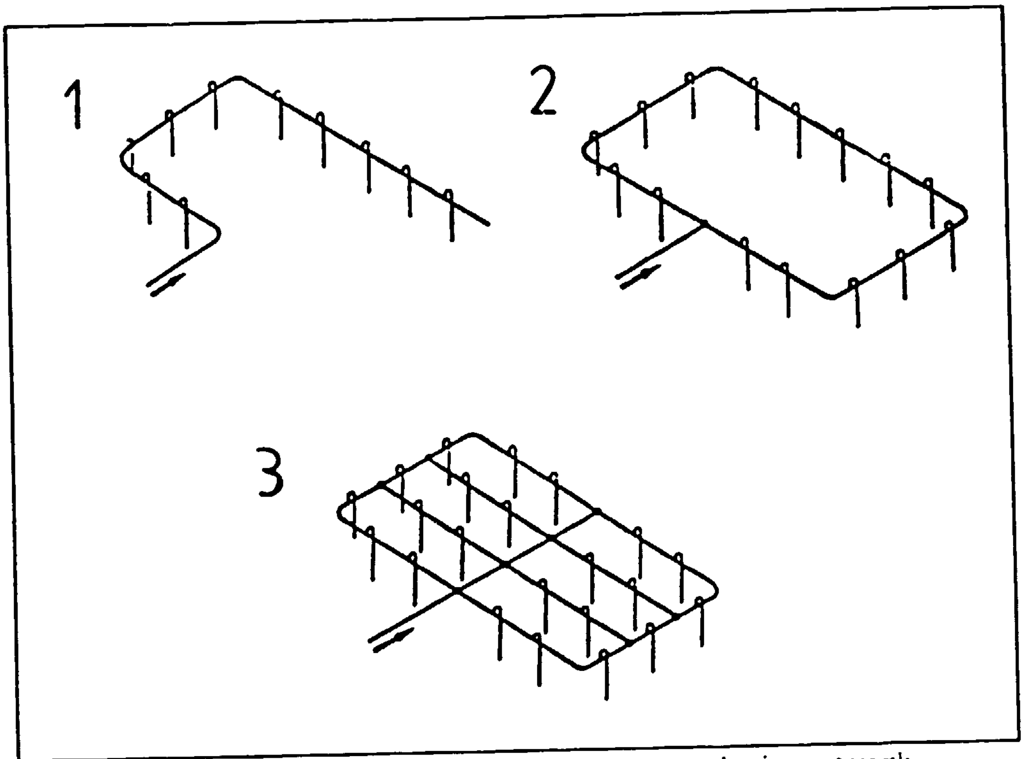


Fig. 11: Different configuration of compressed air network.

The installation of the piping should tilt towards the receiver at a slope of 1:100 to allow the water to flow back to the water trap and be removed. Fig. 12 shows a diagram for piping calculation: with this diagram it is possible to find the diameter of piping imposing a certain drop in pressure or otherwise knowing all the other parameters, it is possible to find

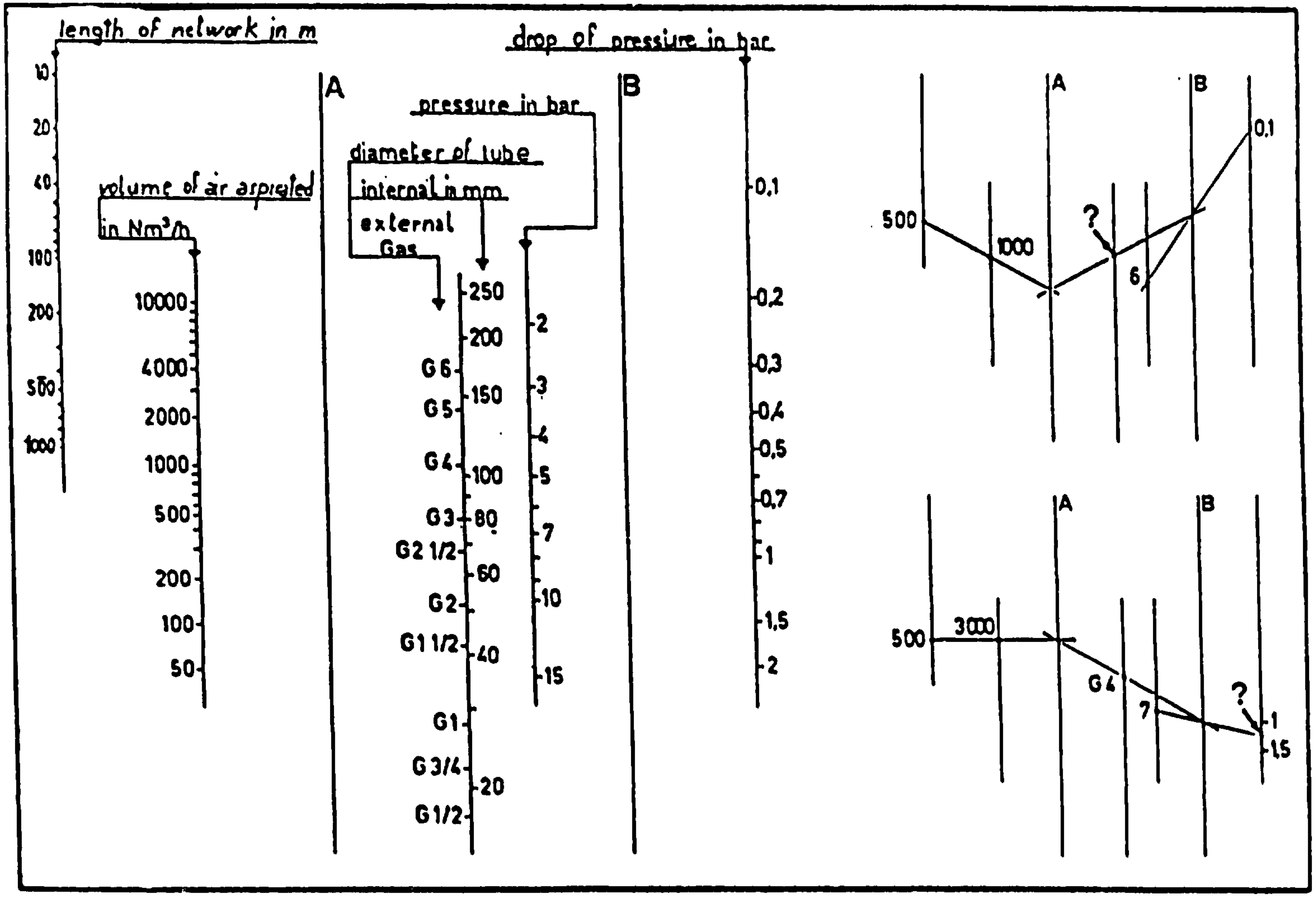


Fig. 12: Diagram for piping calculation.

the drop in pressure. The whole system should be set-up to keep the water far from the utilizations: for this reason, water traps spaced 30-50m from each other are recommended (See fig. 13). The air intake from the pipe system must be dry and clean and it should contain some oil to prevent the wearing of the devices. There are always humidity and dirt particles in the system which cause corrosion. Therefore, the following instructions must be observed:

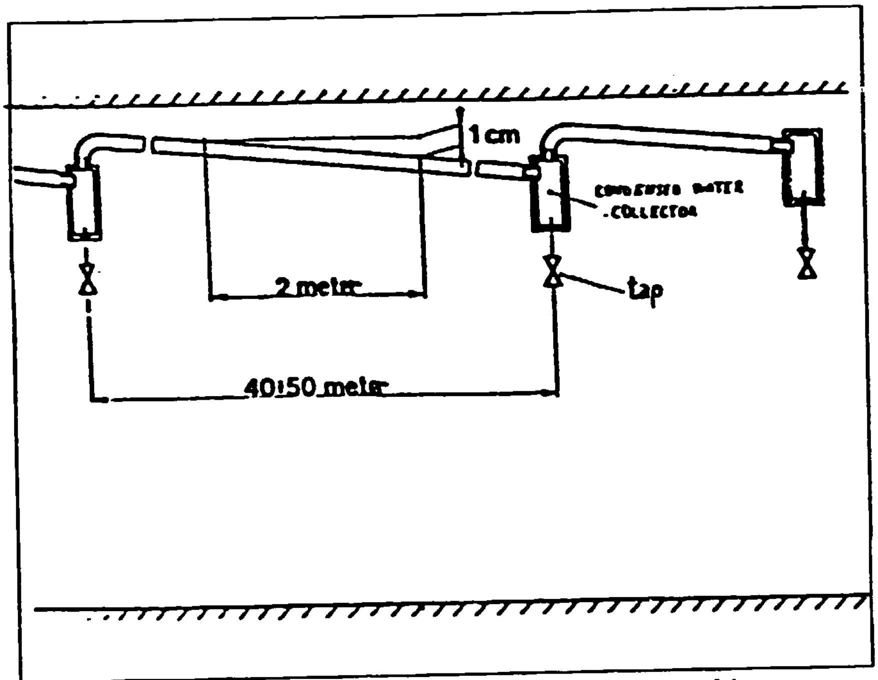


Fig. 13: How to join the main compressed air line.

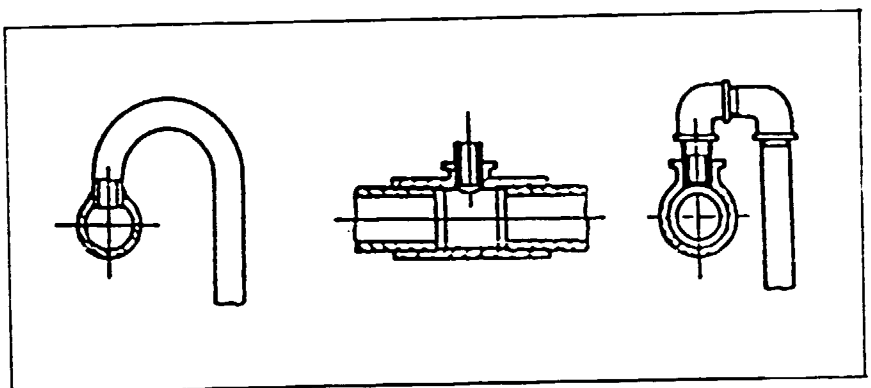


Fig. 14: How to join the main compressed air line.

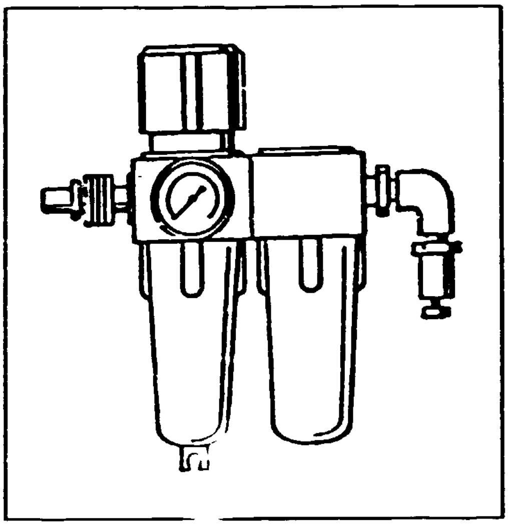


Fig. 15: Air line service unit.

- The air intake should be at the top of the horizontal piping (see Fig. 14).

- The air should be taken through a maintenance (service) unit (see Fig. 15) composed of the following four parts:

(1) A filter to clean the air (see Fig. 16).
(2) A pressure reducing valve which reduces the higher network pressure to the operation pressure and ensures by this means a constant pressure supply to the utilization (see Fig. 17).
(3) A pressure gauge for pressure control.
(4) A lubricator which mixes a small amount of oil with the air. The lubricator is required only if compressed air is driving mechanical devices as pistons (not for spray guns).

- Traps should be drained twice a day

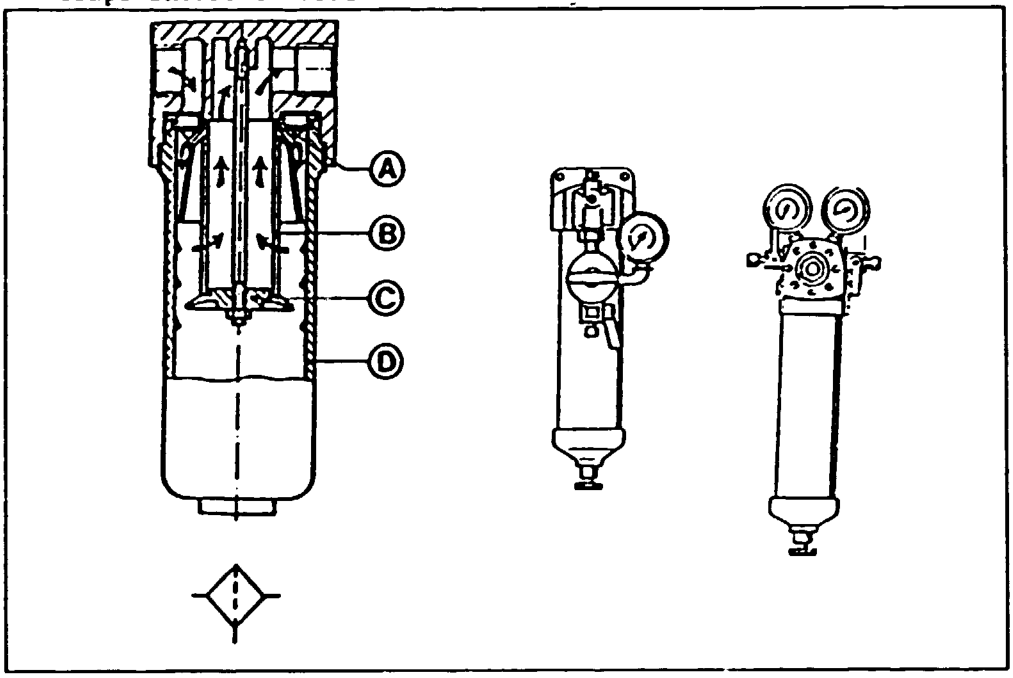


Fig. 16: Air filters.

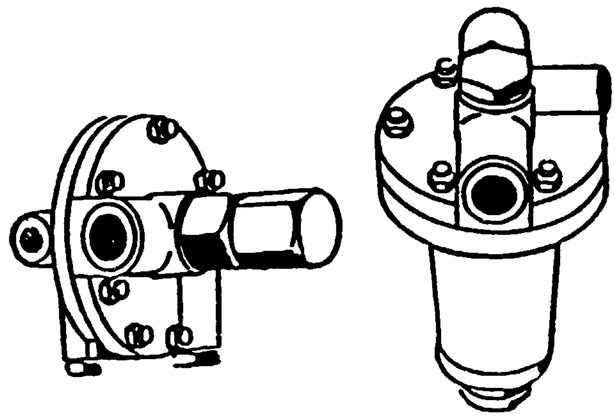


Fig. 17: Pressure regulators.

- Regulators should be drained twice a day.

- Compressors should be drained twice a day.

- Overspray and dust should never be allowed to enter the compressor intake, the air filter should be cleaned periodically.

- The oil in the compressor must be controlled frequently and changed monthly if it is working continuously.

- To check whether the compressed air network is free of water and oil, there is a simple method: Compressed air must be blown on a white clean sheet of paper; the paper should be free of oil mould and dry. It must be remembered that all the varnishes, particularly polyurethanes, can be affected by water and oil.

With respect to the air and paint hoses, it is important to take the following into account:

- The hoses should be kept as short as possible.

- It is important to select the right hose: It must be flexible. PVC and nylon hoses last longer than rubber and nylon is very resistant to solvents.

- Too high a pressure must never be used.

- The air hose should not be submerged in solvent. Only nylon can be immersed since it is completely resistant to solvents.

- The hose should never be stepped on.

- Kicking the hose should be avoided.

- Paint should never be allowed to dry in the hose.

- The outside of the hose must always be kept clean.

- The hose should not be dragged over concrete floors.

The presence of moisture and oil in the compressed air can cause surface defects in the coating applied. To remove these and to be able to control the air pressure, it is essential to fit an air filter and transformer in the compressed air-line as near as possible to the spray gun (see Fig. 18).

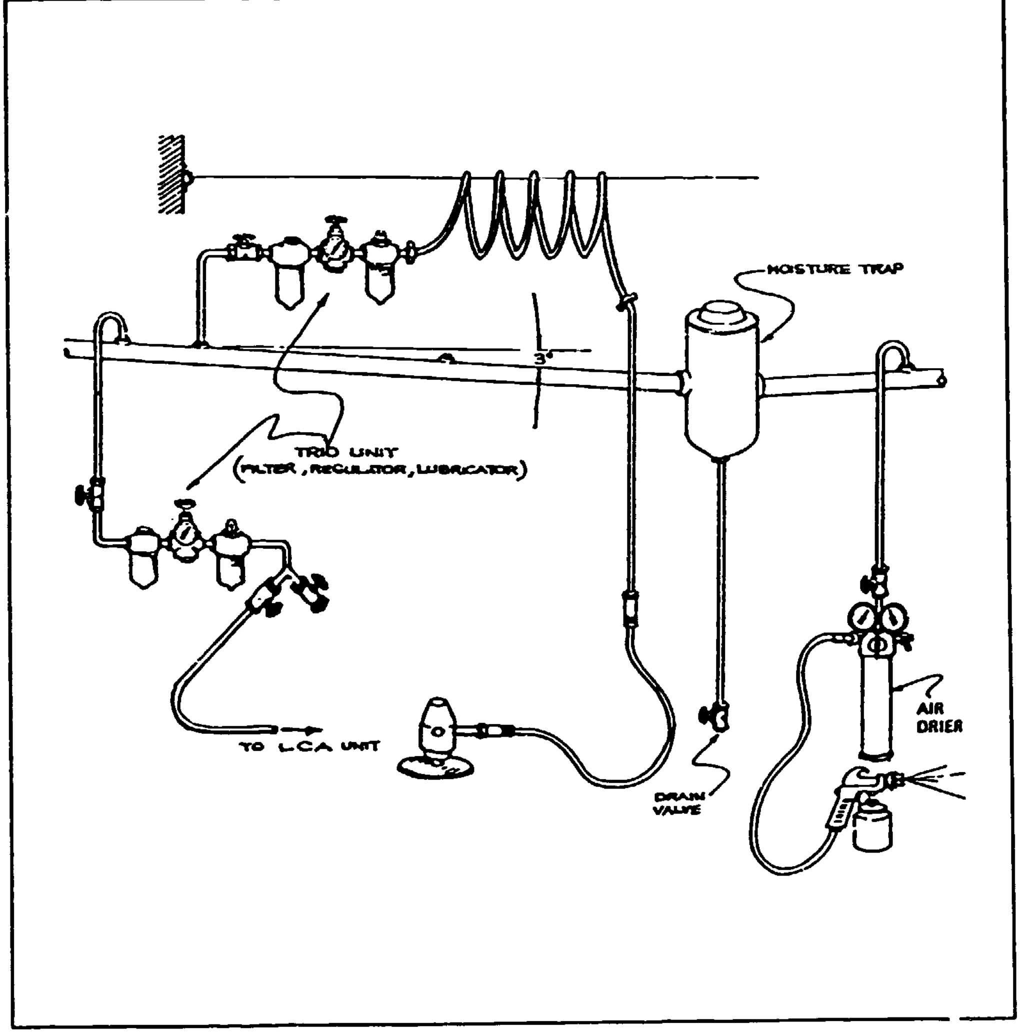


Fig. 18: Air-line system.

Table 2: Suggested pipe sizes for a compressed-air distribution system.

Air flow (cfm)	Air flow (m³/min)	Compressor power (hp)	Compressor power (Kw)	Run 25 feet (7.6 metres)	50 (15.2)	75 (22.8)	100 (30.5)	150 (45.7)	200 (61)	250 (76.2)	300 (91.5)
5 or less	0.14 or less	1.4	1.0	0.622 (15.8)							
10	0.28	2.8	2.1	0.622 (15.8)			0.824 (20.9)				
15	0.43	4.3	3.2	0.622 (15.8)	0.824 (20.9)						
20	0.56	5.6	4.2	0.824 (20.9)							
25	0.70	7.0	5.2	0.824 (20.9)					1.049 (26.6)		
30	0.85	8.5	6.3	0.824 (20.9)			1.049 (26.6)				
35	1.0	10.0	7.5	0.824 (20.9)		1.049 (26.6)					
40	1.12	11.2	8.4	0.824 (20.9)	1.049 (26.6)						
50	1.40	14.0	10.4	1.049 (26.6)							
70	2.0	20.0	14.9	1.049 (26.6)				1.380 (35.0)			

Source: Air Compression Research Council.

Note: The figures in the main body of the table are the inner diameters in inches (millimetres in parenthesis) of standard black pipe that will keep the pressure loss to a reasonable minimum over the runs indicated.

Air hose

A rubber flexible hose normally links the main network to the point of utilization (spray gun). This allows the operator to follow the shape of the work piece with the spray gun. Recently, filters have been set up that can easily handle 1.5 cubic metres of air per minute and the friction air loss is reduced to a minimum. It is important to clean the filter if it is not provided with an automatic cleaning device.

PVC air hoses have replaced rubber for many reasons: PVC has a very smooth glass-like bore which cuts down greatly the friction air pressure drop, whereas the inner moulding of the rubber tubing takes up the configuration of the cotton lamination, leaving a rough inner passage which creates greater friction and impedes air flow. An idea of the pressure drops is given in table 3 hereunder.

Table 3: Air pressure based on rubber air hose (PVC hose less restrictive).

Int.ϕ of hose	Pressure (lb/in^2)	Drop in Air pressure at spray gun kPa (lb/in^2)					
		2M	3M	5M	6M	8M	9M
	Kpa	5 ft. length	10 ft. length	15 ft. length	20 ft. length	25 ft. length	30 ft. length
.25 in. 6 mm	(40) 280	(6) 42	(8) 55	(9.5) 65	(11) 75	(12.75) 85	(24) 165
	(50) 350	(7.5) 50	(10) 70	(12) 85	(14) 95	(16) 110	(28) 190
	(60) 420	(9) 60	(12.5) 85	(14.5) 100	(16.75) 115	(19) 135	(31) 215
	(70) 490	(10.75) 75	(14.5) 100	(17) 115	(19.5) 135	(22.5) 155	(34) 235
	(80) 560	(12.25) 85	(16.5) 115	(19.5) 135	(22.5) 155	(25.5) 175	(37) 255
	(90) 360	(14) 100	(18.75) 130	(33) 230	(25.25) 175	(29) 200	(39.5) 270
.3125 In.	(40) 280	(2.25) 15	(2.75) 20	(3.25) 20	(3.5) 25	(4) 25	(8.5) 60
	(50) 350	(3) 20	(3.5) 25	(4) 25	(4.5) 30	(5) 35	(10) 70
	(60) 420	(3.75) 25	(4.5) 30	(5) 35	(5.5) 40	(6) 40	(11.5) 80
	(70) 490	(4.5) 30	(5.25) 10	(6) 40	(6.75) 45	(7.25) 50	(13) 90
	(80) 560	(5.5) 40	(6.25) 45	(7) 50	(8) 55	(8.75) 60	(14.5) 100
	(90) 630	(6.5) 45	(7.5) 50	(8.5) 60	(9.5) 65	(10.5) 70	(16) 110

IMPORTANT FOR SAFETY IN HANDLING COMPRESSED AIR

* The operator should avoid to clean his own clothes from dust with the compressed air since small particles of dirt can hit the eye.

* Putting compressed air in close contact with the skin should be avoided since this can create blood circulation problems.

* It must be remembered that the mishandling of compressed air can cause injury. This has happened on more than one occasion: the eyes, the blood system, as well as the ears can be affected by the wrong manipulation of compressed air.

II. THE IMPORTANCE OF SANDING IN FINISHING PROCESSES

Sanding is of fundamental importance to reach the best finishing results. A good preparation of the surfaces before spraying is the most important factor. In many developing countries, this step of production is sometimes and even often not given the importance it deserves. The best results can only be obtained when using the proper techniques. The range of sanding machines is wide and it is almost impossible to achieve by hand the same result obtained by using machines. For flat panels, it is very important to choose the right execution criteria to avoid waves and unpleasant unevenness in aspect after finishing. For this reason, it is fundamental that the calibration of the panels be done on a wide belt sanding machine. There are a lot of power tools intended for sanding, but the best results can only be obtained with specific machines. The only phase requiring a massive intervention of hand labour is the sanding between coats of chairs or rattan items. The more automated are the sanding operations, the more uniform, constant and faster will be the results. Sanding, if done by hand, is not an easy job. It will take a long time and will require great skills. Proper sanding not only provides a smooth result, but it also reduces the consumption of lacquers.

ABRASIVE PAPERS AND THEIR PROPER USE

The fundamental role of sanding paper in the furniture industry is to give the products the necessary degree of smoothness.

The components of sanding paper are:

- The paper itself, acting as a support for the grit particles,
- An adhesive to fix the grit on the supporting paper, and
- Grit particles, acting as the working elements in sand paper.

Material used to support the grit particles

Paper, cloth, fibres or a combination of paper and cloth are commonly used by the industries to support the grit particles. The paper used in the production is classified according to its weight, as follows:

Type	Weight (g/m^2)
A	65/75
B	10C/105
C	115/125
D	150/170
E	220/235
F	230/270

Normally, the paper is composed of five layers and is made from nitrocellulose or a vegetal fibre like manila hemp. The cloth used as a support to the grit can be made of cotton or other fibres and have different colours (white, brown and blue). They are divided according to their flexibility, as follows:

X - Stiff backing cloth
J - Flexible backing cloth
F - Super flexible backing cloth
W - High resistance along the cross-direction.

The flexibility of the backing cloth depends on the type and quantity of chemical substance used to cover the back part of the paper. Papers are obtained by curing fibres from cotton or special cellulose with zinc chloride. The reaction of this chemical substance improves the bond between the fibres and makes them plastic. The fibre used for sanding papers are characterized mainly by a thickness of 0.5 to 0.8 mm.

The combination between paper and cloth is formed by a paper of type E and a light cloth. This cloth makes the sanding paper very strong and the combination paper-cloth is used when stress and wear generated by sanding are very high.

Material used for gluing paper and grit

The glues used are animal adhesives or thermo-setting resins.

Two types of animal adhesives are used: one is of low quality, flexibility and durability; the other is for common sanding paper and has good flexibility.

Urea formaldehyde is an adhesive with limited applications. The main advantage of animal glue is its resistance to the heat which is generated during he sanding process.

Phenol formaldehyde resin is the adhesive more widely used. The advantage of this glue is its high resistance to heat generated by the friction between the sanding paper and the pieces being sanded. Another advantage offered by this resin is the possibility for it to be used in combination with an animal adhesive. In this case, the first layer of animal glue is covered with a second layer of phenolic resin.

Sanding grit

The grit used can be made from natural substances as well as from synthetic materials. The natural grit, called garnet, is normally used for low cost and low quality abrasive papers useful for hand sanding. The synthetic grits are aluminum oxide and silicon carbide.

Aluminum oxide is widely used for sanding wood and partly for varnishes. This material hardness varies between 9.0 and 8.4 on the Mohs hardness scale. The grit pieces are sharp and their hardness is very good. Producers of sanding paper blend grits of different hardness together, each producer uses a particular blend.

Silicon carbide is used mainly for sanding varnishes. The principal characteristic of this material is the shape of the grits that are sharper than those of aluminum oxide. The hardness of silicon carbide varies between 8 and 10 on the Mohs hardness scale; it is harder than aluminum oxide and has better cutting characteristics.

The dimension of grits are indicated by a number; the greater the number, the smaller are the grit dimensions. The grades of grit can be divided as follows:

- Macro grits: 12 - 16 - 20 - 24 - 30 - 36 - 40 - 50 - 60 - 80 - 100 - 120 - 150 - 180 - 220.

- Micro grits: 240 - 280 - 320 - 360 - 400 - 500 - 600 - 800 - 1000 - 1200.

Sanding paper production

As a first production step the back of the paper is printed with the brand, type and grade of grit. The paper then passes through a gluing machine and receives a first layer of adhesive, then the grit. There are two methods to dispose the grit on the paper:

(i) the grits fall freely on the paper through sieves, by shaking; and,

(ii) the grits are applied by means of an electrostatic field, with the advantage that the sharper edges of the grit particles are oriented upwards. The paper will then receive a second layer of adhesive. The drying of the adhesive takes place in an oven where the temperatures are gradually reduced to ambient values. After drying, the sand papers are seasoned for three months before delivery.

Uses of flexible abrasive papers

When the sanding process is done by hand, the papers normally used are either of type A or of type B, the glue is an animal adhesive and the grit is garnet, or, better, aluminum oxide. The light-weight backing material enables the operator to follow the shapes of the pieces sanded without problem and avoids loosening of the grits and their backing material. The high flexibility makes these materials also useful for an orbital sanding machine.

High quality, uniformity and precision of sanding are obtained with particular machines. The fundamental operations carried out by sanding machines are:

- calibrating of solid wood, plywood, blockboard, honeycomb panels, etc.

- sanding of frames, solid wood, panels, veneered particle board or plywood, etc.

- sanding between different varnish coats.

The calibrating operations permit to give the desired thickness to the piece of wood or wooden panel. This operation requires high power and the stresses on the sanding belt and the machine are high. The calibration requires:

- High quantity of material removal by the sanding belt so that the machine is submitted to high mechanical stresses.

- High precision imposes the use of a sanding belt of good quality.

The choice of the abrasive paper is linked mainly to the following parameters:

- Quality and type of wood processed.
- Type of sanding machine used.
- Type of sanding operation.

(1) **Type of wood**

(a) Solid wood;
(b) Panels (particle board, blockboard, MDF);
(c) Honeycomb panels, plywoods.

(2) **Type of machine**

(a) Calibrating machine;
(b) Calibrating and sanding machine.

(3) **Type of sanding operation**

(a) calibrating without particular interest in the smoothness of the surface;

(b) calibrating requiring smooth surfaces.

The sanding belt used during calibration depends on whether the calibration is light or heavy. In the first case, the belt is made of backing cloth or a combination between heavy paper and cloth. The adhesive is phenolic resin and silicon carbide is used as grit.

Cloth as a backing material makes the abrasive paper more efficient and also more expensive. The main characteristics of the backing materials are: to have perfect flatness and high resistance to stresses. If the backing material is not perfectly flat, the presence of waves and unevenness will create a high level of vibrations that will lead to an irregularly finished surface. The adhesive used to bond the grits to the backing is phenolic resin, which is highly resistant to heat and guarantees a good adhesion of the silicon carbide grit.

For light calibration, Type E paper is used both for particle board and plywood. The belt backing made of paper offers a good resistance, low cost and high efficiency, and allows the use of an eventual sanding pad for final sanding. An important element in making a belt is to join the paper in such a way as to guarantee resistance, maintain the same thickness of the paper and the uniform cylindrical shape of the belt. Smaller grits are used for hardwoods and bigger grits for softwoods. This is because more power is required for penetration into hardwoods. For a machine with constant power supply, a big grit can be used for softwoods, but only a small grit can be used for hardwoods. The thickness of the wood sanded in a pass depends on the grit number, which are given in table 4.

Table 4: Relation between grit number and thickness sanded off[1].

Number of grit	Thickness sanded off
40	0.4 to 0.5 mm
60	0.3 to 0.35 mm
80	0.15 to 0.2 mm
100	0.1 mm
120	0.05 mm
150	0.02 to 0.03 mm

Sanding of rough pieces

The aim of sanding is to obtain a surface as smooth as possible without having to take into account any possible modifications that will result in the

[1] These values are for a feed belt speed of 20 to 25 m/min.

thickness of the piece. The sanding belts used have a backing paper of Type E with an aluminum oxide grit. It is difficult to apply rules for this sanding process because the finishing solutions adopted after sanding affect the choice. The only advice that can be given is to use normal sand paper having medium to small grit dimension for hardwoods. Open coat sand paper with medium and high dimensions of grits should be used for species containing resins which have the tendency to clog the paper. The difference between the normal and open coat sand paper is that the distance between the particles of grit is lower in the first than in the second. The difference in weight between the grits used in the two cases is 20 to 30 percent. The degree of smoothness obtained with the open coat sand paper is good but normal sand paper offers a better performance. To get the desired efficiency, a double belt sanding machine is normally used with grits of 100 and 150 or 120 and 180.

Sanding between varnish coats

In this case, it is difficult to give exact parameters because of the different materials and finishing solutions that can be used. The varnish coats most often used are polyurethane and polyester, either clear or pigmented. One of the important parameters in choosing a particular sanding process is to know if it will have an open or closed grain finish. If the chosen finish is closed grain, the grade of grit should be 100 to 150; for open grain finish the grade of grit should be 150 to 240. With polyurethane finishes, sanding between coats is done with an open coat sanding paper. The grade of grit used in this process is 220 to 240 for the primer, 240 to 400 for closed grain finishes and 360 to 400 for open grain finishes; during the second sanding process the backing paper is of Type D. To get the best results, it is better to sand two or three times and alternate the sanding direction between the different sanding operations. For high gloss finishes, sanding papers of grit 500 should be used. Different grits are used according to the final end-use of panels: e.g. for internal surfaces of furniture, the degree of finishing is less than for external surfaces. The velocity of the sanding belt varies according to the type of varnish used: for P.U. it is of 4 to 8 m/sec, for polyester it is 16 to 18 m/sec. The other very important parameter is the hardness of the rubber roller that presses the sandpaper against the piece being sanded. For the calibrating operation, a hard roller is required to provide a small contact surface for the sandpaper. For normal sanding a larger contact to the surfaces is required so that the material of the roller is soft.

The rubber hardness is expressed in degree Shore, the scale ranges from 1°sh to 100°sh. The hardness of the roller is normally chosen as follows: 60°sh to 80°sh for calibrating operations; 15°sh to 50°sh for normal sanding and sanding between coats of varnish.

Furthermore, the surface of the roller can be smooth or with grooves. The smooth roller is used for normal sanding, the grooved one is used in calibrating operations.

Table 5 suggests the types of sanding paper and grades of grit suitable for different materials.

Table 5: Selection of type of sanding paper and grit numbers for different materials.

Material to be sanded	Type of sanding process	Backing material and type	Grades of grit suggested
Particle board	Calibrating Sanding	Cloth W + Paper E	36 - 40 - 50 - 80 - 100 - 120
Blockboard	Calibrating Sanding	Paper cloth	40 to 60 100 - 120
Plywood	Sanding	Paper cloth Paper E	100-120 100-120
Veneer	Sanding	Paper E	80-220
Solid wood	Calibrating	Paper cloth + cloth X-Y Paper E	24 - 60
	Sanding	Paper E	80 - 180
Varnishes	First sanding	Paper C	150-220
	Second sanding	Paper C	220-400
Floor	First sanding	Paper cloth	20-40
	Second sanding	Paper E	36-120

Common drawbacks occurring during sanding operations and their causes

1. Sanding belt breaking:

   - Joining of the belt not properly done.
   - Belt not properly fitted to the machine.
   - Too much material sanded at one time.
   - Tension of the belt too weak.
   - Storage conditions of the paper belt not appropriate: environment having too high, or too low relative humidity.
   - Rubber roller damaged.

2. Worked surface uneven and rough:

   - Sanding belt fully clogged with wooden particles between the grits.
   - Belt worn out.
   - Rollers not parallel.
   - Velocity of feed belt not regular.
   - Too much material taken away at one time.
   - Vibrations.

- Improper joining of the abrasive belt.
- Too high lateral oscillations of the belt.

3. Too low efficiency of the abrasive belt:

- Sanding belt clogged with wooden particles between the grits.
- Abrasive belt not suitable for the type of work.
- Too small grade of grit.
- Too high moisture content of the belt.
- Too high moisture content of the pieces being sanded.
- Rubber roller too soft.
- Too much material sanded at one time.

Optimal storage conditions for flexible sand papers.

The flexible abrasive papers have to be handled with care to be used to their maximum efficiency. Poor storage conditions affect the backing materials and the glues that will spoil the sanding products. The optimal storage conditions are:

- Relative humidity 40 to 50%.
- Temperature 15° to 20°C.

A higher relative humidity particularly affects the backing paper and creates undulations as shown in figures 19 and 20, and furthermore reduces the flexibility of the paper thus making it weaker and less resistant to stresses. Continuous variations of temperature and relative humidity create internal stresses between the abrasive paper components and reduce its performance. Importance should be given to storage conditions and for this reason an air conditioned room is recommended. The bigger the dimensions of belts are, the bigger is the necessity to provide good storage conditions. If the working environment conditions are too far from the sanding paper stocking conditions, it is better to allow the paper to acclimatise for a period of two days in the same environment as the machine before its use. The best stocking positions are shown in figure 21.

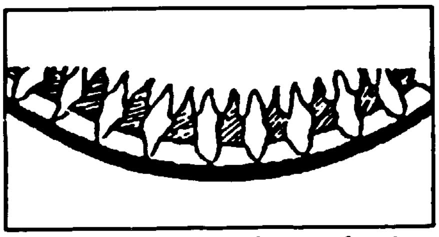


Fig. 19: Too high a relative humidity in the belt.

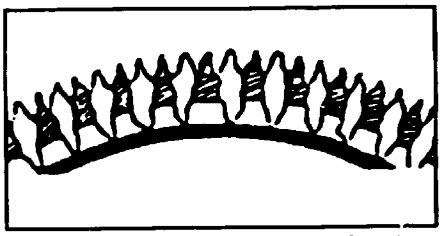
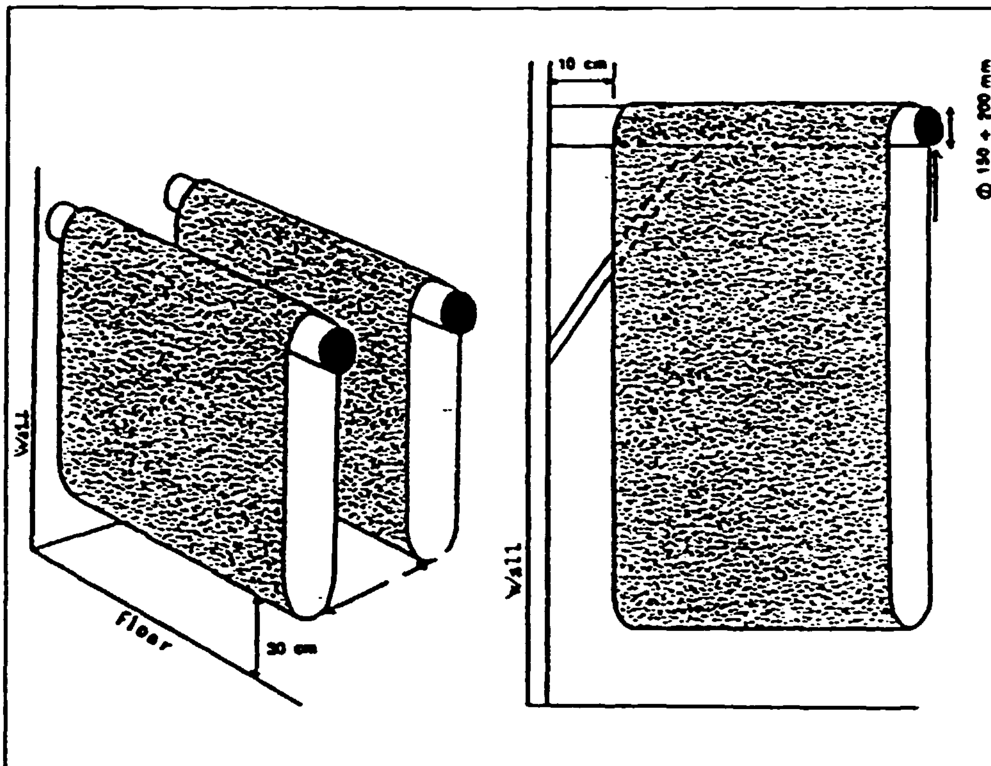


Fig. 20: Too low a relative humidity in the belt.



(a) isometric view (b) side elevation

Fig. 21: Proper storage of sanding belts.

A few hints on sanding

1. The lowest sanding pressure possible has to be used so that the sharp edges of the grits do not break off. If they break off at the start, the whole sanding process will be slower. A low sanding pressure also leaves a nice surface, whereas a higher sanding pressure often leaves a poorer surface, which causes an unnecessarily high consumption of lacquer. Low sanding pressure also means lower power consumption.

2. A flexible sanding shoe should be used. It preserves the edges of the grits. To obtain suitable flexibility, the sanding pad's core on manually operated belt sanders may be covered with 2 mm thick rubber of 40° Shore hardness and graphite cloth. The sanding of the surface is improved and the sanding belt lasts longer.

3. Preliminary sanding is recommended until the surface is quite free from adhesive tape, glue, etc. The strain between preliminary sanding and fine sanding must be properly distributed. The workpiece should therefore be turned between the sanding processes and the sanding done in the opposite direction when the sanding is performed in two stages.

4. Fine sanding must only be continued until the grooves from the preliminary sanding are eliminated. That gives the best result.

5. The stiffest possible quality of textile must be used - they last longer.

6. The direction of movement for continuous belts must be checked - the back of the belt carries an indication of the correct direction in the form of arrows.

7. The sanding belt should be left to sag when the machine is not in operation. It will not swell and it will last longer.

8. To reduce friction heat, the back of narrow continuous belts (up to a width of 200 mm) should be coated with graphite. The simplest way is to use a graphite stick which gives a uniform distribution.

9. The most suitable belt speed must be selected - when sanding wood between: 25 and 30 m/sec, and when sanding lacquer: between 4 to 15 m/sec.

10. When sanding edges or vertical surfaces, working against a hard support - such as steel - must be avoided; this might cause swelling and burns. If the machine has a stop of steel, it should be covered with a 2 mm 40° Shore rubber sheet and graphite cloth.

11. All dust must be removed by suction so that the machine and the workpiece remain clean.

12. To achieve the best surfaces and smoothness, it is important to use the sharpest abrasives.

13. Sanding must be started with the coarser grit following the sequence, ensuring that the gaps between the abrasives used are not too big; e.g. it is not possible to go from grit 80 to 180, it is better to follow this order: 80 - 120 - 180. The proper selection of appropriate grits is vital to obtain the best sanding results. (As a rule of thumb the next number should not exceed the previous one used by more than 50 percent).

SANDING MACHINES

Various types are commonly used. Fig. 22 shows the positions of belts on various machines.

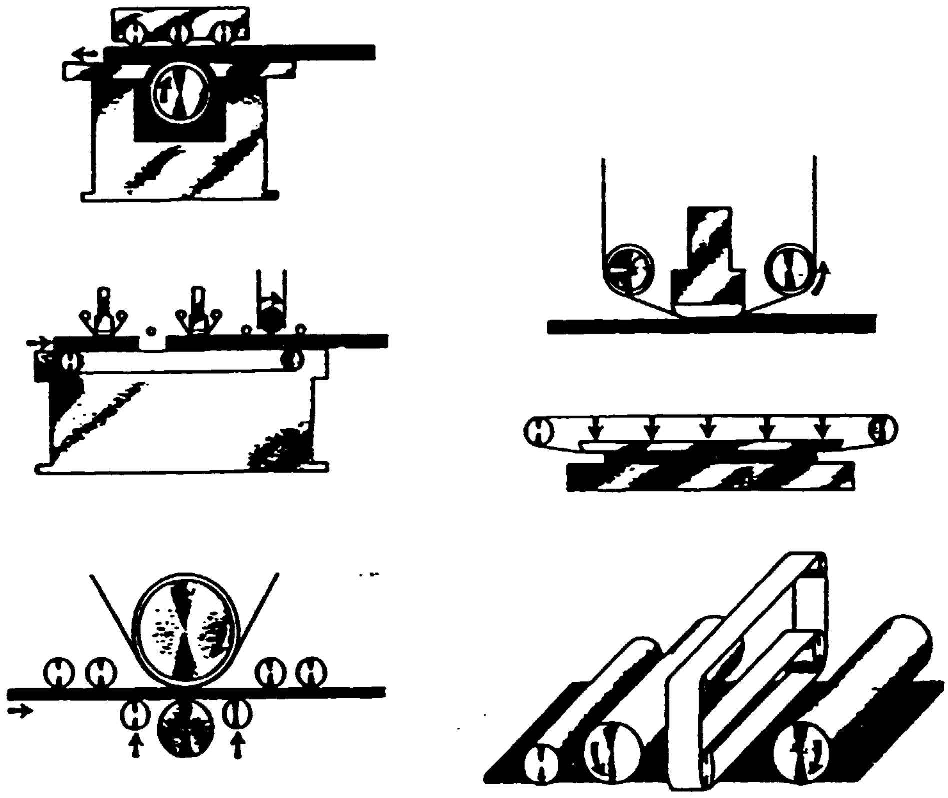


Fig. 22: Different types of sanding machines.
(Sketches showing positions of belts.)

NARROW BELT SANDERS

This machine is simple and cheap and is suitable for sanding panels and flat components. It requires a skilled operator to get the best results (see fig. 23).

Typical specifications for such a machine are:

Length of table	1500 mm
Width of table	540 mm
Vertical stroke of table	700 mm
Motor power	2 HP
Max. length of sanding belt	4200 mm
Min length of sanding belt	3960 mm

Standard width of sanding belt	100 mm
Belt speed	24 m/sec
Overall dimensions	2190 x 1470 x 1410 mm

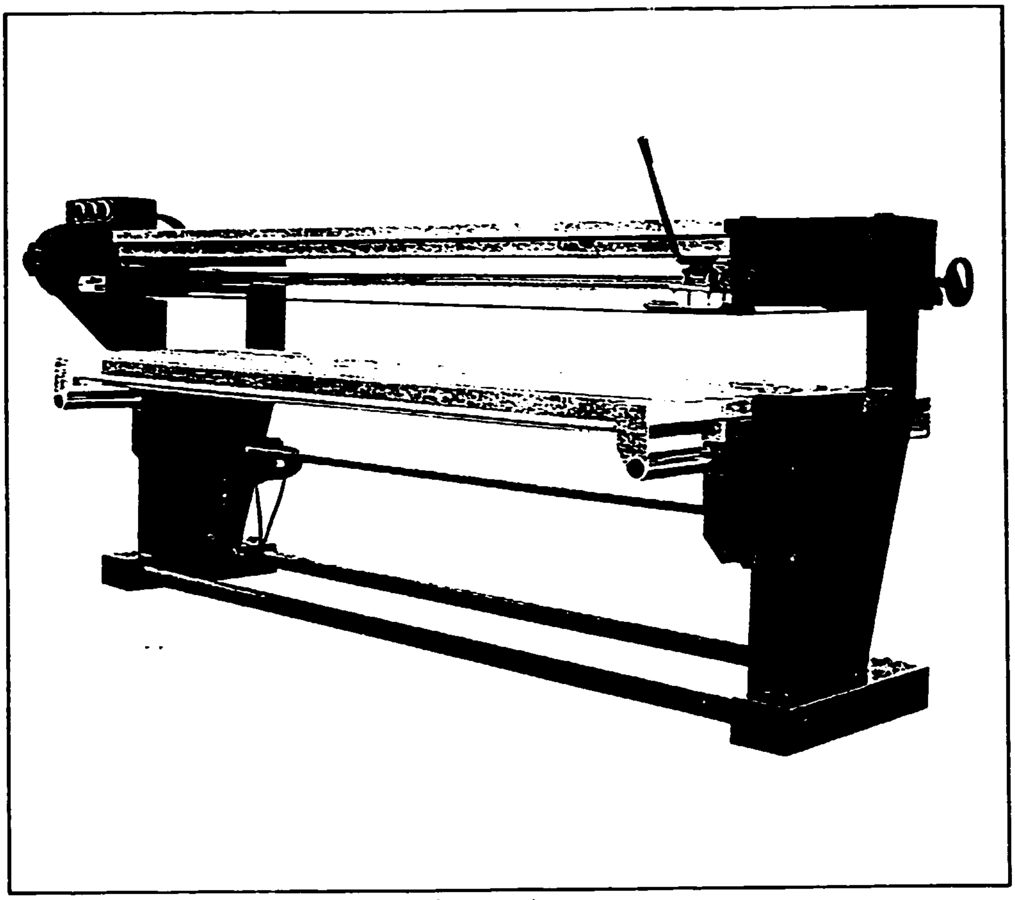


Fig. 23: Single (narrow) belt sander.

Wide belt sanders.

This machine offers the best solution for sanding panels and straight wood components.

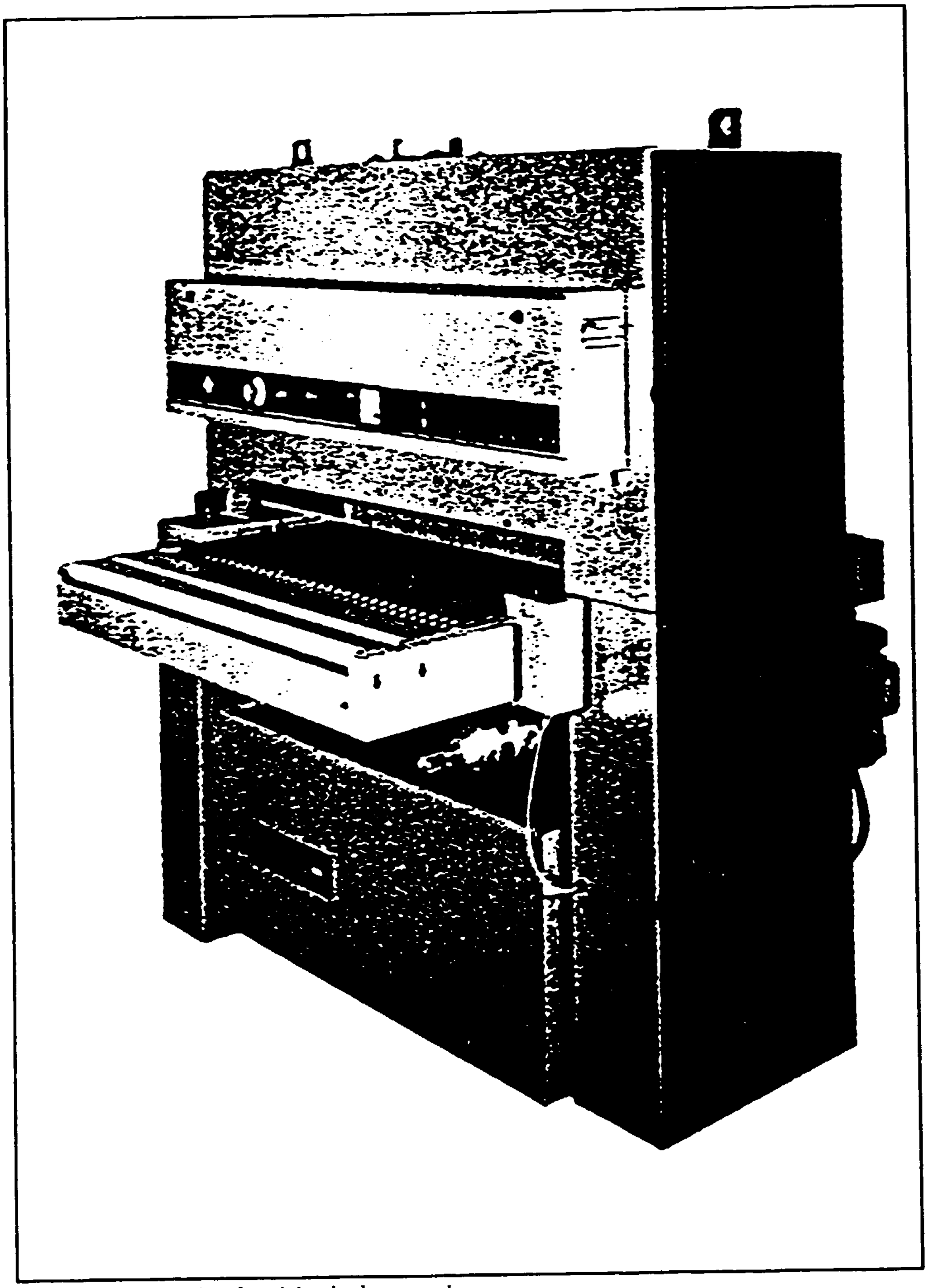


Fig. 24: Typical wide belt sander.

Other sanders

Figures 25 and 26 show other, less common types of sanders.

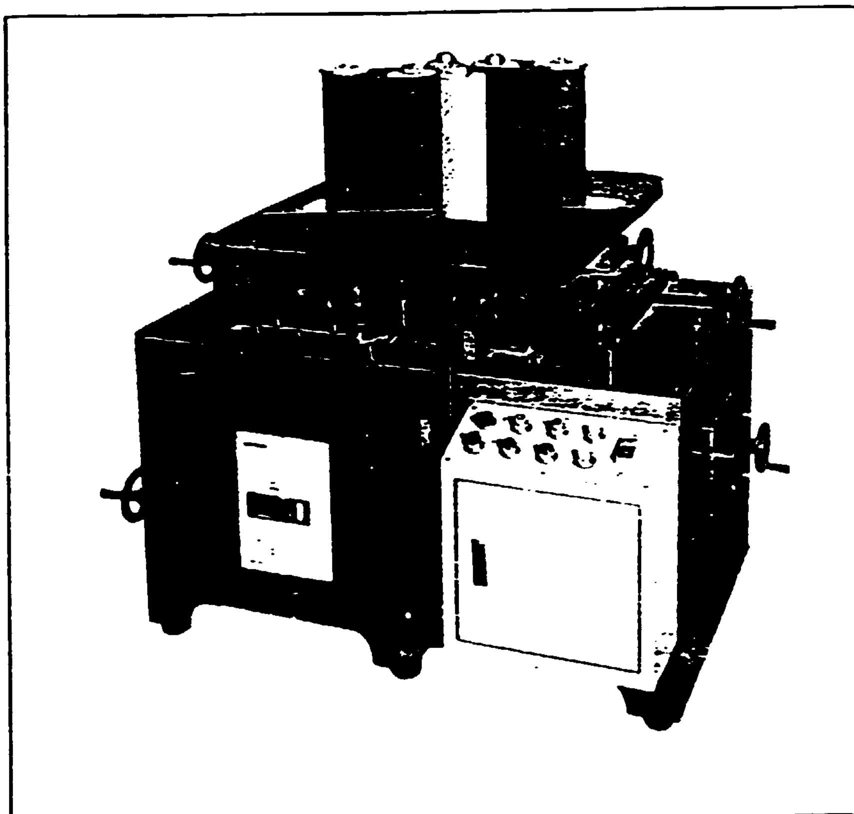


Fig. 25: Sanding machine designed specially for thin sides of workpieces and lacquer sanding.

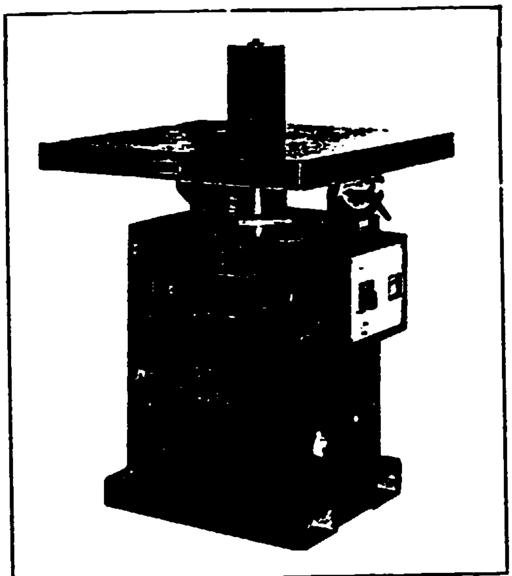


Fig. 26: Vertical sponge sander: ideas for sanding the edges and bent surfaces of wooden furniture components.

III. BRUSH FINISHING

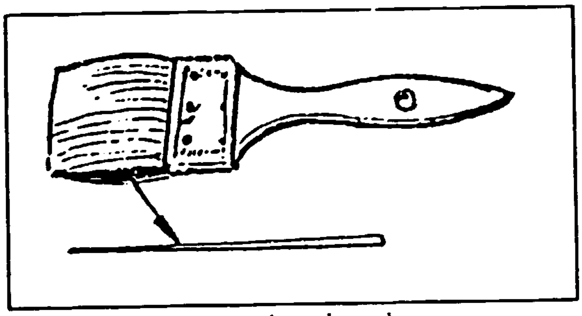


Fig. 27: Lacquering brush.

Painting with a brush (Fig. 27) is the traditional way of finishing. The equipment is very simple and cheap. it allows a continuous check of the work quality and the wastage of paint is reduced to almost nil. This system however requires high involvement of expensive labour. the results are not very good. the productivity is very low. a lot of defects can spoil the final aspect of items finished with the brush. A few instructions for a correct utilization of the brush are given hereunder.

(a) The surfaces to be lacquered are preferably set horizontally so that light is reflected from the lacquered surface (fig. 28).

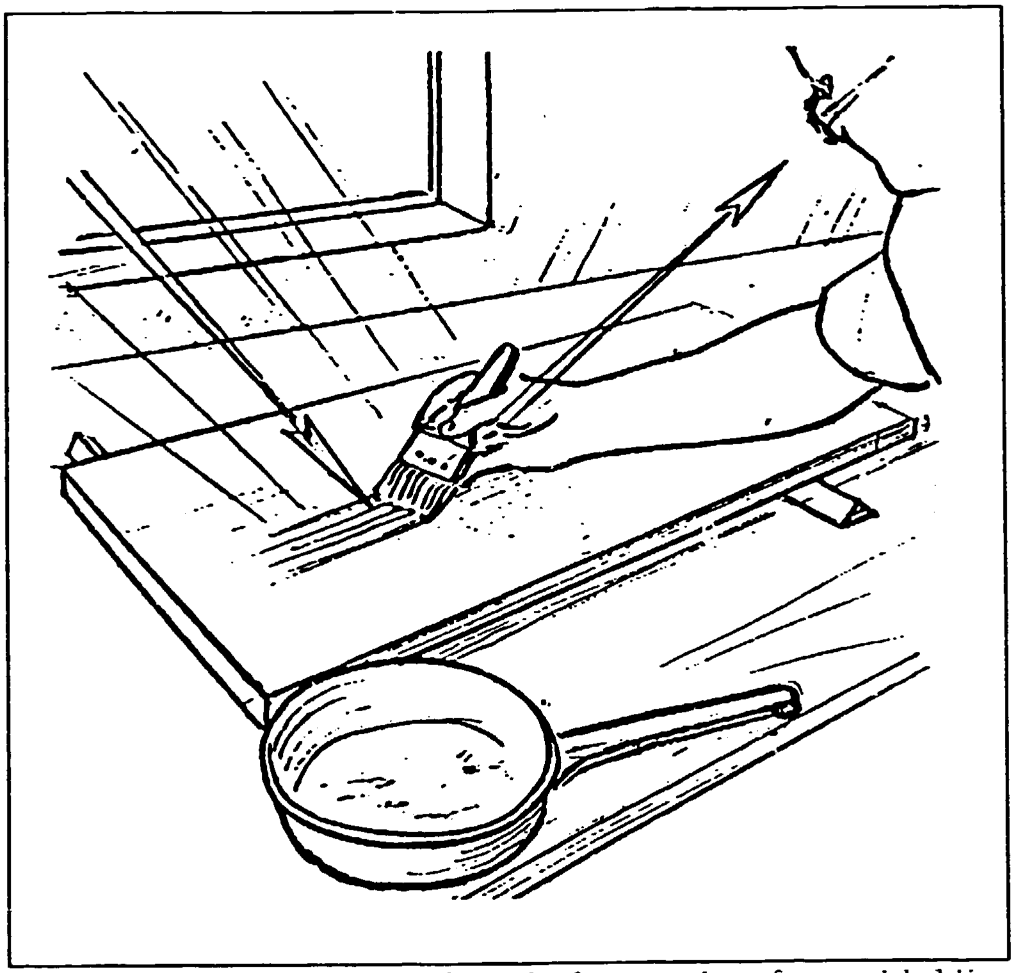


Fig. 28: Reflection of light from the lacquered surface and holding the brush.

(b) Lacquer application must begin from the edge furthest from the worker;

(c) Lacquer is applied from the centre towards the ends.

(d) Lacquer, immediately after application , is levelled with strokes across the whole surface, beginning exactly from one edge and making the stroke lighter on getting closer to the other edge.

(e) The brush must be held at an angle of about 60° towards the surface and near the brushing (fig. 28).

(f) The stroke speed and pressure of the brush must be suitable.

(g) The lacquer that has flowed on the edge must be immediately wiped off before the underlying lacquer coating becomes soft.

(h) With each stroke the surface must be observed against the light.

(i) It is advisable to coat horizontal surfaces with a thick layer of lacquer to make the surface level off.

(j) For vertical surfaces, the brush strokes must be from the bottom to the top.

(k) The lacquering sequence of an object must be planned so that the whole object can be lacquered at the same time, whenever possible.

(l) The surfaces must be allowed to dry sufficiently before they can be turned onto their own base, an exception being a case in which a special lacquering and drying base can be used.

(m) Between coatings, the surface is either sanded lightly or scraped to remove lacquer points.

(n) Cellulose lacquer dissolves the underlying layer of lacquer but catalyst lacquer does not.

In lacquering with a brush, the viscosity of the lacquer does not play an important role. In prime coating, both the cellulose and the catalyst lacquers are thinned 10 to 30 percent, depending on the temperature of the air, to ensure better adhesion.

IV. SPRAY GUNS: MAINTENANCE, CORRECT USE, IMPORTANT CONTROLS OF MATERIALS AND EQUIPMENT

Air atomization is one of the oldest methods of spraying paint with a gun, and the one most used. This method was introduced in the United States of America towards the end of the last century and it was launched at the same time as the Nitro Cellulose (NC) products. The advantages with respect to using the brush are:

- The finished surfaces are smoother and more uniform.

- The productivity is greatly increased.

Air atomization is a process in which paints or stains are mixed with air at low pressure outside the spray gun. The liquid leaves the nozzle in the form of a fine mist, which can be directed at the work piece.

The conventional spray guns can be divided into the following classes:

(1) Suction cup spray gun (Figs. 29 and 30)
for - low viscosity paints,
- frequent changes of material, and
- small quantities.

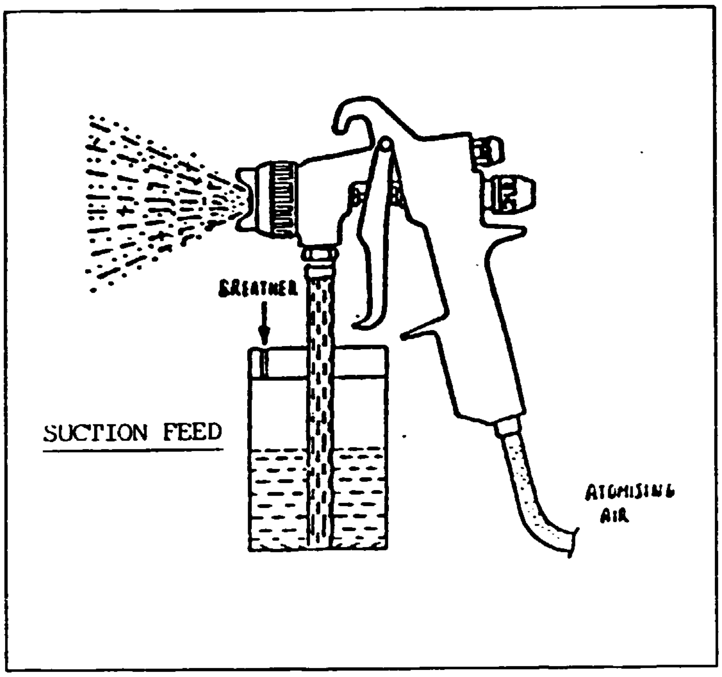


Fig. 29: Suction feed spray gun.

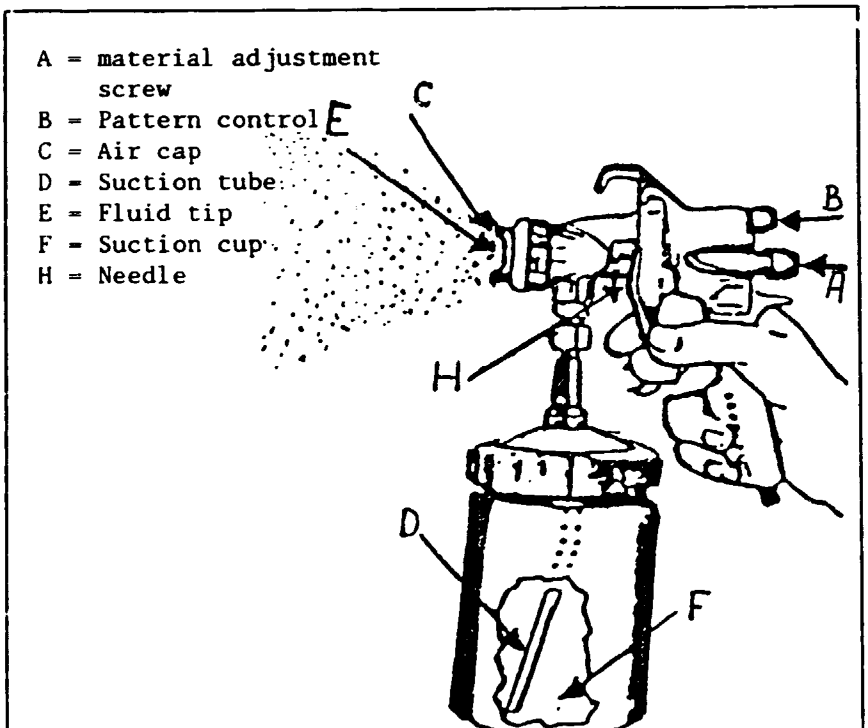


Fig. 30: Principal parts of a suction cup spray gun.

(2) Gravity - flow spraying (Fig. 31)
for - low viscosity products,
- frequent changes of material, and
- small quantities.

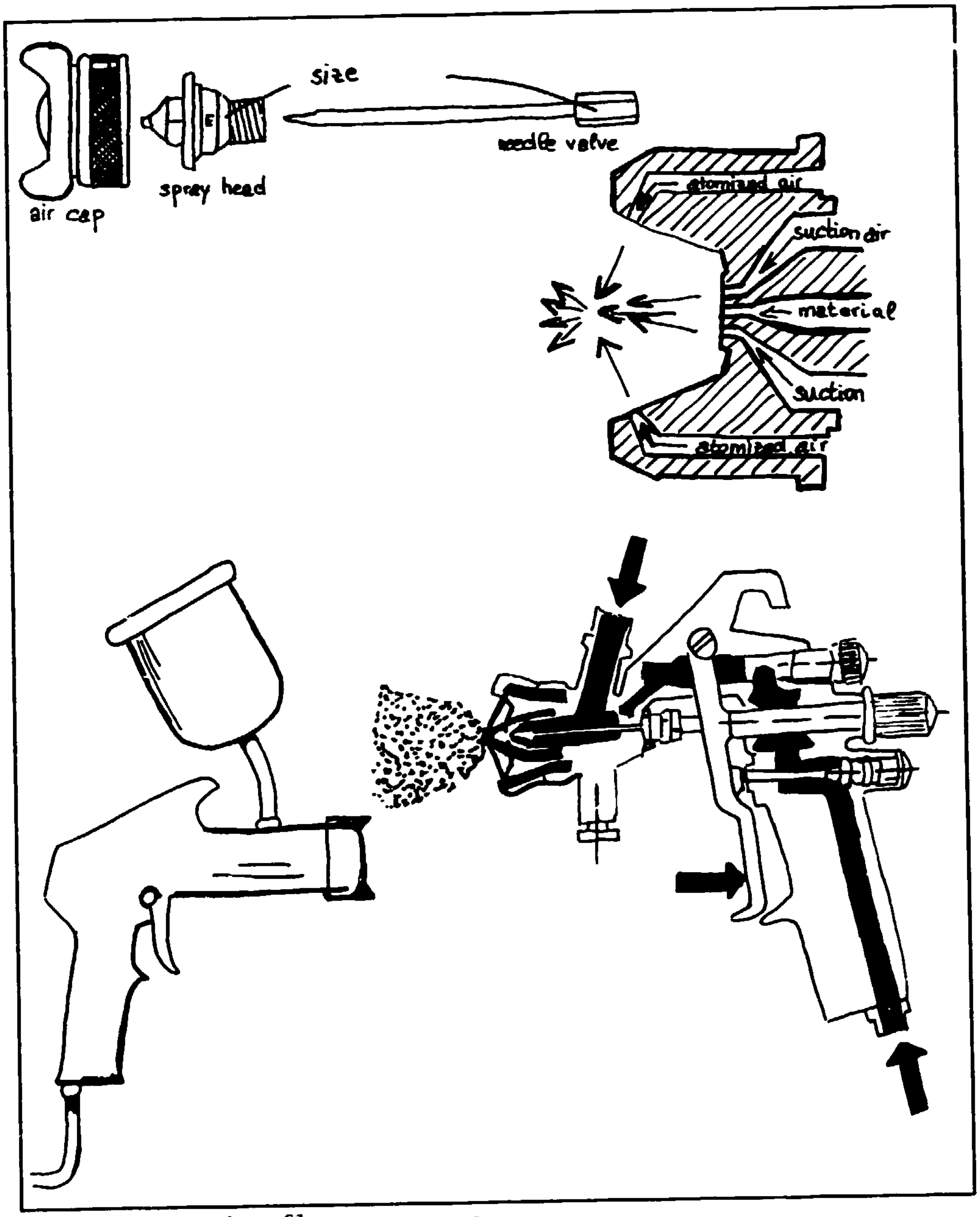


Fig. 31: Gravity flow spray gun.

(3) Pneumatic spray guns with pressure tank (pressure pot) (fig. 32)
for - low viscosity paints,
- average to thick coatings, and
- high outputs for extended periods.

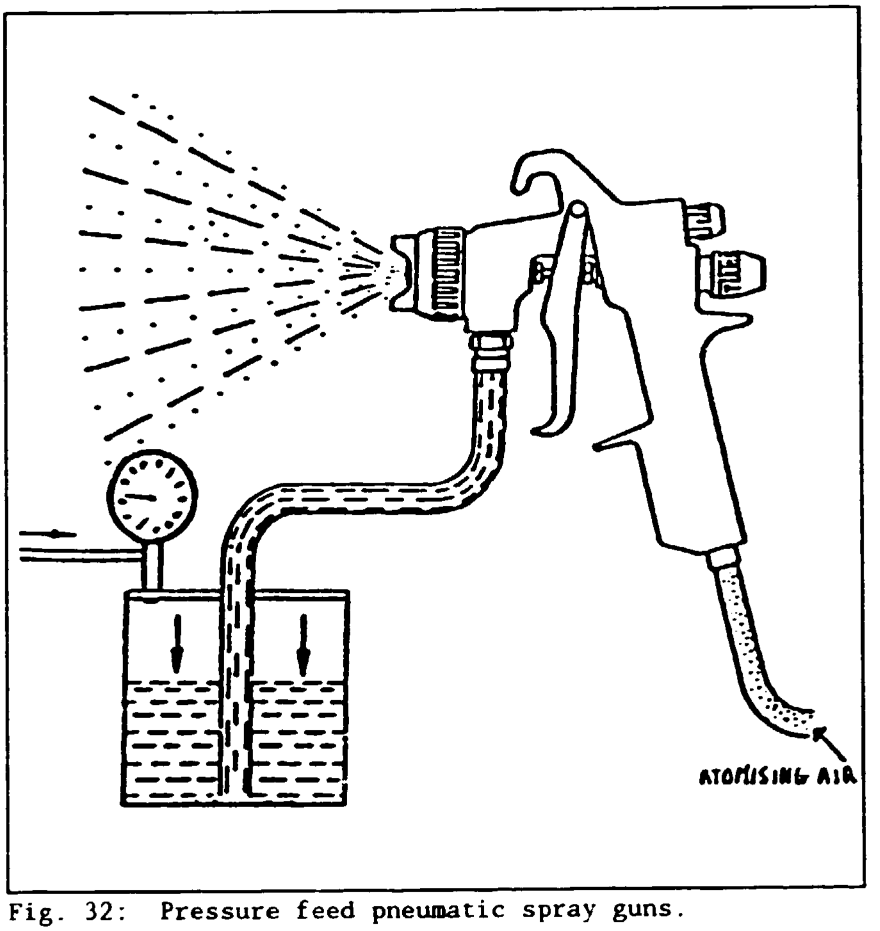


Fig. 32: Pressure feed pneumatic spray guns.

(4) Pneumatic spray guns with paint pump
for - low viscosity paints,
- average to thick coatings,
- high outputs for unbroken production runs, and
- suitability for circulating systems.

The paint is stored in a cup with a capacity of up to a litre, attached directly to the gun. When the trigger is pulled, the rapid flow of air creates a vacuum which causes the paint to rise through a tube and mix with the air. The paint then passes through the fluid tip and is atomized into a cone-shaped pattern. The air cap (C of Fig. 30) directs the compressed air into the stream of liquid, atomizing it into a spray pattern. With a suction feed gun, the stream of air and paint mixes outside the gun. With the spreader adjustment valve (B of fig. 30) in the open position air flows through the horn holes of the air cap. When the spreader adjustment valve is closed, the spray pattern is round. As the valve opens, the pattern widens and becomes more oblong.

The sizes of the air cap and fluid tip depend on the type of material being used. More viscous materials require a larger fluid tip than thin materials.

The material adjustment screw (A of fig. 30) controls the amount of liquid flowing through the fluid tip by restricting the needle travel and changing the distance the needle moves away from its seat when the trigger is pulled. The needle remains closed or seated unless the trigger is pulled.

Important controls on materials and equipment

Filtering

When appliances with pneumatic pumps are fitted with suction filters, no special filtering of the spray materials will be necessary. But if a suction-cup, gravity or pressure tank feed spray gun system is employed, filtering the spraying material prior to its use is strongly recommended. The choice of a suitable filter will depend upon the nature of the material to be sprayed:

- for top coats of all kinds: mesh size 0.2 mm
- for undercoats: mesh size 0.4 mm

(Nylon stockings could also be used - see Fig. 33)

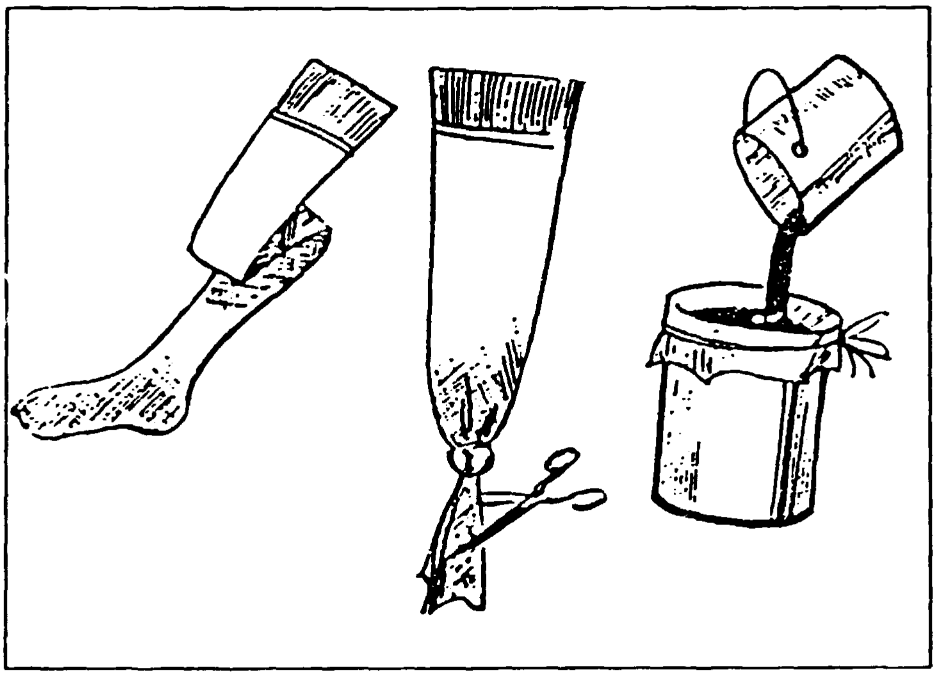


Fig. 33: Use of nylon stocking for filtering paint.

Viscosity

The viscosity of the paint to be applied by the air spraying process is of the greatest importance. The best results will be obtained with values between 14 and 20 sec (ISO) (measuring using ISO 4 mm flow cut). If the material is too viscous, the paint droplets formed will be too large and the coated surface will be affected by blisters or the familiar "orange peel" effect. On the other hand if the paint is too thin, it may run slightly after application. The correct viscosity can be achieved by adding a suitable solvent or thinner to the paint.

Air supply

The air used for atomizing the paint should be at a pressure between 3 bar and 5 bar, a good value is 3.5-3.8 bar (50-55 psi). The best results will be obtained only if the air pressure is kept constant, and the air is free of impurities. When using a pressure pot, the pressure pot's air cap has more air holes to assist in better atomization due to the high delivery rate of paint and can result in a build-up of paint in the air cap. Spray gun pressure using a 1.00 mm fluid nozzle should be 350-380 kPa (50-55 psi). The pressure in the pot should be set at 40 kPa (6 psi) to a maximum of 70 kPa (10 psi). To balance the pot pressure with the delivery rate, the air supply to the spray gun should be turned off, and the gun held high. The trigger should be pulled back and it should be ensured that the stream of paint starts to bend down approximately 1 m from the operator and the paint should touch the ground 2 m from the operator. Excessive pressure results in waste of material.

Fundamental conditions to get good finishes

The fundamental considerations for the best results in finishing are:

- suitable environmental parameters;
- items to be finished are to be delivered in good condition (moisture content, sanding, etc.);
- suitable finishing materials;
- proper use of varnishes;
- proper selection of the finishing technology and equipment and its correct application.

The quality of the products used in finishing is certainly the most controlled parameter. Controls of the materials are done in effect during all production phases starting from the components to the final product. It is desirable for the varnish producer to offer a very high quality product to the furniture industry so that the quality of the product is of standard condition and after delivery particular material checks are not required. The only thing to take into account are the shelf life and all the specifications contained in the technical sheet to store and use the products correctly.

Instruments needed to control all the parameters necessary to ensure a good finish:

(1) **Specification sheets:** These are the fundamental source of all the necessary instructions for a correct use of the products. It is fundamental that all finishing materials have the specifications that have to be read and strictly adhered to.

(2) **Hygrometer:** Useful to measure the relative humidity of the environment during spraying operations. For good results the relative humidity (RH) should be between 40 and 75 percent. It is important to control many times a day the RH and modify the environmental conditions if need be. Stopping the finishing

operation if the RH varies too much from the optimal value should be considered.

(3) **Electric timber moisture meter (fig. 34):** Useful to measure the wood's moisture content. The optimal value of moisture content ranges from 8 to 14 percent, depending on the equilibrium moisture content where the item will finally be used. It should be lower for ambient conditions were central heating or air conditioning is used. If this condition is not observed a lot of defects could affect the final results.

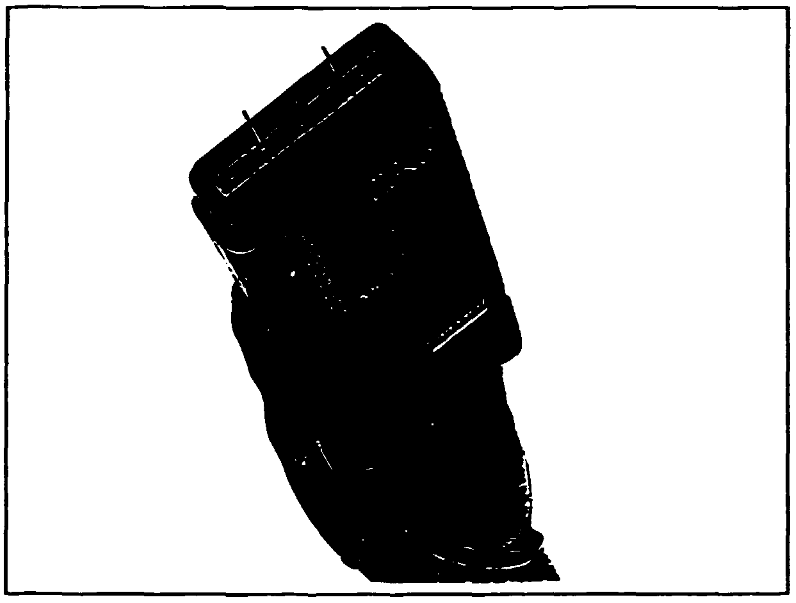
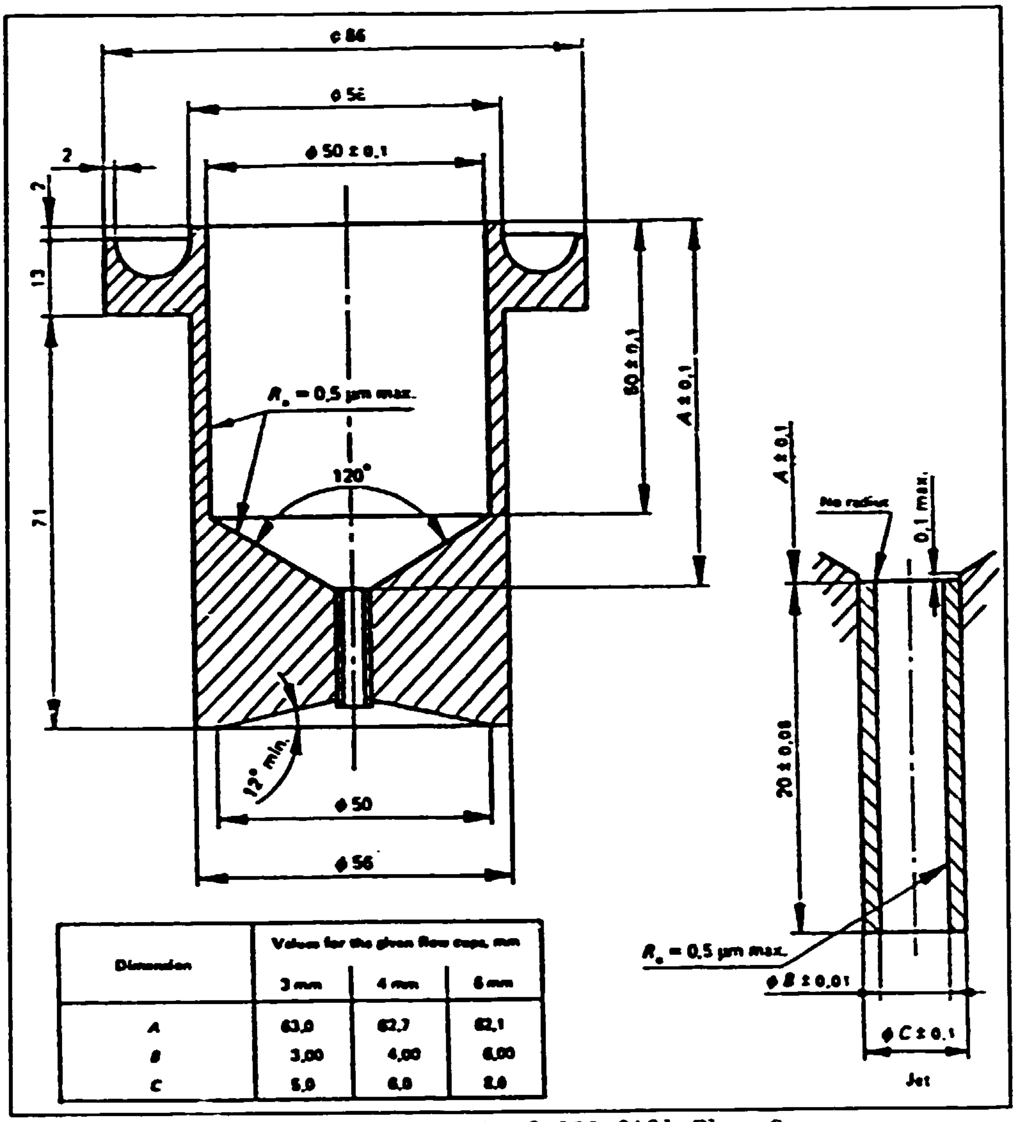


Fig. 34: Simple and sturdy electric moisture meter for moisture reading in wood. The instrument gives an immeidate direct read-out in percentage.

(4) **Viscosimeter (fig. 35):** This is an instrument designed to determine the viscosity of the products and consists of a small cup having a hole in the bottom part. The diameter of the hole can vary but is usually 4 mm for furniture finishing materials. The time that the varnish needs to flow through the hole until the cup is empty, indicates the viscosity of the product. Cheap plastic viscosimetric cups are now available on the market. To obtain constant and good results in finishing the viscosity of products is a fundamental parameter to take into account.



Dimension	Values for the given flow cups, mm		
	3 mm	4 mm	6 mm
A	63,0	62,7	62,1
B	3,00	4,00	6,00
C	5,0	6,0	8,0

Fig. 35 (a): Dimensions (in mm) of ISO 2431 Flow Cups.

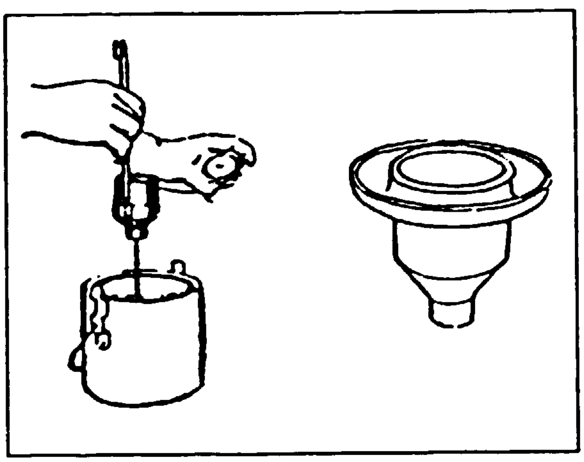


Fig. 35 (b): Measuring viscosity.

(5) **Thermometer:** To measure the temperature of the environment and materials before and during the spraying operations. For the best results, the temperature for all the production should be between 18°C and 29°C. The influence of temperature on different finishing products are:

- Polyester: Temperatures below 18°C and above 22°C should be avoided. The correct catalyst and paraffin should be used.
- Polyurethanes are easier to use than polyesters. At temperatures ranging between 14°C and 16°C, the drying time and pot life become longer. At temperatures of 24-26°C the pot life and drying time are shorter and there is a risk of some defects on dried films.
- Nitrocellulose products are very easy to use at low temperatures. If the temperature is too high it is better to use appropriate solvents to respect the proper drying time.

(6) **Balance:** Needed to weigh with precision the different varnish components, solvents and additives to comply exactly with the specifications. The balance is also useful to determine the quantity of product applied per square meter.

(7) **Magnifying lens:** A magnifying lens with a magnification power of 10x is normally used. Usually the lens is equipped with a lateral light to improve the visibility. The magnifying lens is an important instrument to analyze the defects of the paint film and consequently apply the necessary remedies.

Spraying patterns

The figures hereunder show the correct spraying pattern (fig. 36) and irregular patterns (figs. 37 to 40).

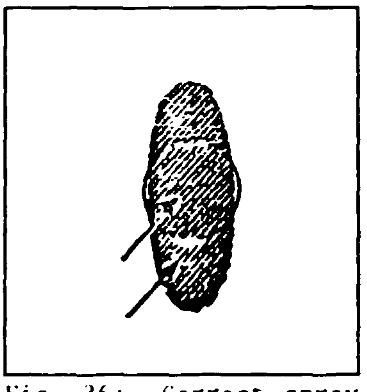
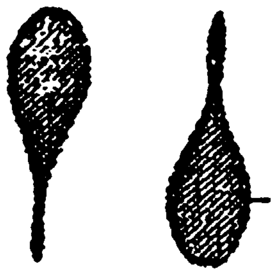
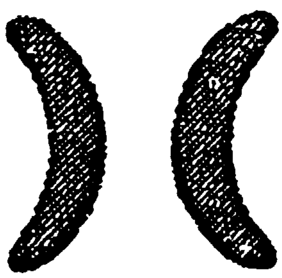


Fig. 36: Correct spray pattern.



The reason for the narrowing of the pattern at the bottom or top could be that the side openings of the spray head are blocked, that the spray head is partly blocked or that impurities exist in the air cap or spray head.

Fig. 37: Irregular spray pattern.



The reason for the pattern turning to the left or right could be a blocked side opening of the air cap, left or right, or a partly blocked spray head.

Fig. 38: Irregular spray pattern.

Source: DeVilbiss Company, Toledo, Ohio, U.S.A.

The reason for the pattern spreading in the middle could be: too narrow a spray; too low a pressure or paint is too thick; too small an air cap with pressure feed; or too large a spray head.

Fig. 39: Irregular spary pattern.

If the pattern narrows in the middle, the reason could be wrong pressure. Make the spray narrower or add pressure. Regulating the pressure increases the amount of colour but the spray movements must be speeded up.

Fig. 40: Irregular spray pattern.

Source: DeVilbiss Company, Toledo, Ohio, U.S.A.

Common defects in equipment

A. Paint leak through the air cap (Fig. 41):

The reason for a leak through the air cap could be:

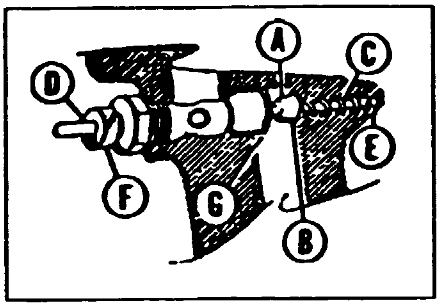


Fig. 41.

(A) Impurities in the sealing surfaces of the air valve;
(B) Sealing cone of needle or its chuck worn or damaged;
(C) A weak spring;
(D) Poor greasing;
(E) Bent needle.
(F) Too light a seal.
(G) Damaged or poor seal.

B. Paint leak through the needle valve seal (Fig. 42):

If the paint leaks through the tightening nut of the needle valve seal, the reason might be:

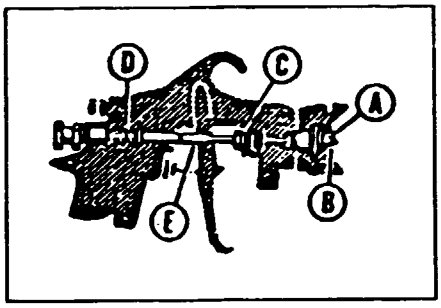


Fig. 42.

(A) Damaged or worn needle valve or spray head.
(B) Impurities in spray head.
(C) Too tight a seal for needle valve.
(D) A weak spring.
(E) Colour needle and spray head not of the same size.

Possible reasons for uneven spray could be (fig. 43):

(i) If the colour sprayed is uneven, the defect could be owing to any of the following reasons:

(A) Too little colour in the container.
(B) Position of container too slanted.
(C) Blocked suction pipe.
(D) Loose or damaged suction pipe.
(E) Loose or damaged seal.

(ii) When using a suction container also, defects could be because:

(F) Colour is too thick.
(G) Opening in the lid of container is blocked.
(H) Air pipe or pipe connector is damaged.
(I) Seal of needle valve is poor or loose.

Difficulty arises if the colour tube reaches the container bottom.

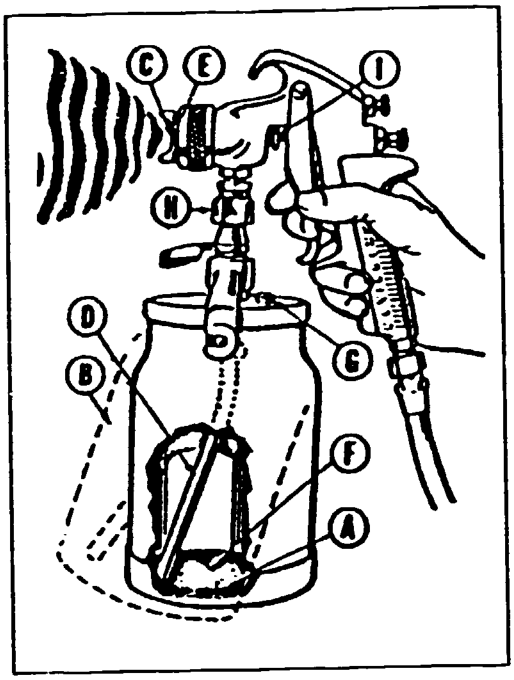


Fig. 43.

D. <u>Greasing the spray gun</u> (fig. 44):

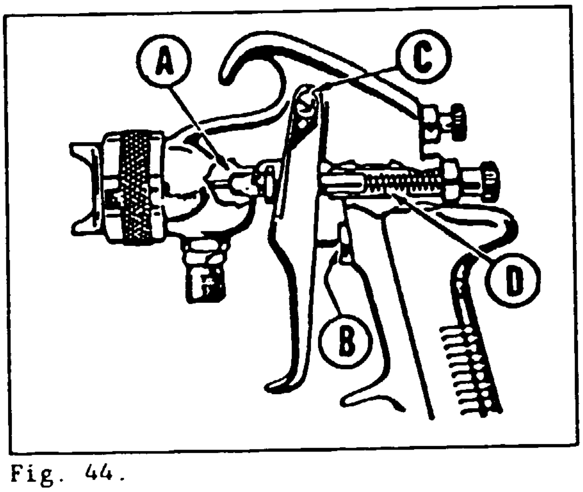


Fig. 44.

The following parts of the spray gun are greased regularly:

(A) Seal of the needle valve;
(B) Seal of the air valve.
(C) Tightening bolt of trigger.
(D) Springs of the needle.

E. Cleaning the spray gun (Fig. 45):

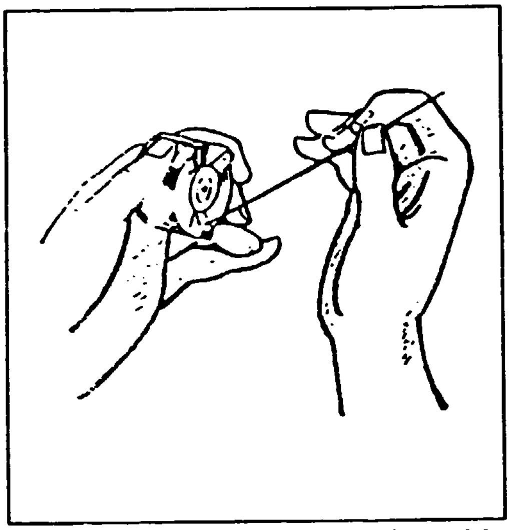


Fig. 45 (a): cleaning the side openings.

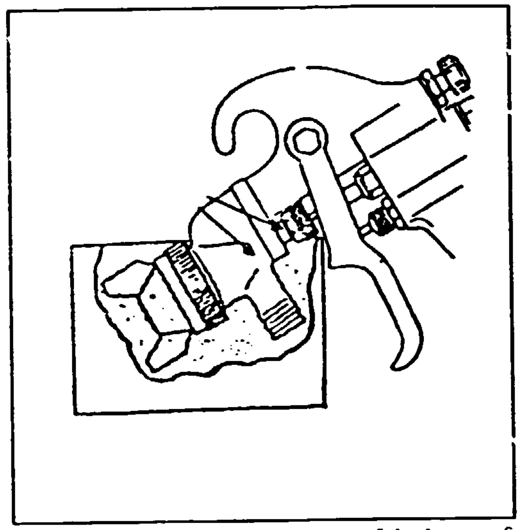


Fig. 45 (b): Upper limit of thinner must not rise above seal.

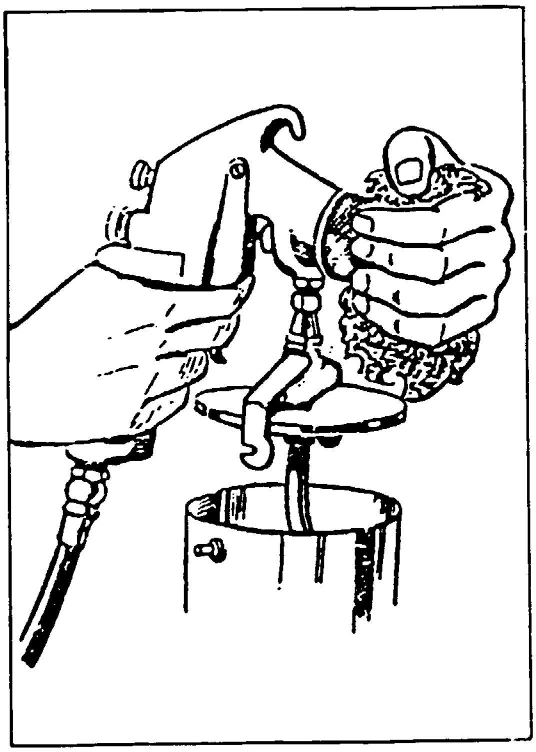


Fig. 45 (c): Cleaning spray gun with suction feed container.

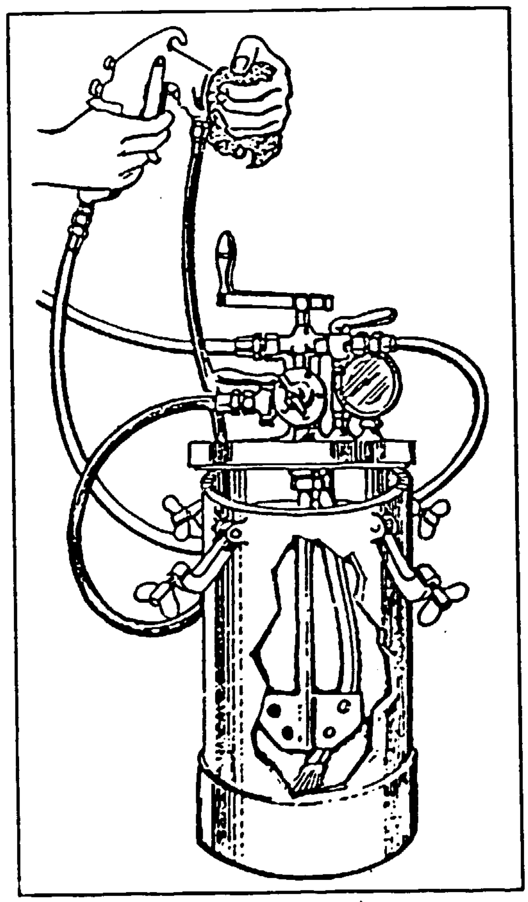


Fig. 45 (d): Cleaning the pressure system.

Table 4: Different combinations for suction cup guns.

TYPE OF PRODUCT TO BE SPRAYED	Nozzle φ in mm	Air cup	Litres/min at 3.5 bar	Cubic feet per minute at 50 psi	Compressor power in HP
VERY FINE: < 15 secs. No. 4 Ford Cup. Dyes, stains, spot removers, solvents, deoderants	0,50 0,75 1,00	355 351 351	50 135 135	1,80 4,80 4,80	0,50 1,00 1,00
VERY FINE: 10-15 secs. No. 4 Ford Cup Water, solvents, deodorants, leather dyes and softeners, wood stainers	1,40 1,40 1,40	35 58 90	153 193 285	5,40 6,80 10,00	1,50 2,00 3,00
FINE: 15-20 secs. No. 4 Ford Cup Dyes, sealers, silicones, lacquers, graphite, primers	1,40 1,78 1,78 1,78 1,78 1,50	43 35 58 30 43 90	300 153 193 267 300 285	10,60 5,40 6,80 9,40 10,60 10,00	3,00 1,50 2,00 2,50 3,00 3,00
FINE: 15-20 secs. No. 4 Ford Cup Lacquers, varnishes, enamels, car painting and refinishing	1,00 1,25 1,50 1,50	351 351 350 352	135 135 200 150	4,80 4,80 7,00 5,30	1,00 1,00 2,00 1,50
MEDIUM: 20-30 secs. No. 4 Ford Cup Application of paints in general, metallic paints, silicones, epoxies, polyurethanes, enamels, lubricants.	1,78 1,78 1,78	30 43 90	267 300 285	9,40 10,60 10,00	2,50 3,00 3,00
MEDIUM: > 20 secs. No. 4 Ford cup. Metallic paints, polyurethane, pottery and ceramic industries	1,50 1,50 1,50 1,78 1,78 1,78	350 352 356 350 352 356	200 150 235 200 150 235	7,00 5,30 8,30 7,00 5,30 8,30	2,00 1,50 2,00 2,00 1,50 2,00
HEAVY: > 30 secs. No. 4 Ford Cup. Primers, epoxi-polyamides, vinyls, impact adhesives, fillers. Car refinishing with synthetic enamel, lacquers, and acrylic and metallic products	2,18 2,18 2,80	306 64S 62S	297 283 292	10,50 10,00 10,30	3,00 3,00 3,00

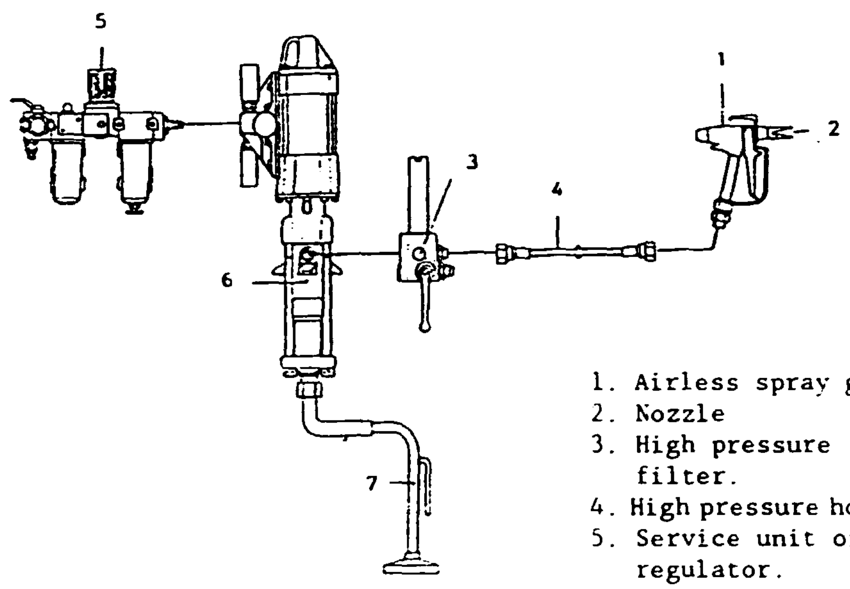
<u>Table 5:</u> Different combinations for a pressure feed gun.

TYPE OF PRODUCT TO BE SPRAYED	Nozzle φ in mm	Air cup	Litres/min at 3.5 bar	Cubic feet per minute at 50 psi	Compressor power in HP
VERY FINE: < 15 secs. No. 4 Ford Cup. General car, wagon, lorry and tractor refinishing. Application of inks, solvents, deodorants.	1,08	705	306	10,50	3,00
	1,40	705	306	10,50	3,00
	1,08	704	315	11,00	3,00
	1,40	704	315	11,00	3,00
	1,08	765	320	11,30	3,00
	1,40	765	320	11,30	3,00
FINE: 15-20 secs. No. 4 Ford Cup. High speed application in car painting and refinishing and other industries with cellulose, synthetic enamels, lacquers and varnishes.	1,19	775	340	12,00	3,50
	1,78	775	340	12,00	3,50
	1,40	78	325	11,50	3,00
	1,78	78	325	11,50	3,00
MEDIUM: 20-30 secs. No. 4 Ford Cup. Clear and pigmented lacquers, varnish, aircraft compounds, lubricants	1,08	777	328	11,60	3,00
	1,40	777	328	11,60	3,00
	1,40	54	216	7,60	3,00
	1,78	54	216	7,60	3,00
	1,78	704	315	11,00	3,00
	1,78	765	320	11,30	3,00
HEAVY: > 30 secs. No. 4 Ford Cup. Application in general of all heavy products, water based coatings, mill whites, plastic, rubber based and masonry paints.	1,78	704	315	11,00	3,00
	1,78	765	320	11,30	3,00
	1,78	777	328	11,60	3,00
	2,18	64	321	11,30	3,00
	2,80	62	325	11,50	3,00
VERY HEAVY: Sound deadners, corrosion resisting coatings, greases, heavy oils, tar.	1,78	704	315	11,00	3,00
	2,18	64	321	11,30	3,00
	2,80	62	325	11,50	3,00
ABRASIVES: Glazes, porcelain enamels, buffing compounds	1,19	765	320	11,20	3,00
	1,78	30	270	9,50	2,50
	1,78	67	330	11,70	3,00
	2,18	64	321	11,30	3,00
	2,80	62	325	11,50	3,00

V. AIRLESS SPRAYING

Airless spraying is a high-pressure process. The pressure is derived from a special piston or diaphragm pump, which is driven by compressed air. The consumption of compressed air is 70 to 80 percent lower than for ordinary spray guns, as air is required only for the operation of the pump.

The pump feeds the lacquer through a filter to the spray gun. The lacquer is forced at very high pressure through the spray nozzle (see fig. 46). The quantity of lacquer may be determined by means of the pressure, the spray nozzle, and the viscosity. Because of the pressure drop in the nozzle, the lacquer is vaporized into very fine particles. The loss of material with this type of spraying is substantially lower than in conventional spraying. Airless spray lacquering allows working at higher viscosities, and thicker and less porous films are achieved.



1. Airless spray gun.
2. Nozzle
3. High pressure filter.
4. High pressure hose.
5. Service unit or regulator.
6. Pneumatic pump.
7. Suction system.

Fig. 46: General layout of an airless spray unit.

The system may also be combined with preheating equipment so that the lacquer is sprayed warm (see fig. 47). Thus, by way of example, only one quarter of the pressure is required for spraying at 90°C. The relation between temperature and viscosity is given in Fig. 48. This method entails a lower over-spraying effect because the lacquer particles have lower velocity. The wear and tear on the nozzle is also smaller. High pressure spraying necessitates a contact safety device.

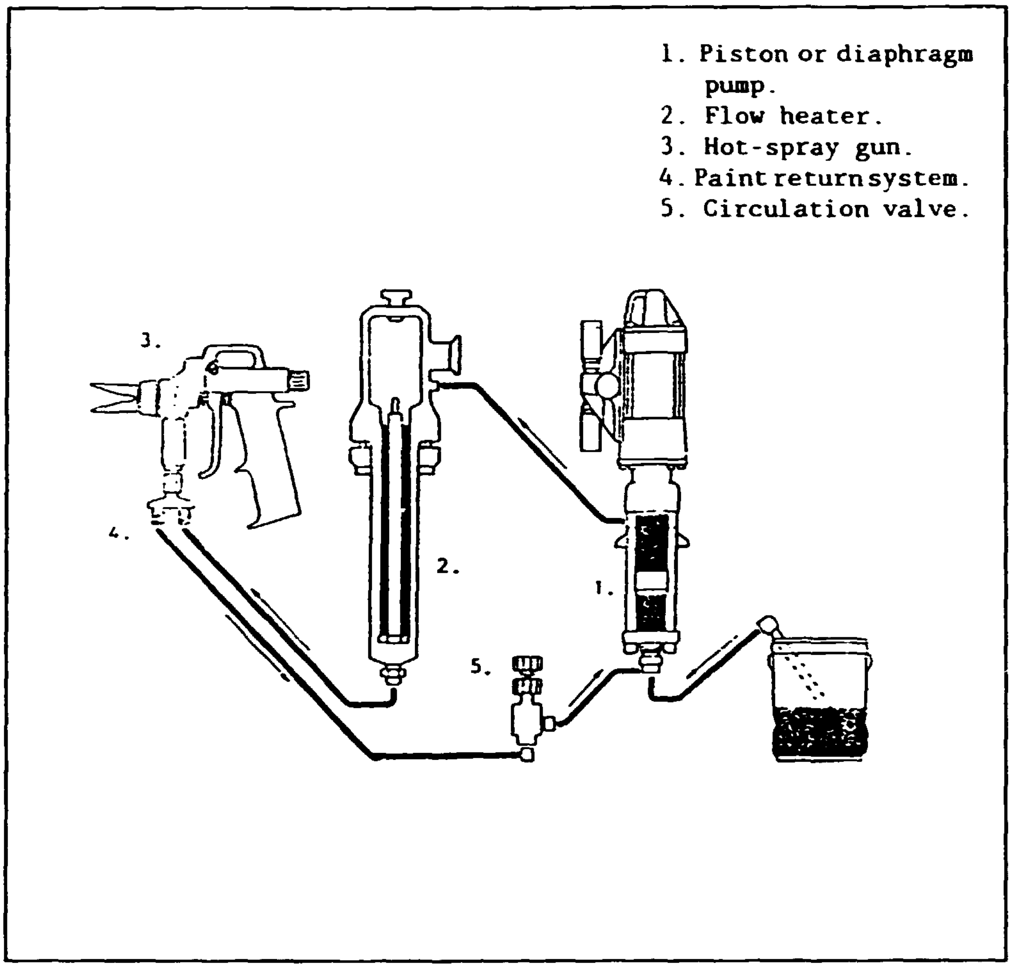


Fig. 47: Hot spraying system.

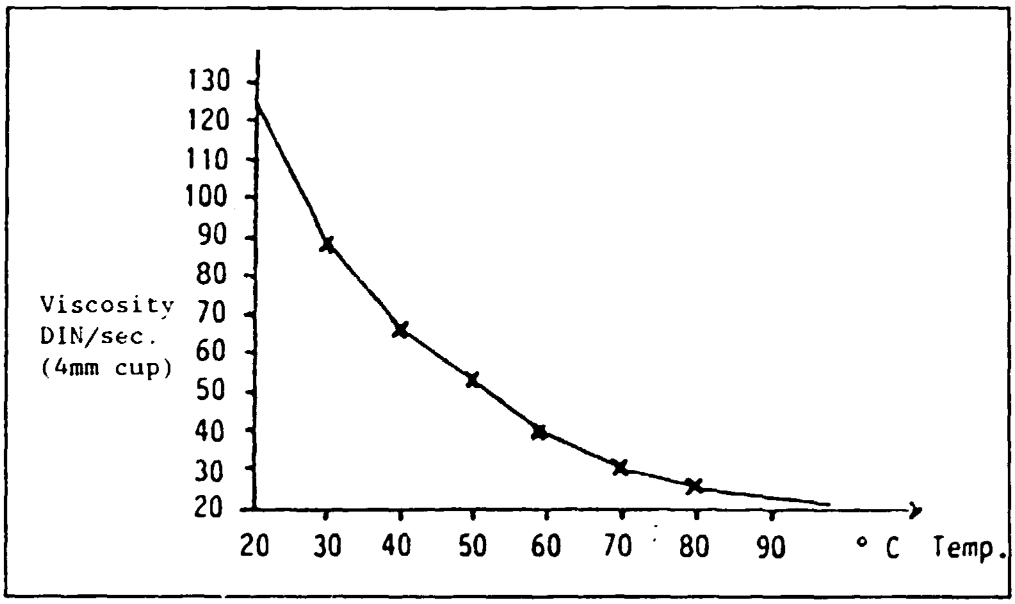


Fig. 48: Relation between temperature and viscosity of a hot-spray synthetic resin paint.

Advantages of airless spraying

The main advantage offered by airless spraying is economy.

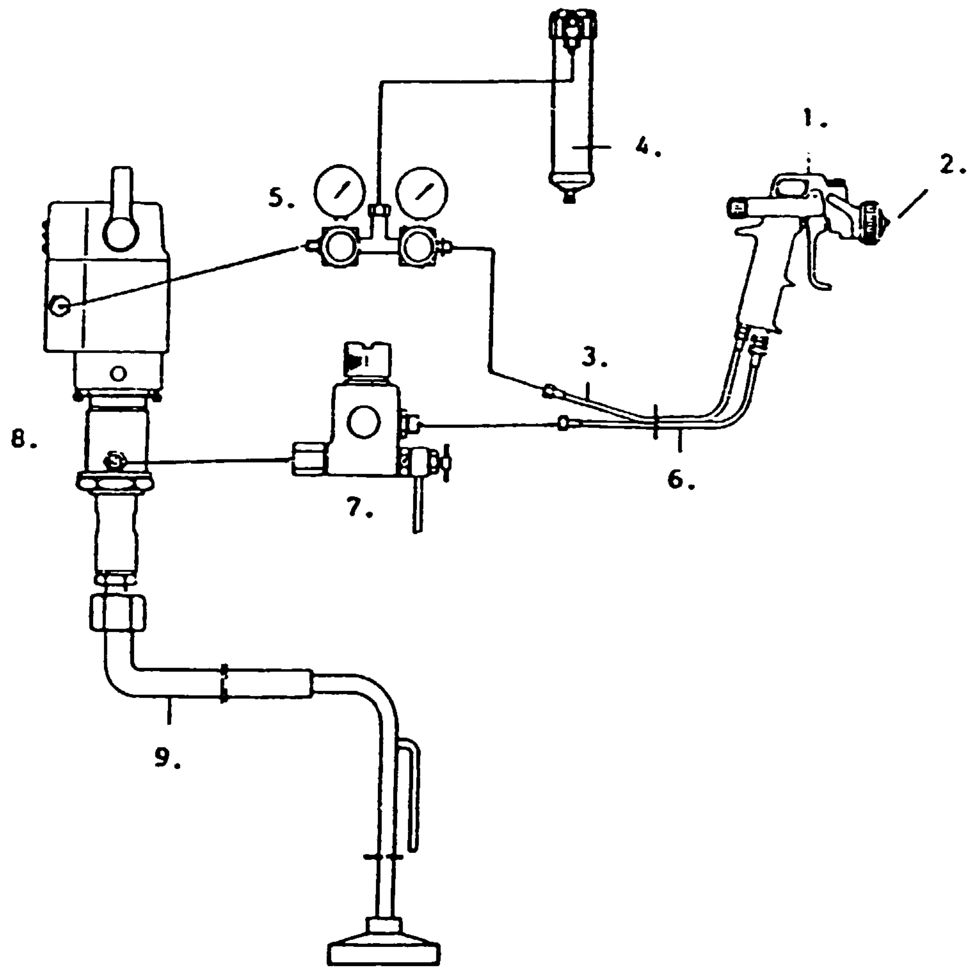
- It produces high-quality, non-porous coatings free from air bubbles.
- Relatively thick layers can be applied in one operation.
- It will cover the surface very rapidly.
- Both low and high viscosity materials can be sprayed without difficulty. In many cases, it is possible to reduce the quantity of thinner employed, or even to dispense with thinner altogether. There is less solvent to pollute the environment.
- Atmospheric pollution by solvents, paint mist and over-spraying is slight.
- The airless spray jet is well suited for coating complex workpieces with hollows, cavities and recesses. The air-cushion effect associated with air spraying is eliminated.
- Surface defects caused by impurities in the air used for atomization are eliminated.

AIRCOAT OR AIRMIX

With the aircoat process the material to be sprayed is fed to the spray gun by a pneumatic pump operating at pressures between approximately 50 and 250 bar. Actuation of the spray gun trigger opens the paint valve, the paint is forced through the narrow cross-section of the nozzle and is immediately diffused into extremely fine particles. The spraying air valve opens simultaneously and a jacket of air is formed by a specially designed annular slot around the nozzle, the air jacket surrounds the jet of material and helps to ensure that the edges of the jet are fully atomized (see fig. 49).

This system produces a jet of finely atomized paint directed at the workpiece having a low kinetic energy and enclosed in a jacket of air. The latter prevents excessive spread, particularly at the edges, and prevents the particles of material from rebounding or otherwise escaping from the surface of the workpiece. The formation of spray mist is thus considerably reduced.

- The result is a spray pattern with a soft, flowing outline.
- Both flat jet nozzles, in a very wide variety of sizes, and adjustable circular jet nozzles may be used with the aircoat process.
- Aircoat nozzles have very small dimensions: It is therefore essential to use high-pressure filters to avoid clogging.
- To avoid the possibility of paint film contamination, it is advisable to make provision for cleaning the air supply.



1. Aircoat spray gun.
2. Nozzle.
3. Air hose.
4. Air cleaner.
5. Control unit.
6. High pressure hose.
7. High pressure filter.
8. Pneumatic pump.
9. Suction system.

Fig. 49: Aircoat equipment.

Advantages of aircoat spraying

Aircoat spraying is suitable for the economic and decorative application of paints and similar materials.

- Both low and high viscosity materials can be sprayed without difficulty. In many cases, it is possible to reduce the quantity of thinner used, or even to dispense with a thinner altogether. Less solvent is needed, with a corresponding reduction in environmental pollution.

- The quantity of material applied can be regulated within wide limits, making it possible to apply the required layer thickness with great precision in a single coating.

- A uniform coating thickness is simple to achieve. The soft edges of the aircoat jet means that problems with overlapping are a thing of the past. Optimum results can therefore be obtained in minimum time.

- The aircoat spray jet is also suited to coating hollows, cavities and recesses. (The air cushion effect associated with air spraying is eliminated).

- Spray mist is also virtually eliminated. The escaping spraying air contains only a very small proportion of the pigment particles that left the spray gun, so that environmental pollution and the consequent waste disposal requirements are greatly reduced.

- Workpiece edges and apertures can be efficiently coated with significantly less wastage of material than is the case with airless spraying.

- The outstanding features of the Aircoat process can be supplemented and even further improved, where appropriate, by using it in conjunction with electrostatic or hot spraying equipment.

- The bounce back of paints and spray fog is greatly reduced and this is due to the reduction of the travel speed of particles as indicated hereunder.

Conventional air spray	9.2 m/sec (30ft/sec)
Airless spray	0.92 m/sec (3 ft/sec)
Aircoat systems	0.62 m/sec (2 ft/sec)

Electrostatic spraying units

Electrostatics is the science of static electricity and electrostatic forces.

A high tension (h.t.) electrode and a pole with an opposite charge will produce a field between them with lines of force in a pattern determined by the laws of physics.

The strength of the field will depend on the potential difference between the poles, on the distance separating them and on the electrical properties of the medium separating them.

Any substance close to the h.t. electrode will be charged with electrons and repelled along the lines of force in the field in the direction of the oppositely charged pole, which itself exerts a force of attraction.

If the pole opposite to the h.t. electrode is earthed, the strength of the field between them will be constant since the electrons reaching it are able to escape via the earth, and thus maintain the difference in voltage.

If the opposite pole were not earthed, it would be charged by the electrons attracted to it; the potential difference and the strength of the field would diminish steadily.

To maintain the efficiency of an electrostatic system, the flow of electrons must be enclosed within a circuit, i.e. the electrons must be able to flow back to the high tension generator via the earth (see fig. 50).

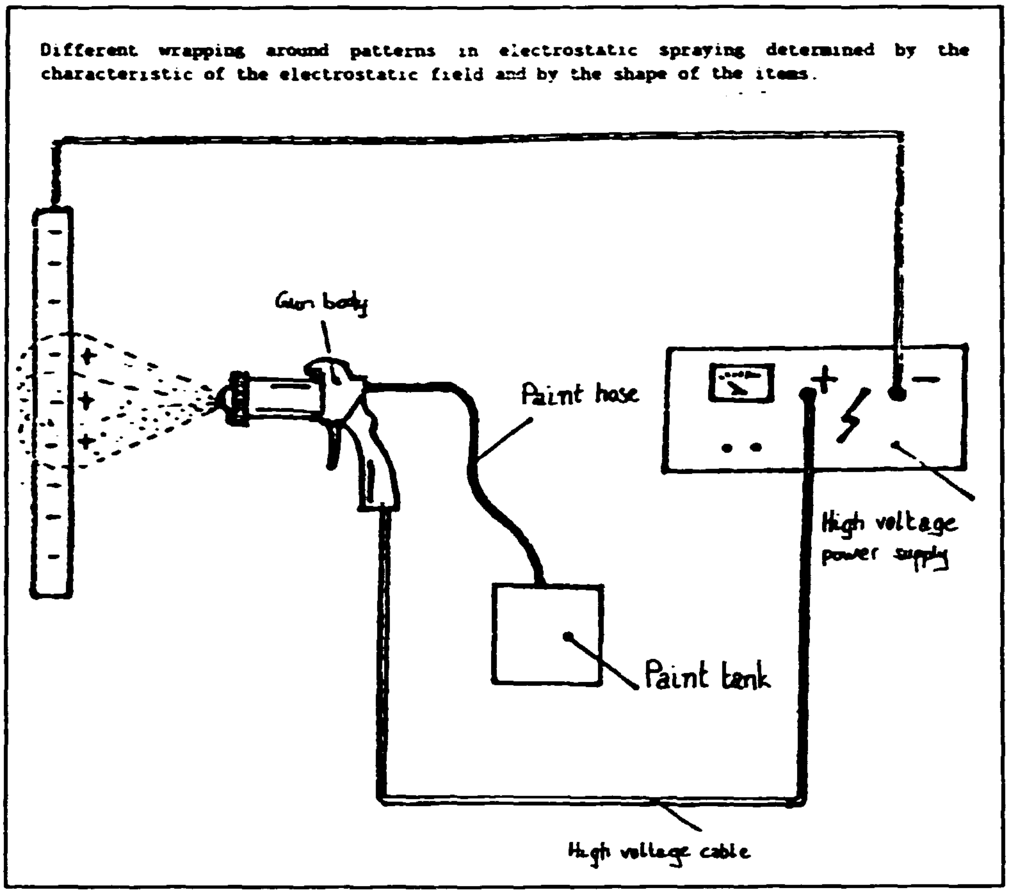


Fig. 50: Electrostatic spraying unit.

This law of physics is made use of in electrostatic spraying as a means of carrying the paint particles from the spray gun to the workpiece.

- The spray gun is fitted with h.t. electrodes.
- The workpiece is earthed.

The electrostatic spraying method is mainly used for chairs, turned pieces, window frames and all the wooden items or components having intricate and complex shapes. The airless spraying system at first was giving problems with the electrostatic but recent solutions made the airless spraying system perfectly acceptable. The airless pressure is normally 70-80 bar. In Italy, the products utilized with the electrostatic systems are as follow:

- First coat Polyurethane 80%, Nitrocellulose 18% others 2%.

- Top coat Polyurethane 50%, Acid curing 30%, Nitrocellulose 10% others 10%.

The staining of the wood is creating problems, due to the Faraday cage effect, mainly with dark stain and in the angles of the items. The use of the electrostatic system for chair finishes was successfully introduced in Italy in 1965. Before 1965, spraying chairs was a difficult job requiring highly skilled workmanship and the productivity was of 30 to 40 chairs per hour. The spraying was done in two phases: first the bottom part, then the top part was sprayed after turning over the chair. With the electrostatic spraying the saving in material reached in certain cases 50 percent and the productivity increased from 30 to 40 chairs per hour to 120 to 150, i.e. four times more!

Also a less skilled operator is required. At present, in Italy, the chairs are sprayed exclusively by means of electrostatic units. Recently robots are substituting little by little the direct intervention of workmanship as far as the finishing of chairs is concerned. In Italy, electrostatic units are largely utilized for rattan items because of its relative advantages over all the other systems.

- An electrostatic field of force is generated between the gun and the workpiece.

- The particles of paint atomized by the spray gun are conveyed along the lines of force to the workpiece, to which they adhere, finely distributed over its surface (see fig. 51).

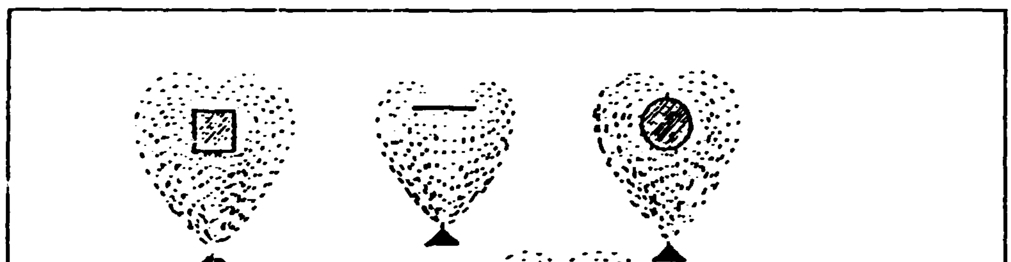


Fig. 51: Some typical patterns of flow of paint particles in electrostatic spraying.

The voltage normally used for an electrostatic unit ranges from 40 K Volt to 100 K Volt. The higher the moisture content of the wood the better is the wrapping around effect of the electrostatic unit; a moisture of 11-12 percent already gives good results. The resistance of paints is another important parameter to take into account and check; if the conductivity is not good there are additives that allow the obtention of the desired value. The atomization of the paint can be obtained using any of the systems previously considered: air, airless, airmix. The flash point of paints should not be less than 21°C to avoid fire risk. There is no risk of electrical discharges, because the gun is provided with a device dropping the voltage to zero when it touches the workpiece.

The advantages of the electrostatic system are as follows:

- The workpiece attracts the paint so that wastage is reduced to a minimum.
- Less pollution of the environment.
- Less maintenance of the spray booths.
- Less maintenance of filter extraction fans, etc.
- Less maintenance of conveyors, trolleys, etc.
- Less skill required from the operator.
- Productivity greatly increased.

VI. PRODUCT SELECTION, EVALUATION AND COST CONSIDERATION OF FINISHES

Staining

Staining of wood is a process used to change the colour of wood through particular coloured substances that penetrate into the wood without forming films on top of the surfaces. Staining is a process as old as the art of producing furniture. Very high skills were developed in staining in the fifteenth and sixteenth centuries by the craftsmen producing inlays. The development of the chemical industry brought on the market a lot of products and their quality is very high. The fact that the paint industry offers products having a high consistency of colour and high quality characteristics under all aspects is very important. National and international standards impose a lot of well defined rules and testing methods and the quality of products is very high. The staining of wood plays a big role also in the fine line industry where this technique reached very good results. Wood is normally stained to change its colour before coating with clear lacquer.

Wood can be stained for different reasons. First of all it is very difficult to find wood of the same colour all over its surface, there are spots than can be lighter or darker, the colour can vary also between pieces of wood from the same species depending on the age of the tree, its provenance, the speed of growth, the characteristics of the soil etc. However, the aesthetic requirements of a piece of furniture allow only slight changes in colour so, to match different coloured spots, it is important to use stains. Another reason for staining can be that dark woods are highly in demand and cost a lot, so sometimes the furniture maker tends to utilize cheap lighter coloured wood, costing less and having almost the same structure and by staining it, he is able to combine different species of wood to reduce the cost of furniture. For this reason, whitish tropical species are in high demand in Western European countries.

Stains are normally composed of dyes dissolved in water or solvents. The function of solvents and water is to bring the stain into the wood structure of the surface to be treated. The solvent-borne stains dry faster than the water borne ones. Problems can arise from the different degree of absorption of wood, so sometimes, it can be difficult to match the colours. Differences in sanding can also lead to differences in colours: the rougher parts will always result in darker colours. Thus sanding also plays its role in obtaining good results in staining.

Dyes

Dyes are coloured substances, powders or liquids, which dissolve in a medium like water or other solvents. Dyes are similar to organic pigments except that they are, to a certain degree, transparent to light.

Fillers

Fillers are materials which do not react with the finishing coats and are used to fill or level porous surfaces. Normally they are used after staining and are coloured to match the colour of the treated surface. Nowadays, fillers are often substituted by better spraying materials.

Sealers

These are diluted clear finishing materials used on bare wood to seal the pores and stiffen the fibres and also to prevent suction or absorbtion of top coats. They are applied after staining and filling to fix the materials and prevent colour bleaching. Nowadays, spraying primers of high quality are available. They are applied to the surfaces to fill and seal the pores and provide a proper surface to the subsequent coats. These primers can be based on Nitrocellulose, Polyurethane or polyesters. The higher their solid content, the faster is the filling of the grains because less coats are required to reach the desired effect.

STRUCTURE OF LACQUER AND PAINT

The lacquer consists of binders, solvents and additives. To give to a clear gloss lacquer a matter appearance, a matting agent is added. Paints are given shades of colours by adding pigments.

Binders

These may be divided according to their chemical composition, or according to how the film is formed when the lacquer dries. The most frequently used binders for materials for surface treatment on wood are alkyd/amine combinations, cellulose, polyurethane and polyester. One product can contain more than one binder to make use of the different advantages of each. Certain binders dry up as the solvent evaporates: the so-called physical drying. The film can be dissolved again in this case by the effect of solvents. Others dry up to an insoluble film by a chemical process, which is started by hardeners that are added to the lacquer before use or already during manufacturing. The binder gives the final characteristics in connection with application and drying and eventually determines the properties of the finished surface.

Solvents

The binder is usually soaked in solvents to give the paint a suitable application quality related to the equipment utilized. According to their chemical structure, they can be divided into: aromatic hydrocarbons, esters, alcohols, etc. One solvent alone cannot dissolve all types of binders. If a paint contains only slightly dissolving or non-dissolving solvents, they are called *thinners* and are added before use to adjust the viscosity of lacquers and paints, they are mixtures of various solvents whose dissolving properties and speed of evaporation influence the drying process of the film. Thinners are normally formulated to give the proper balance between the properties of a solvent with respect to the intended fast or slow working speed. The hardener, which is added to two-component lacquers and paints, also contain solvents with the required properties to get good quality finishes.

Pigments

These are added to the lacquers to make them opaque and coloured. The opacity is related to the reflection or absorbtion of incident light, white pigment reflects light, whereas black pigment absorbs all the incident light. An excessive content of pigment can reduce the properties of the cured film: the elasticity of the film decreases along with its resistance to scratch and wear, glossy paints have a lower content of pigments than matt paints or similar colour and have therefore a lower opacity. Paint and lacquers contain also *fillers* which are fine grained solid compounds. The fillers do not alter or influence the colour of the paint but increase the matting properties. For primers and sealers the correct choice of filler may improve the sanding properties. Matting pigments are added to the clear glossy lacquers to reduce the gloss to the desired level.

Additives

These are substances added to influence certain characteristics of lacquers and to make them suitable to a particular application techniques or drying systems, e.g. U.V. lacquer (lacquer for U.V. drying). Additives can be used in connection with particular conditions of use: cold or hot weather etc. or can be utilized directly by the paint producer to enhance particular characteristics. The use of additives requires proper know-how and it is better to refer in all cases to the specifications of the paint producers.

Tables 8 and 9 give the characteristics of the main products in use.

Table 8: Advantages and disadvantages of the three main categories of finishing products (in very general terms).

Category	Advantages	Disadvantages
Cellulose based products	Fast drying. Comparatively low price. Easy to use. One component. No pot-life problem	Poor wearability. Low resistance to liquids. Not very flexible. Poor filling properties. May turn yellow.
Acid curing products	Hard wearing. Resistant. Flexible. Good filling properties. Comparatively easy to use. Pot-life min 2 days. Medium priced. Dry fast under forced drying.	Strong smell, need good ventilation. Need forced drying for optimum resistance at high humidity. Slow drying at low temperatures.
Polyurethane products	Extremely hard wearing. Resistant. Flexible. Good filling properties.	Slow drying, even at elevated temperatures. Difficult to use. Short pot-life. Expensive.

Table 9: General comparison of various types of furniture finishing materials.

Category	Base	Type	Solids by Weight, incl. hardness (average percent)	Solids by weight at spraying, viscosity (average percent)	Pot-life at 30°C and 80oRH (average)	Average drying time at 25°C	Average drying time at 50°C	Application	Price level
Clear lacquers: A. Nitro-cellulose clear lacquer	Nitro-cellulose softeners	1-component dries trough evaporation of solvents	25	12	unlimited	1 hour	10 minutes	brush, spraying, curtain coater, roller coater.	low
B. Polyurethane clear lacquer, pure	Isocyanate binders	2-component dries through a chemical reaction between two binders	45	40	5 hours	12 hours	3 hours	spraying	high
B1. Polyurethane clear lacquer, modified	Isocyanate binders + nitro-cellulose	2-component dries through a chemical reaction between two binders	30	25	6 hours	6 hours	1 hour	spraying, curtain coater	medium to high
C. Acid curing clear lacquer, pure	Alkyd-amino binders	2-component dries through a chemical reaction between the binders and an acid hardener	50	40	2 days	8 hours	50 minutes	spraying, curtain coater, roller coater	medium
C1. Acid curing clear lacquer, modified	Alkyd-amino binders + NC/PVC	2-component/ precatalyzed dries through a chemical reaction between the binders and an acid hardener	35	25	4 days (6 months shelf-live)	2 hours	15 minutes	spraying, curtain coater, roller coater	medium
ENAMELS D. Nitro-cellulose primer/ enamel	Nitro-cellulose softeners pigments	1-component dries through evaporation of solvents	40	20	unlimited	2 hours	30 minutes	brush spraying, curtain coater, roller coater	low

Category	Base	Type	Solids by Weight, incl. hardness (average percent)	Solids by weight at spraying, viscosity (average percent)	Pot-life at 30°C and 80oRH (average)	Average drying time at 25°C	Average drying time at 50°C	Application	Price level
E. Polyurethane primer/ enamel, pure	Isocyanate binders pigments	2-component dries through a chemical reaction between two binders	60	50	5 hours	12 hours	4 hours	spraying	high
F. Acid curing primer/ enamel, pure	Alkyd amino binders pigments	2-component dries through a chemical reaction between the birders and an acid hardener	70	55	6 hours	8 hours	50 minutes	spraying curtain coater	medium to high
F1. Acid curing primer/ enamel, modified	Alkyd amino binders NC/PVC pigments	2-component dries through a chemical reaction between the binders and an acid hardener	45	32	1-2 days	4 hours	30 minutes	spraying, curtain coater, roller coater	medium
G. Polyester lacquer/ enamel	Polyester binder styrene	3-component dries through a chemical reaction between the binder and cobalt/ peroxide	75-95	75-95	5-30 minutes	12-24 hours	3-5 hours	spraying, curtain coater	high
H. UV lacquer	Polyester binder/ styrene or acrylic binder	1 component dries through UV radiation	75-100	75-100	6 months	10-20 seconds	--	roller coater	high

DIFFERENT FINISHING SOLUTIONS

For the problems of finishing to be properly solved, knowledge is needed of the following fundamental items:

- kind of material of the surfaces,
- kind of finishes required,
- reliable finishing technologies,
- reliable drying/curing facilities,
- kind of equipment available in the finishing shop.

Materials to be finished

- solid wood of different species,
- particle boards faced with veneer,
- particle boards faced with paper,
- plywood,
- fibreboards,
- MDF,
- rattan.

Kind of finishes: There are three aspects to consider:

(a) As far as the structure of wood is concerned, there are four different solutions:
- open grain,
- semi-open grain,
- semi closed grain,
- closed grain.

(b) Gloss:
- matt (less than 10 percent gloss),
- satin (10 to 30 percent gloss),
- semi-gloss (30 to 60 percent gloss),
- full gloss (above 60 percent gloss).

(c) The following distinctions related to the transparency or opacity of the film can be made:
- clear lacquers,
- pigmented lacquers or enamel.

The complete range of finishes is very wide because it is obtained by the combination of the above mentioned parameters so a finish can be: open grained, matt, clear or close grained, full gloss, clear, etc.

COST CONSIDERATIONS IN FINISHING

The market offers numerous solutions for finishes and it is important for the furniture maker to know the exact characteristics of each of them. Finishes are, most of the time, a matter of agreement between the customer and the supplier, but, when there are no specific requirements from the customers, the producers must be able to choose the right finishing solutions taking into account considerations related to the costs, quality, profits, etc. The destination and the final use of the furniture are other important parameters for the determination of the kind of finishing product more suitable in each circumstance; e.g. finishes for kitchen furniture should be more resistant to damage than those on bedroom furniture. The type of furniture products determine also the best finishing technique so that for a chair, electrostatic spraying is today the best system. For panels, the right solution is airmix or airless spraying systems. The size of the batch of the furniture produced is another parameter playing a fundamental role in selecting the proper equipment. The higher the production, the more sophisticated are the finishing techniques. So, in each case, it is important to consider all the parameters and remember that a correct selection of materials and techniques can be a considerable source of benefits in terms of quality and profits. In the following pages, cost aspects of different finishing technologies are considered. As the real situations of finishes and finishing problems vary from producer to producer, it is almost impossible to give the right solution for each case, suggestions on the fundamental parameters to consider in choosing a finishing product or technology are given hereunder.

Analysis of costs of finishing operations

The *overall cost* of surface treatment in finishing is made up of numerous different items. The price of paint, which is often used for comparison of different paints is only a part of the total cost of a surface treatment. Significant costs include: those for premises, equipment and staff in connection with lacquering, handling and control of the individual parts. Table 10 hereunder gives a general idea of the cost breakdown.

Table 10: Indicative cost breakdown for finishing operations in developed countries.

Workmanship	40%
Cost of materials (lacquer, stains, solvents, etc.)	30%
Equipment and premises, space required for application, curing	8%
Operating costs power, water, etc	6%
Environmental purification of water, removal of wastes	6%
Maintenance, insurance, personal protection	10%

The above values were compiled for industrialized countries; for developing countries these percentages should be modified, taking into account that certainly the cost of labour is less and there are no strict requirements and controls for the prevention of pollution. Materials - especially if imported - tend to cost more.

Cost of equipment

Equipment plays a big role. Particular attention should be given to the type of product to be finished and their quantity. The choice of the right equipment can improve productivity, reduce labour costs and reduce wastage of paints and compressed air. Table 11 hereunder illustrates this.

Table 11: Initial costs and operating requirements for various types of equipment used in surface finishing.

Equipment	Indicative cost (US$)	Waste (percent)	Air compressor power required	Type of production
Conventional cup gun	100	60	3.5-5	Low productivity all items
Pressure pot 20 litres	800-1000	60	4.5-6	Medium productivity all items
Airless	1800	40	1-2	Medium productivity all items but mainly panels
Airmix	1800	30	1-3	Medium productivity all items
Electrostatic	5000	20	1-3	Medium-high productivity mainly chairs and small components
Automatic spraying machine for mouldings	15000	little waste	10-15	High output only mouldings
Curtain coater	8000-15000	No waste	5-6	High output flat panels
Roller coater	10000-20000	No waste	5-6	High output flat panels
Roller coater with U.V. curing system	100000	No waste	15-30	High output flat panels

The high productivity of air mix, airless and electrostatic systems, must be borne in mind. In the case of electrostatic, the increase in productivity can be as high as five times that of a conventional spray gun.

Fig. 52 gives an idea about the utilization of paints related to the more common spraying equipment.

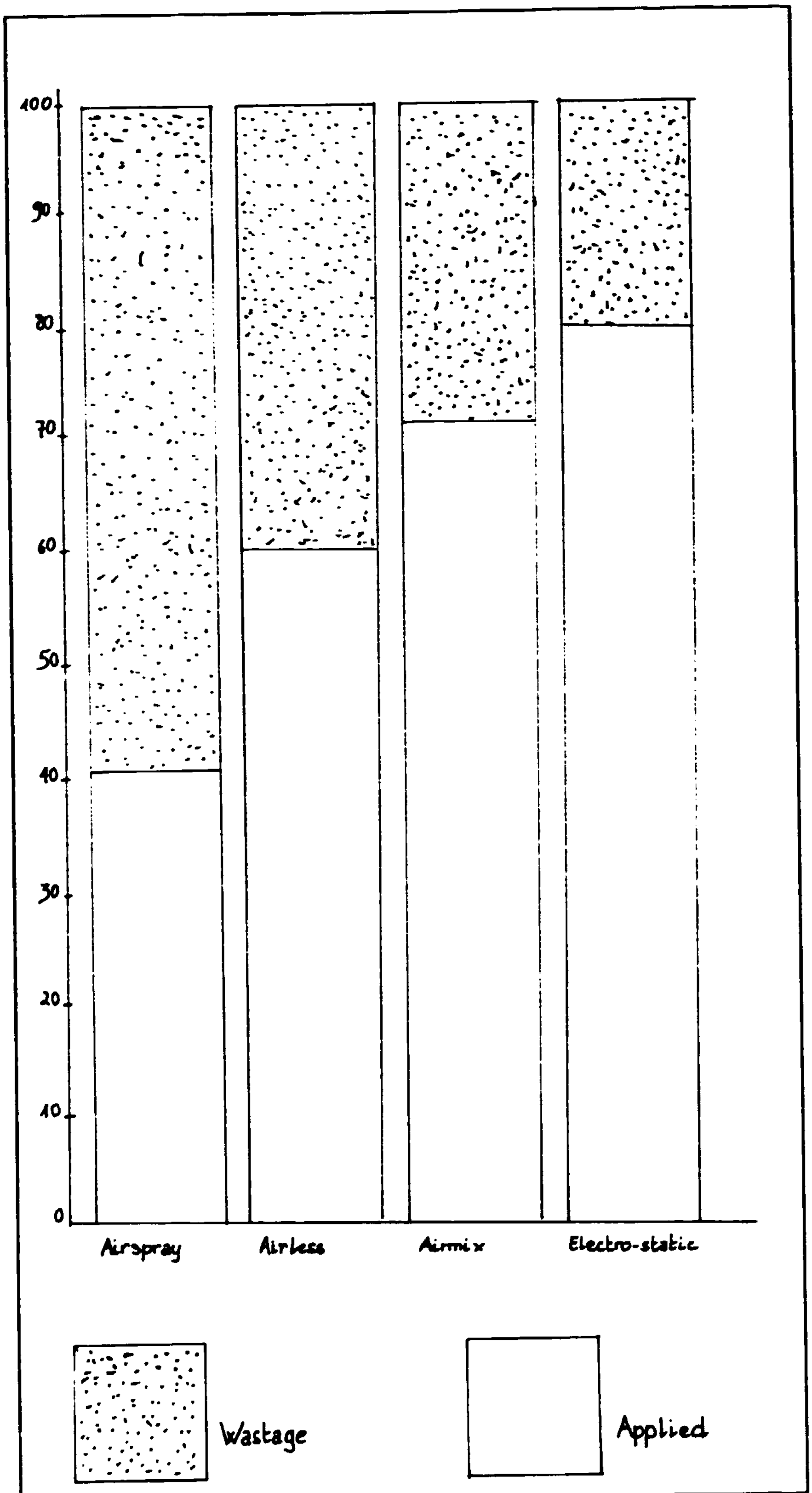


Fig. 52: Comparative paint transfer efficiencies of various spraying systems.

EVALUATION COSTS OF FINISHING PRODUCTS

As mentioned previously, it is not so important to refer to the cost per litre to choose a product. It is better to refer also to other parameters; a very important one is the solid content.

The content of solids by weight indicates the percentage by weight of solids in the product, i.e. how many grammes remain on the base and form the film after the solvents have evaporated. The solid content figure is always an indication of the efficiency of the product. Lacquers also have different efficiency since some of them tend to settle on the surface whereas others sink into the pores.

When comparing prices of different finishing products, it is important to know the price per percentage of solid content. Volumes (litres) should never be compared. The solid content indicates the percentage of the liquid lacquer that will be left on the surface once the solvents have evaporated. The higher the solids the better the filling and less coatings are needed. All solvents evaporate, they do not contribute to the formation of a solid film nor to the quality of the finished surfaces.

THE CORRECT USE OF SPRAY GUNS

A number of basic rules have to be followed to obtain the very best results with a spray gun.

Trigger operation

The operation of the spray gun is controlled by the trigger, and the operator must squeeze the trigger at the appropriate moment each time he begins a new pass. The further the trigger is depressed, the greater is the flow of paint to the nozzle. To avoid an excess of paint building up at each end of the pass, the movement should begin before the gun is in line with the workpiece, the trigger being actuated just after the beginning of the movement and released immediately prior to the finish of the pass. Triggering is the heart of successful spraying, the key to good results is to ensure that the edge of the workpiece at which the pass starts is properly covered without, at the same time, wasting a significant quantity of material by spraying outside (before the start and after the end) the edges of the workpiece.

Spraying a large flat surface such as a table top requires a succession of alternating left to right and right to left passes. The trigger must be depressed at the beginning of each pass, and every pass must cover the lower half of the area covered by the previous pass so that the material is applied evenly and without visible joints. When spraying flat surfaces it is advisable, if possible, to dispose the work piece in a horizontal position, but for drying, the vertical position gives faster results. In the following figures (53 to 67), simple drawings show how to handle a spray gun and how to fact different spraying situations.

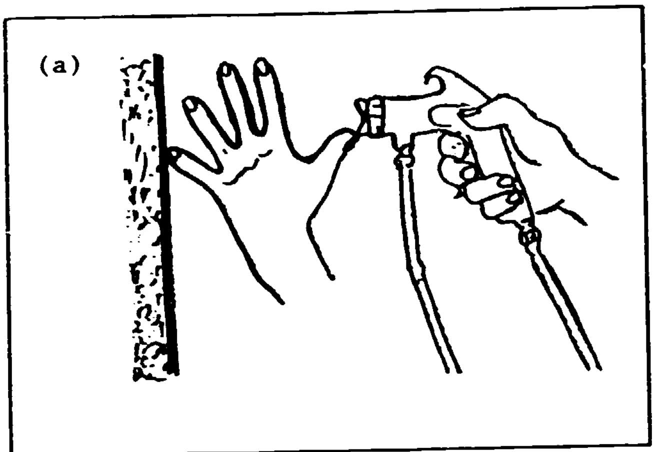


Fig. 53 (a): Distance of gun from object.

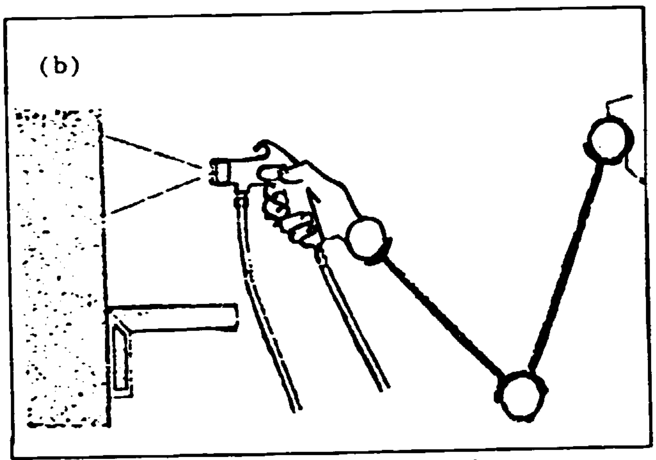


Fig. 53(b): position of gun with respect to shoulder.

The paint is sprayed with long even strokes. The arm must not be held rigidly, but all joint must move and in this matter the gun can be pointed straight, which is essential to achieve an even surface.

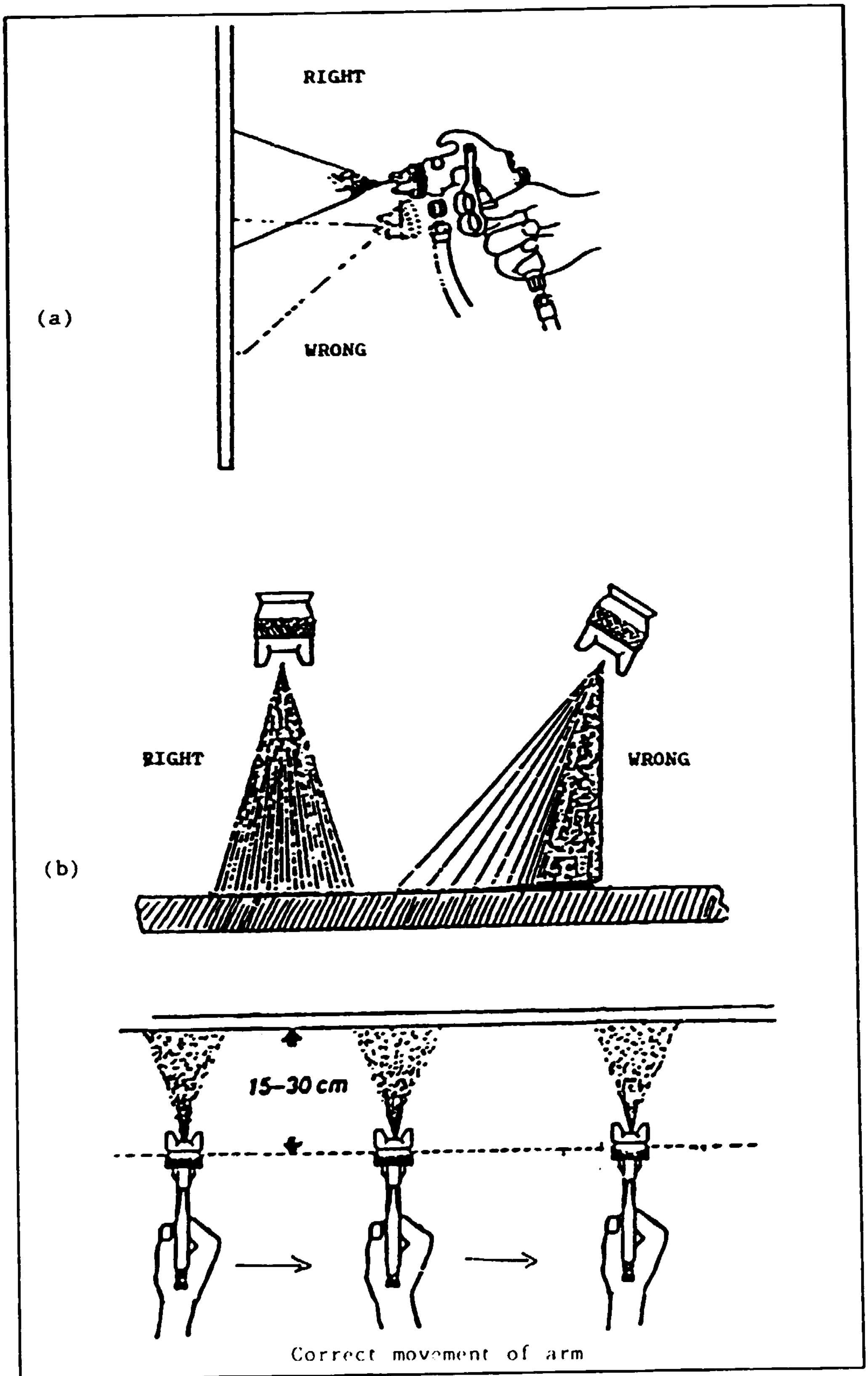


Fig. 54: (a) and (b) correct (and incorrect) inclination of gun.

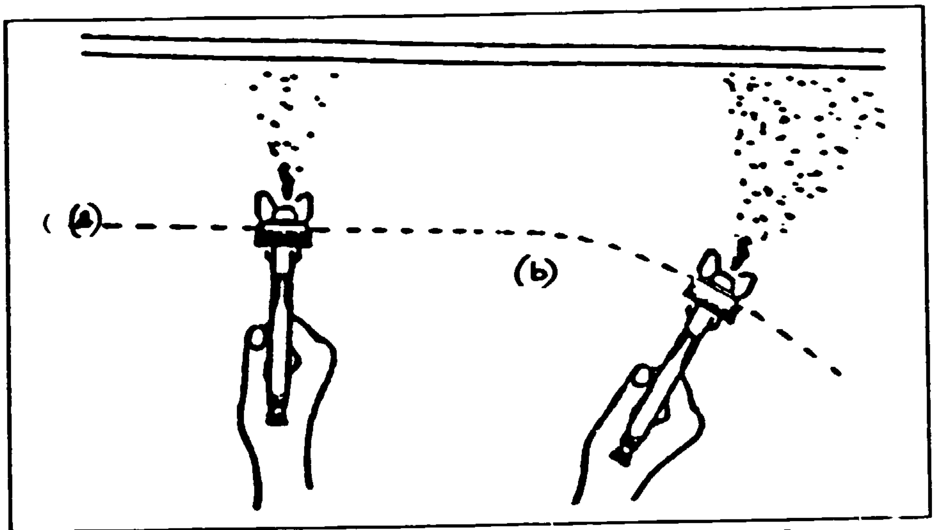


Fig. 55: Correct (a) and incorrect (b) movement of arm w[illegible]en spraying surfaces.

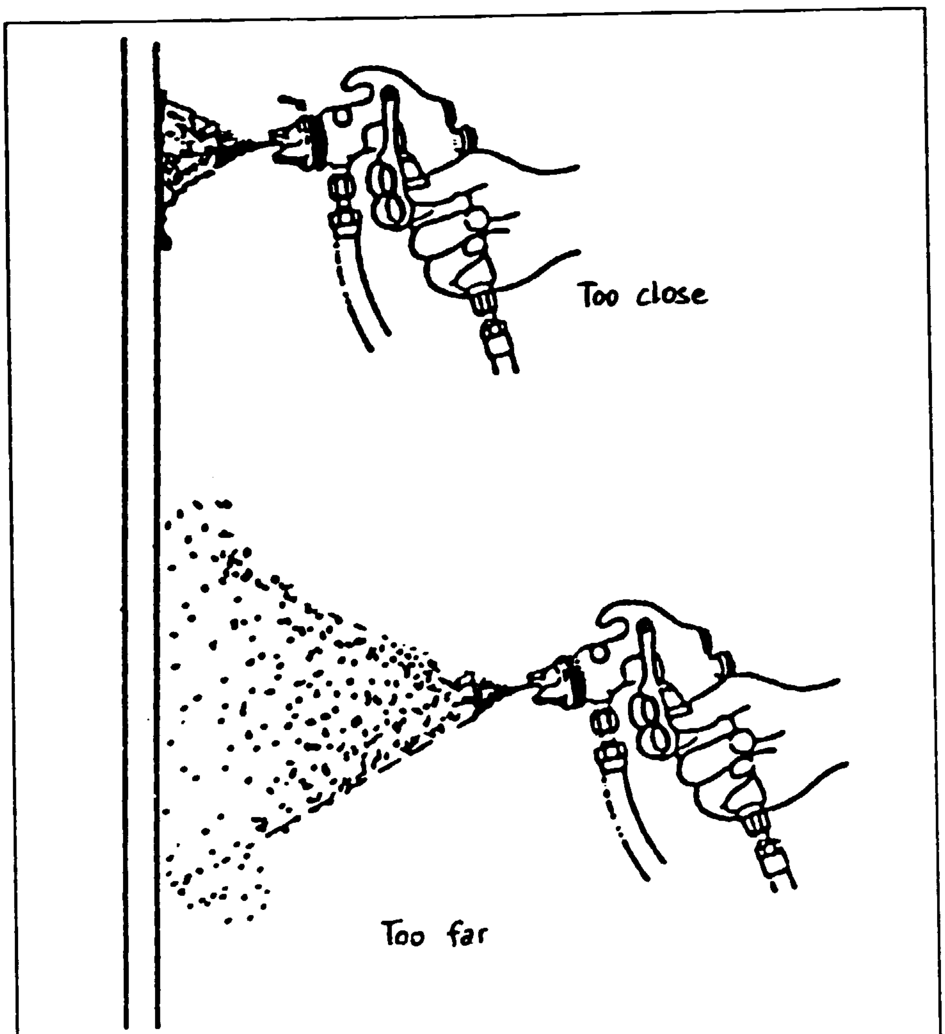
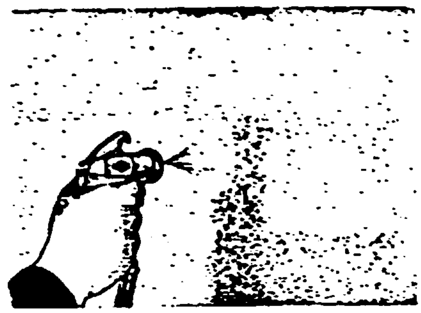
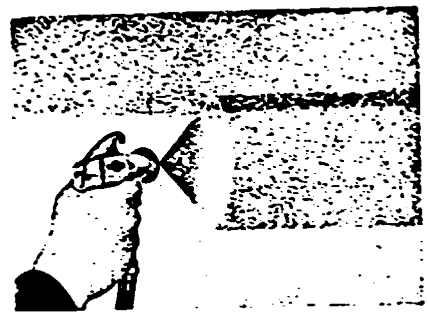


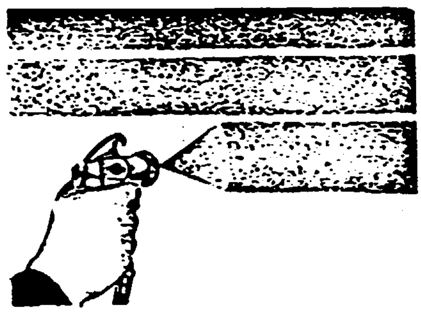
Fig. 56: Effects of incorrect spraying distance on surface.



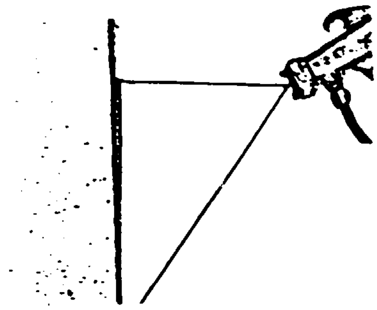
The direction of the movement should not be changed during spraying; otherwise the surface spread valve will change at the turning point.



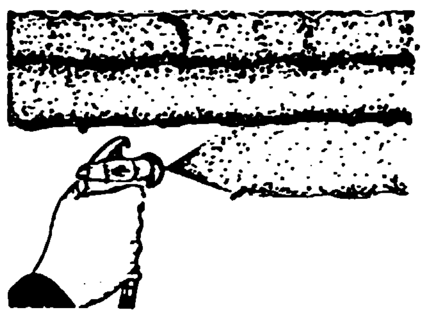
The sprayed coatings must not overlap too much.



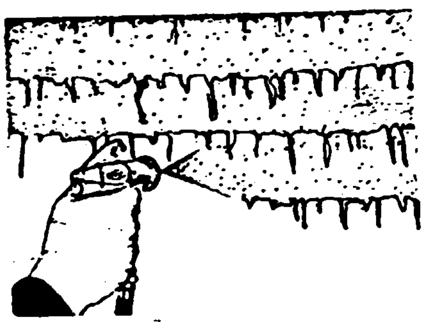
Unless the sprayings cover each other the surface becomes striped.



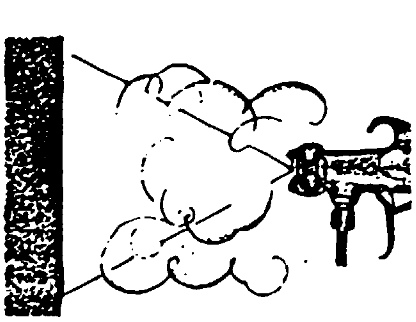
The gun should not be held diagonally or the coatings of paint will have different thicknesses.



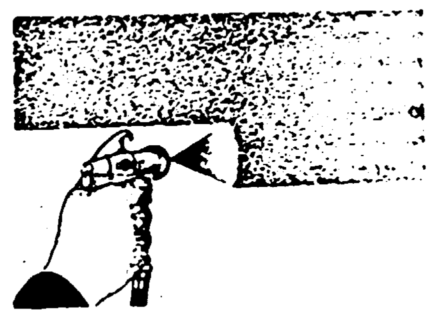
Too much and too thick a paint will settle in folds.



Too much and too thin a paint will run.



The pressure should not be too high or the surface will be like the peel of an orange.



The distance between the surface and the gun must not be too great or the paint will dry on its way.

Fig. 57: Hints for correct spraying.

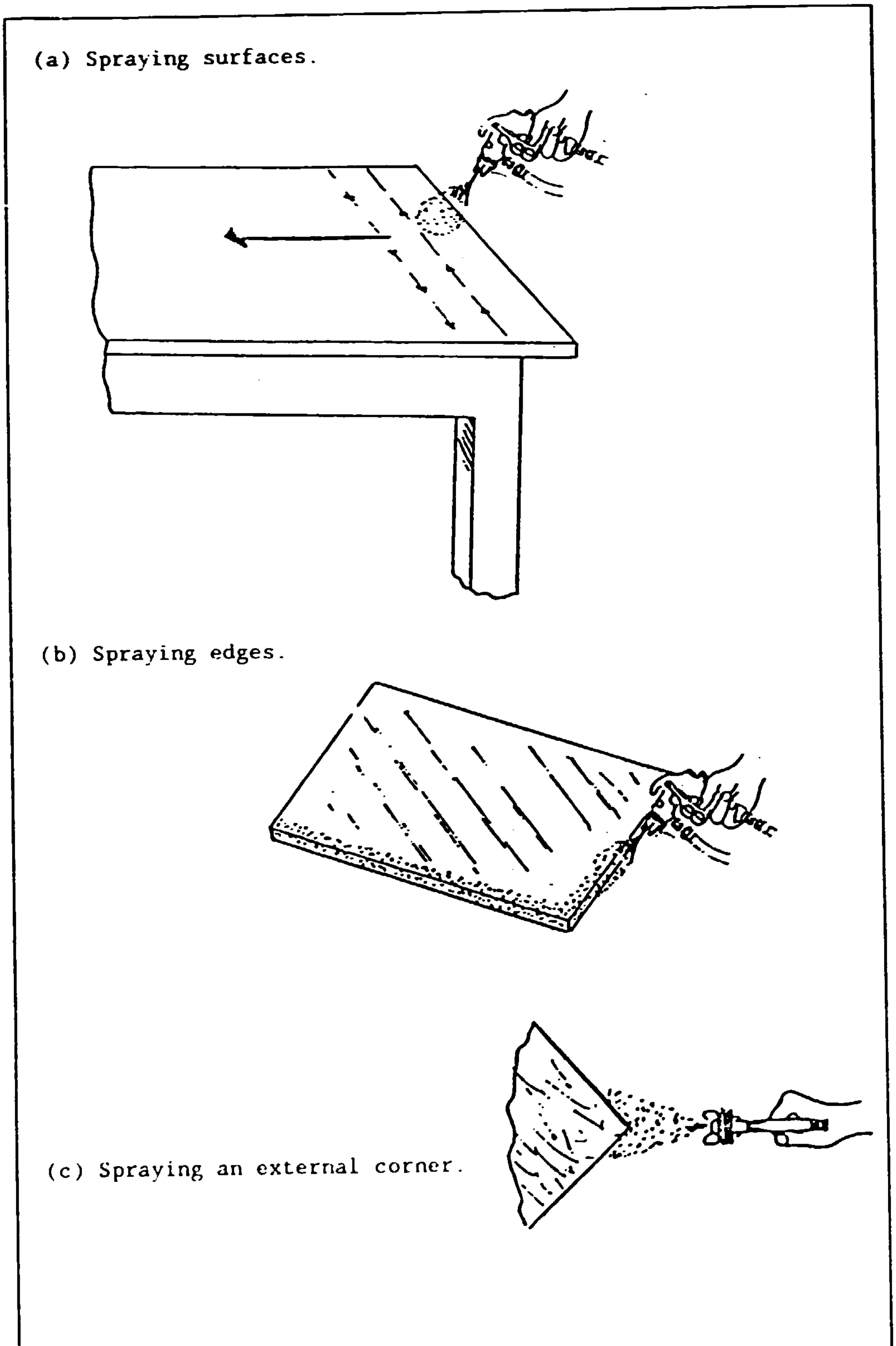


Fig. 58: How to spray a table top.

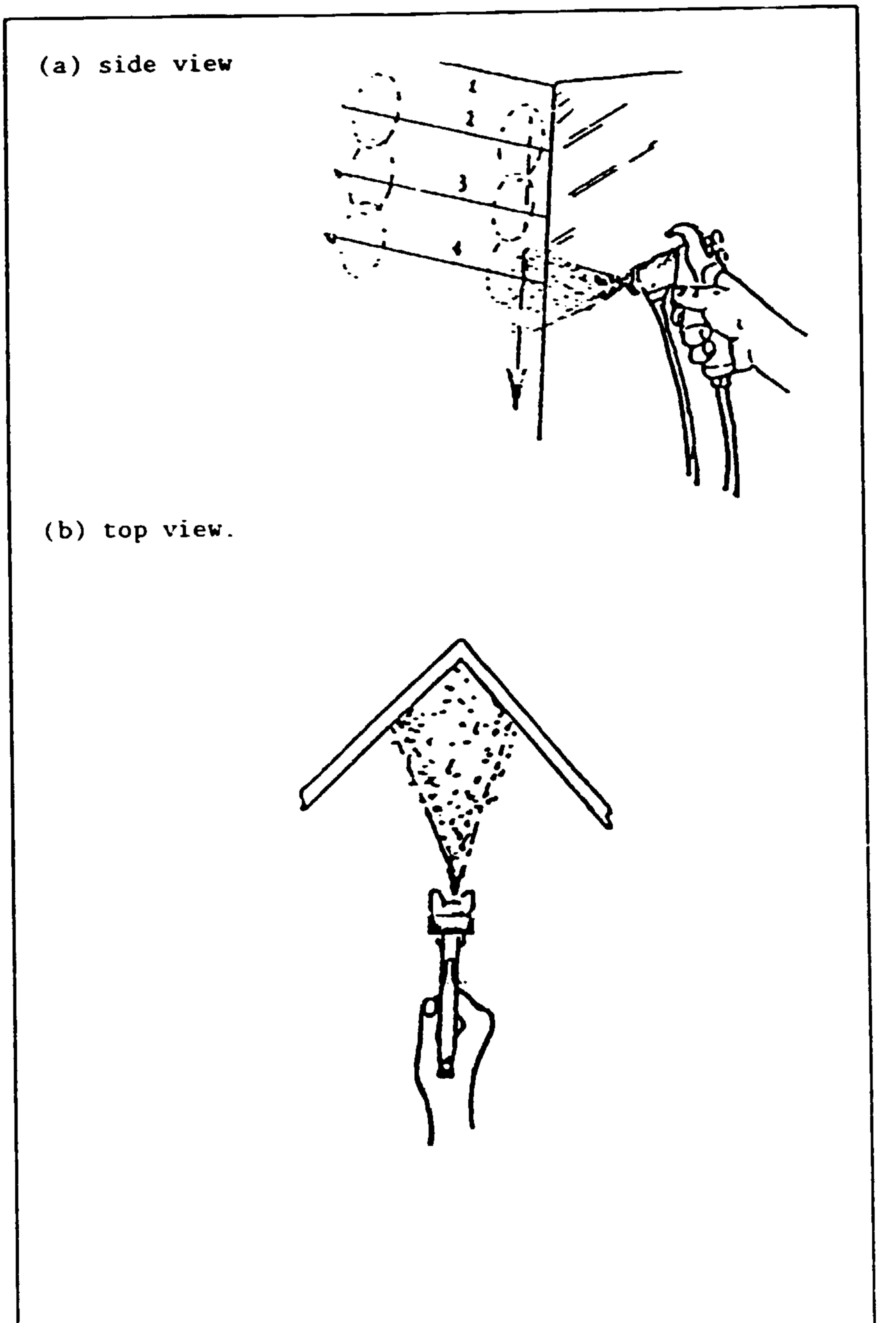


Fig. 59: Spraying an inside corner.

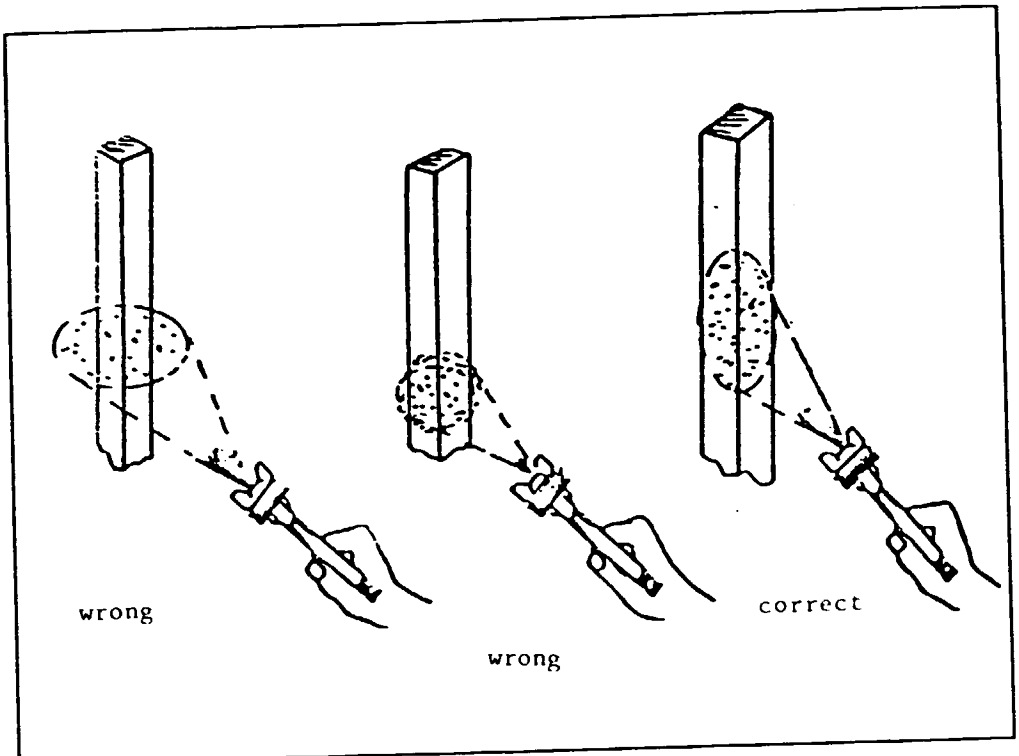


Fig. 60: Spraying slender work.

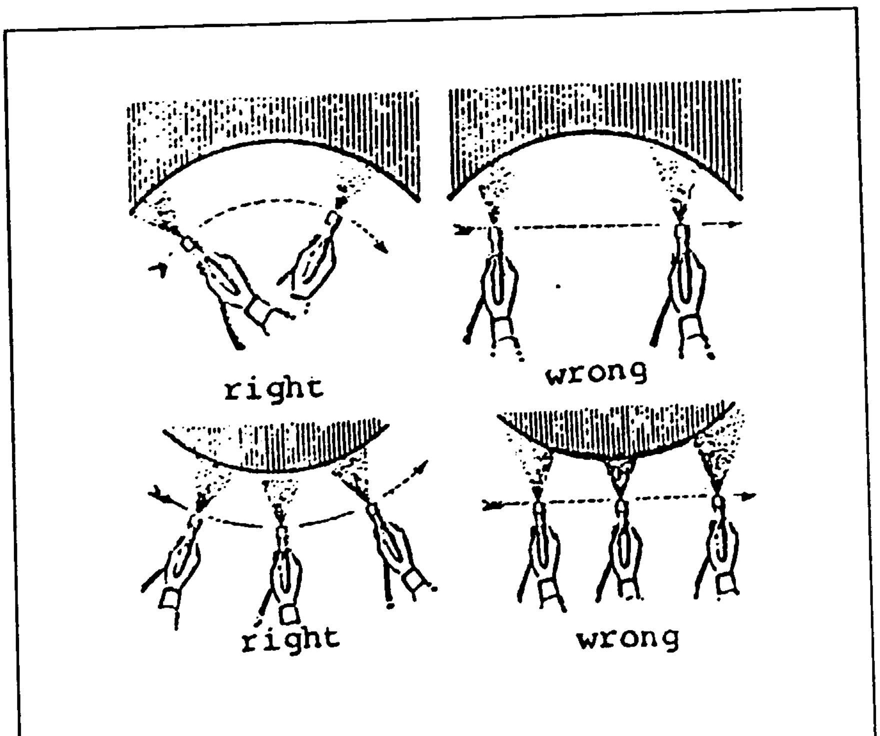


Fig. 61: Spraying curved surfaces.

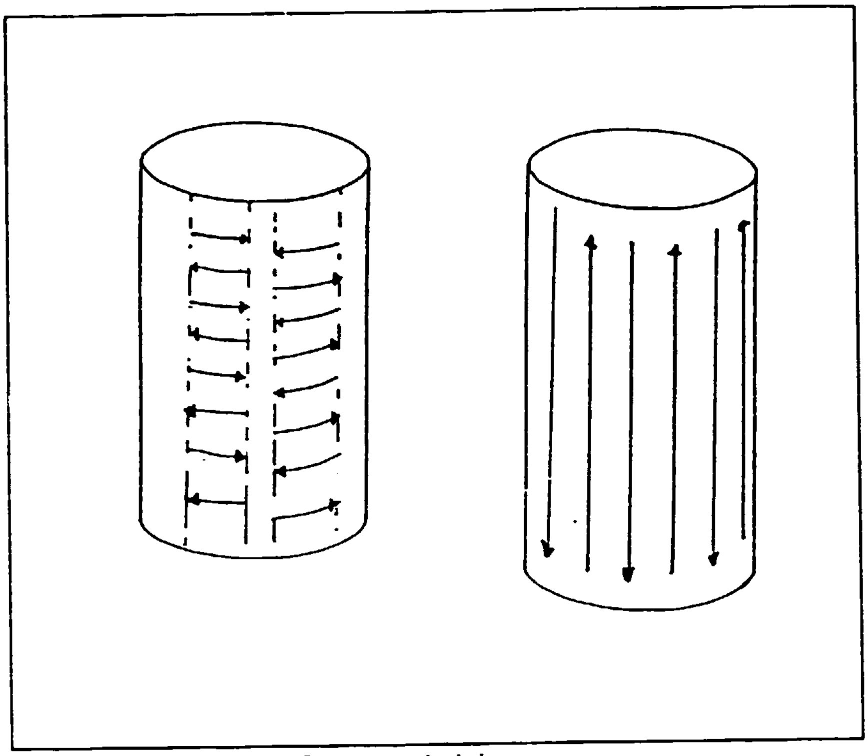


Fig. 62: Spraying of a round job.

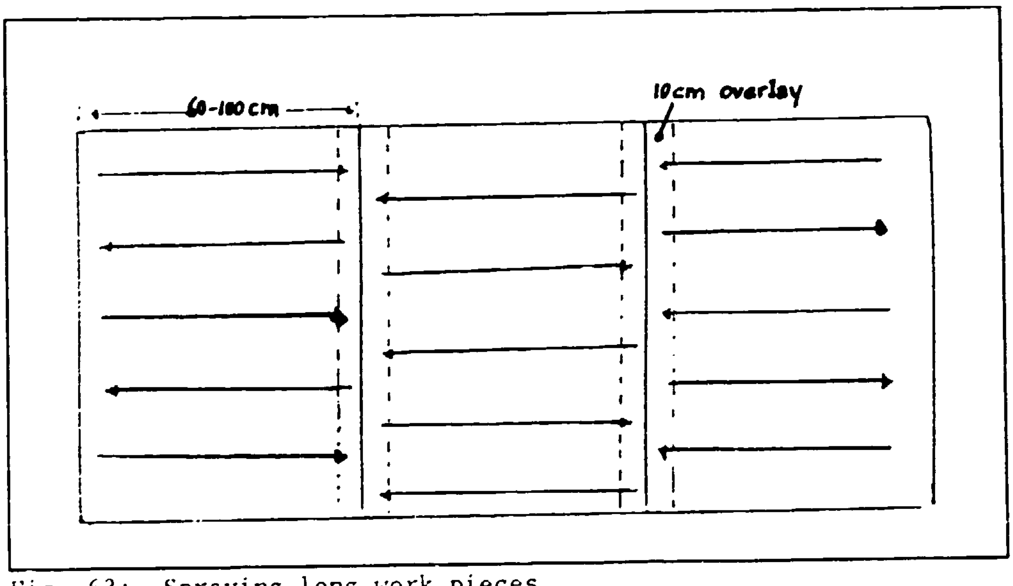


Fig. 63: Spraying long work pieces.

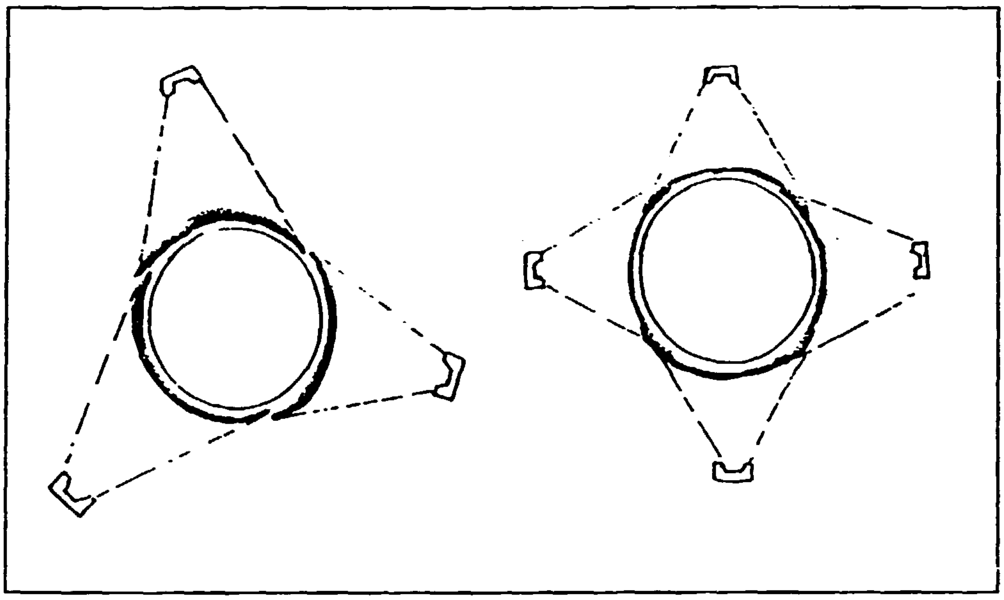


Fig. 64: Spraying small cylindrical parts (at least 3 passes are required for a good covering. 4 passes result in too much overlapping.

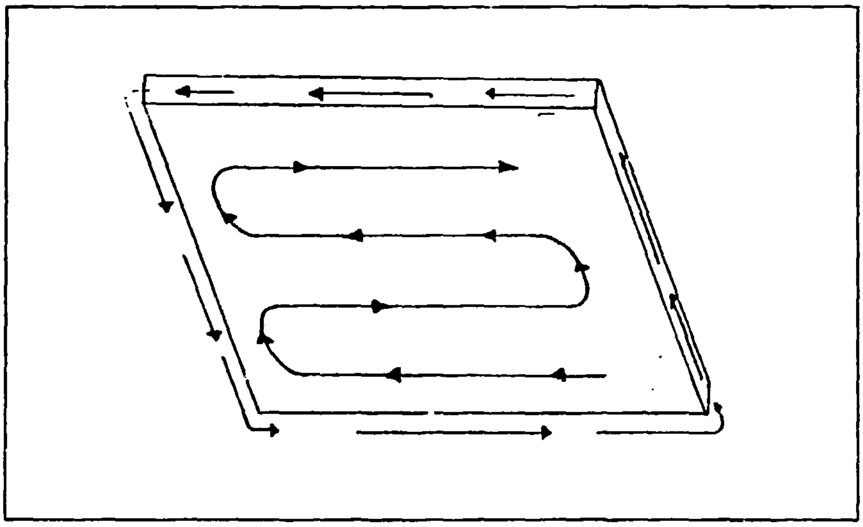


Fig. 65: Continuous spraying.

VIII. DIFFERENT DRYING METHODS FOR PAINTS/FINISHES

The range of possibilities for drying or curing varnishes is very wide. There are technologies that allow to cure surfaces in few seconds as well as products that require hours or days to be cured. There is no necessity for a large factory to be equipped for fast drying processes; there are large factories utilizing products requiring drying times of hours; in a few words, it is not true that the most sophisticated production line is the most profitable. All factories should be constantly aware of new possibilities offered by technological developments and they should study the finishing problems in depth, remembering that there is always a way to save time, material and consequently money.

Today, the range of methods for the reduction of drying times of lacquers and stains on wood is very wide. These possibilities range from a primitive drying room with a fan to electronic discharge curing plants where the lacquered surfaces dry in less than one second. The finishing technology has reached a point where the production capabilities of the biggest furniture factories are too low when compared with the efficiency of the finishing lines available. Consequently, finishing lines are sometimes operated only two days a week, and, in any case, it is very difficult to produce components in sufficient numbers to maintain a modern finishing line in continuous operation.

The choice of a drying method and consequently the layout and purchase of equipment will be influenced by the nature and volume of the production; the customer, market or design requirements of the finished surfaces, the stain and paint types used, methods and equipment for application, the available premises and facilities, official requirements from the government, requirements set by laws or national/international standards, and, last but not least, economic considerations.

The last years have seen the introduction of numerous new technologies as well as considerable improvements in the already existing curing methods. The conditions under which the application, drying or curing of lacquers are undertaken have considerable influence on the final result with respect to the surface appearance (smoothness, gloss etc.) as well as of other physical properties (resistance to moisture, heat, liquids, attack by chemicals, scratches, etc.). The conventional way to dry a lacquer on wood is that it starts from the base of the film to avoid blistering and "boiling-up" of the paint layer. For this reason preheating and a reasonable setting and flash-off times are important to avoid problems. The drying/curing methods play a big role in the final results, and errors may lead to disastrous effects. Numerous parameters should be taken into consideration to achieve the best results.

- Paints and thinners should have a temperature of not less than 20°C before spraying.

- The temperature of the surfaces should not be less than 20°C before spraying.

- The moisture content of wood should not exceed 14 percent. Low moisture contents of 8 to 10 percent result in finishes with a better quality.

- The relative humidity of the air above 75 percent can create problems and it is advisable to maintain the environment's relative humidity below 65 percent.

- The environmental temperature in the curing and spraying area should not be less than 20°C.

- Ammonia vapours disturb the drying and curing of lacquers (this may occur when ammonia is added to the stain).

- If the difference of temperature between the warehouse, where items are kept before lacquering, and the lacquering room is too high, there is a real risk of air bubbles in the film (This will happen when the temperature of the warehouse is less than the temperature of the spraying or finishing room.) Fast drying lacquers will enhance this risk. This blistering is due to the fact that the cold air in the open pores of the surface will not have time to rise whilst the lacquer film is still liquid and it will be trapped by the air-filled blisters. For this reason, paints and wood pieces must always be allowed to acclimatize before finishing and drying.

The conventional types of finishing products require a minimum of ventilation and certain heat from the start of the curing process. If there is an interruption in the curing process because of low temperature or lack of ventilation, when acid-curing paints are used, there is no point in increasing the temperature at a later stage; the quality of finishes will in this case be greatly affected. Furthermore, a second coat of paint may cause the previous layer that has not yet cured to boil up.

There are different curing methods, the following will be considered here:

- air drying,
- forced drying,
- convection drying,
- radiation drying, and
- combined drying.

AIR DRYING

Air drying is the drying method usually utilized in developing countries. This method is still also widely used in highly industrialized countries, both by small producers and big factories. This system does not require sophisticated equipment nor heavy investments and offers the big advantage of flexibility. It is thus possible to finish, at the same time, panels, cabinets or chairs and the only limitation is the availability of space. Apart from the volume of production and space availability considerations, there is still another requirement which is the need to provide a good exchange of air in the drying room as well as in the finishing shop.

The normal way to circulate the air is to capture clean and fresh air from outside. The air must be filtered and the air saturated with fumes of solvents must be extracted from the finishing shop and the curing room. The circulation of air plays a big role in the quality of finishing because it provides the necessary environment for a correct curing of the paint. Experience has shown that sometimes the poor quality of finishes and the low resistance of the film to mechanical stresses is due to the poor ventilation and also (in a cold country) to the low temperature during the curing phase. Dust and impurity in the finishing shop and curing room is another big problem that can adversely affect the quality of finishes. The moments immediately after the paint is applied are very sensitive to dust; air drafts can also disturb the fresh paint film and create a whitish "cloud" and unevenness on the surface colours. Dust settling on freshly painted surfaces is incorporated by the lacquer and confers to the surface a nibbing aspect easier to notice on glossier surfaces. It is easy to detect the presence of particles incorporated on a finished surface simply by touching it. To avoid dust contamination the following aspects are important:

- The production area should be isolated from the finishing shop and the curing room by means of walls and sliding doors.

- A positive pressure should be provided in the drying and spraying rooms by injecting 5 to 10 percent more air than is sucked out.

- The temperature of the air blown in should not be less than 20°C and its relative humidity should be low.

- The fresh air should, if possible, be blown in through filters in to capture all particles in suspension.

- Fresh air fans should be placed close to the ceiling and extraction ducts should be placed low, near or on the floor. This is because solvents and overspray are heavier than air and the tendency is for them to settle near the floor.

- If recently finished items are placed on trolleys or stacked in some way, the minimum distance between the pieces should be 10 cm to allow a sufficiently quick evaporation of solvents or water (in case of stains or water-based products). If the pieces are too near one another, the circulation of air can be inadequate.

Drying times are reduced by increasing the flow of air; e.g. by changing the speed of the air across the work pieces from 0.5 m/sec to 1.0 m/sec, it is possible to halve the drying time. Furthermore, warm air will absorb substantially greater quantities of solvent as well as water vapour and also the chemical reaction in the paint film is also accelerated.

FORCED DRYING

Forced drying systems are usually set up to improve the finishing capacity. They certainly require an investment bigger than that involved in setting-up a conventional air drying curing room. The forced drying process is divided into sectors or zones, such as:

- preheating,
- setting,
- flash-off,
- oven drying,
- cooling.

Preheating

This operation takes place before the paint application. The surface of the panels is heated to 32 to 60°C just before applying the paint. The heating of the surfaces can be by using warm air or infra-red radiations. By this means, the paint penetrates better into the grains of the wood structure and the risk of blisters is reduced.

Setting

In this area, the paint applied must spread out and settle so as to form a smooth film without wrinkles or blisters. The temperature in this area should be of the order of 20 to 40°C and air speed across the pieces of 1 to 2 m/sec; if the temperature and air speed are higher there is the risk that the surface of the film starts to dry, trapping the solvent under the surface of the paint layer and when the item reaches the oven, the solvent evaporates, creating blisters.

Flash off

This is the area where the solvent is supposed to flash off from the surface, before the painted pieces enter the oven. In this area, it is also necessary to avoid differences in temperature between the workpiece and the environment. A good ventilation is fundamental to remove the particles of solvent. Practically, flash-off and setting zones are often treated as one and the setting time, which is a precondition for a successful result, is confused with the flash-off zone. The setting and flash-off times are important: the longer these times are, the better the result (obviously within certain limits). To shorten these times is a risky operation and certainly increases the possibility of blistering.

Oven zone

In this area the varnish is cured by transfer of heat through heated air or by means of infra-red or ultra-violet radiations, or, in the case of the latest technologies, through electronic discharge.

Cooling zone

This area is important when the work pieces must be stacked or packed immediately after drying. To avoid damages, when stacking of items is required, the temperature of the surface should not be more than 35°C. If the temperature is too high, there is the risk of spots and sticking. This does not happen when U.V. or electronic discharge curing systems are used. Normally, cooling is done by circulating air taken from the external environment, but if the weather is too hot, it is preferable to blow the air through cooling units. The cooling zone should be provided with its own conveyor line, if this is not the case the cooling effect will be reduced and the energy consumption will increase.

CONVECTION DRYING

In this case, the heat is transferred to the workpieces by means of hot air; a current of hot air is fed across the workpieces so that the remaining solvent particles are drawn off and the curing process (when chemically curing paints are used) is accelerated. The drying takes place in a closed room or in an oven and a suction system ensures that the air is maintained at a solvent concentration which is low enough to avoid exceeding the prescribed limits. The air is replaced at the far end of the oven where the pieces are at the last drying phase and the concentration of solvent is lowest. This is in order to avoid to feed air containing solvent across the dry workpieces. Normally, the oven is divided into different temperature areas. At the start and at the end of the oven, the temperature is low, about 40 to 50°C, in the central part the temperature is 70 to 80°C, or even more, depending on the type of heat source, the material used, and the product employed. The air can be heated by means of electricity, or by hot water, steam or heated oil which are heated in plants using wood chips, other wood waste, coal, gas or oil as fuel. The air can be circulated as a uniform continuous current or in bursts depending on the needs. There are two types of convection dryers:

(1) Convection at low air speeds (0.5 to 5 m/sec) with temperatures from 30°C to 150°C.

(2) Convection at high a. speeds (15 to 25 m/sec) with temperatures from 45°C to 250°C.

The first type is used for: drying room, closed ovens, tunnel ovens, drying ovens, for plane items, vertical stacking (or elevator) drying ovens. The second type is used for nozzle drying ovens, interval drying ovens, and low-frequency ovens.

Drying rooms

This is the most primitive form for drying stains and paints and it consists of a room provided with insulated walls. The insulation can be obtained with fibreglass or mineral wood covered with asbestos cement or aluminum plates. The circulating air in the room must be free from dust, so the inlet fan is equipped with a dust filter. The inlet air is taken near the ceiling and outlets are placed near or on the floor, as solvents are heavier than air. Replacement of air is a necessary condition but heating of the air is the particular characteristic of this drying system. Such drying rooms usually operate at a temperature of 20 to 45°C and with an air speed of 0.3 to 0.5 m/sec. The advantages of this method are: low initial investment, low maintenance costs, flexibility in production an choice of finishing products. Disadvantages are manual operation, environmental problems, long drying times.

Closed ovens

This are smaller chambers than drying rooms with a strictly limited volume. They are intended for a limited production. The temperature is usually more than 40°C and can reach 60°C, the air speed is 0.5 to 5 m/sec, a setting and flash-off zone is normally required to avoid blisters. Advantages and disadvantages are the same as for a drying room.

Tunnel ovens

This oven should follow more or less the shape of the workpieces or the shape of the trolleys carrying them. It is normally available as plant-made modular units ready for assembling and installation on the spot. Various possibilities exist to fill the oven: floor conveyors, overhead conveyors for chairs or components, or trolleys fixed to the floor (see figs. 66 to 68). It can be set up with different temperature zones, is very flexible and can be adapted to mixed production or changes in production. It is probably the most popular type of oven for drying paints in the furniture industry.

Times and temperatures can be arranged in such a way that it is possible to follow all the exigencies imposed by the type of lacquer of kind of workpieces (e.g. pine containing resins that tend to exude at high temperature calls for lower temperatures). The calculation of the length of setting and flash-off area, the oven zone, and, if required a cooling zone, is based on the determination of drying time of products at the given temperature, the quantity applied, and of course the time needed for filling a trolley or a conveyor line. The air speed ranges from 3 to 5 m/sec and the temperature form 45 to 100°C.

Among its advantages are versatility, small risk of exudation (pine wood), reduced risk of loosening for hot melt glued edges, short cooling time before stacking, low initial cost. Disadvantages are unsatisfactory working environment for the workers filling the line and comparatively long drying time.

The temperature curve for such an oven is given in Fig. 69.

Vertical ovens (see fig. 66).

These are used for very large productions of uniform work pieces, e.g. doors. Their advantages are very good space-saving, they operate at relatively low temperatures 40-80°C, they have a short cooling time, the passage time is 15 to 30 minutes, while the disadvantages are: possible lacquer irregularities only discovered after finishing many workpieces.

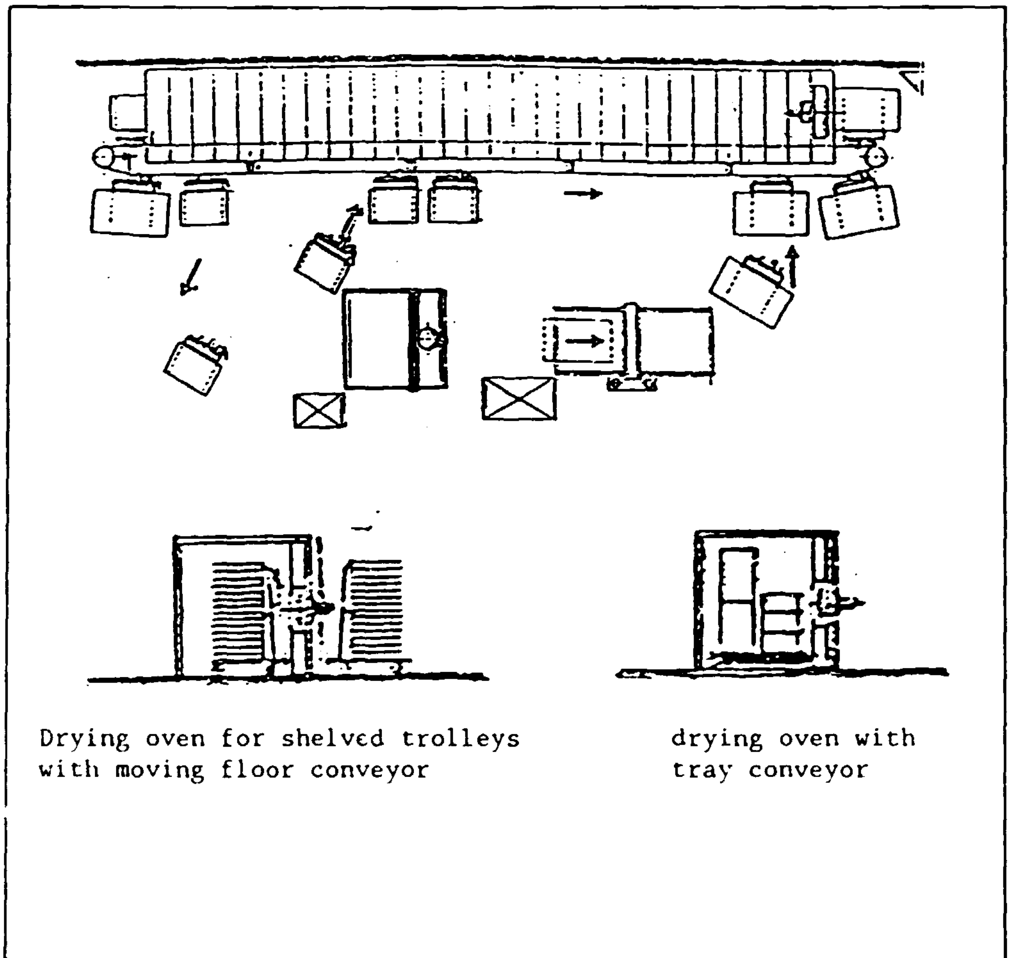


Fig. 66: tunnel oven with moving floor conveyor.

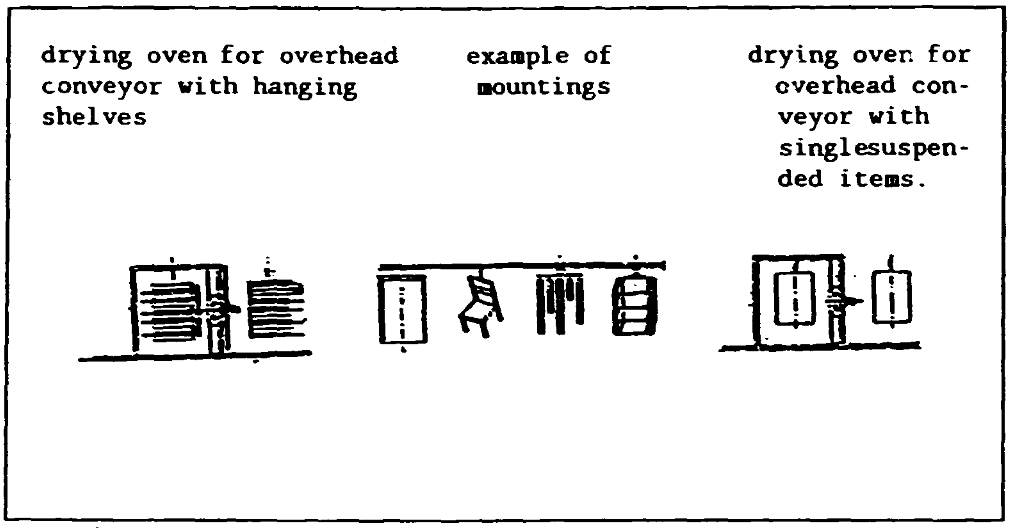


Fig. 67: Tunnel oven with a suspended monorail conveyor and various types of items to be dried.

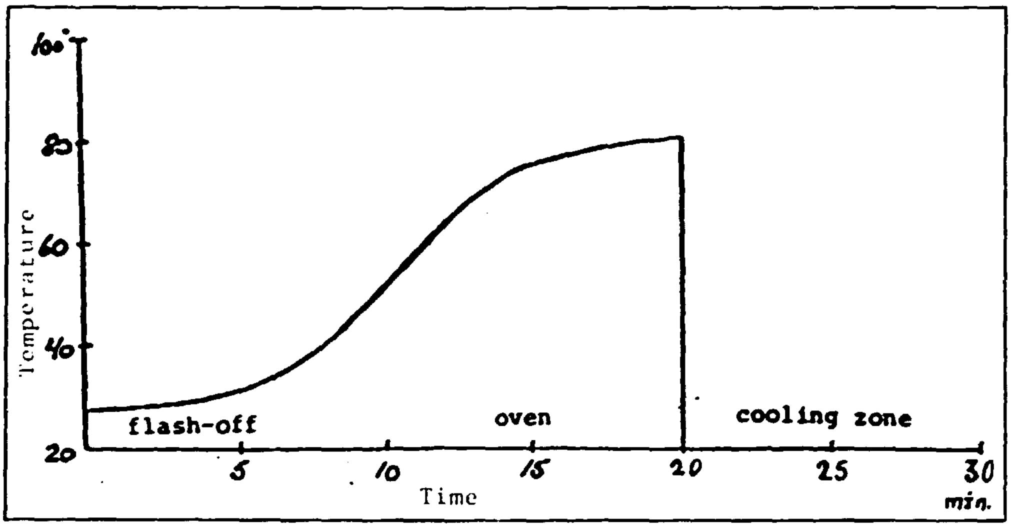


Fig. 68: Normal temperature curve in a tunnel oven for drying of 90-100g/m² of acid-curing lacquer.

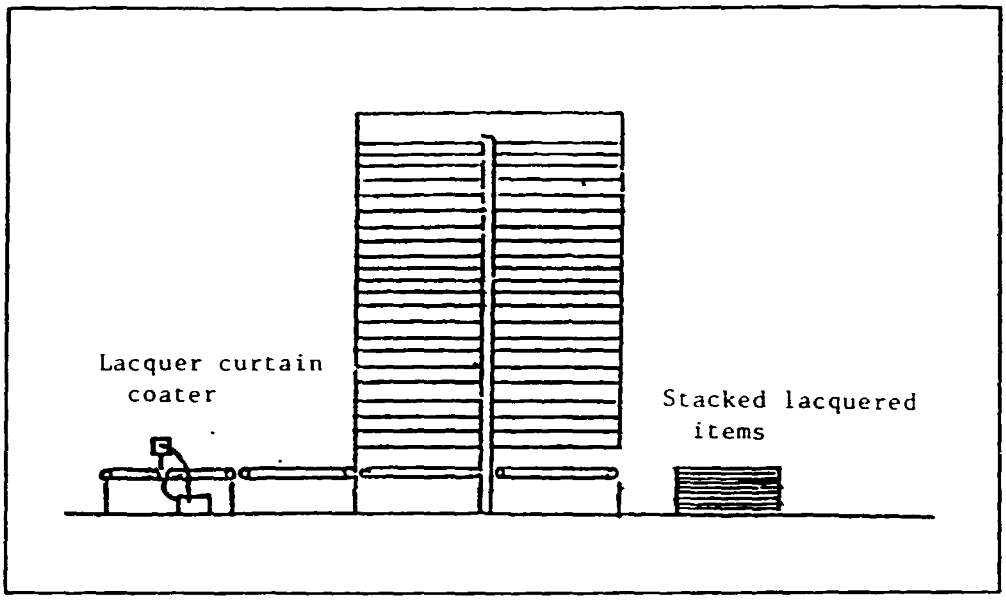


Fig. 69: A vertical oven.

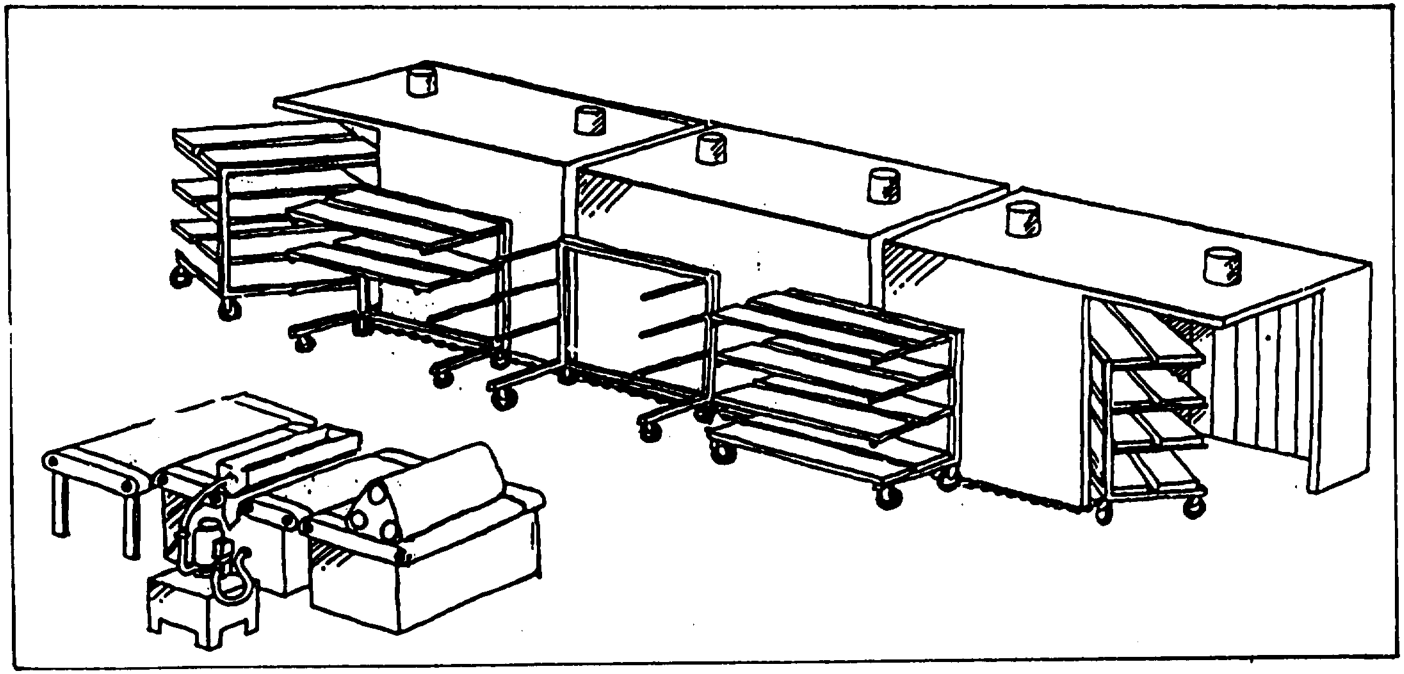


Fig. 70: Tunnel oven with trolleys. (In this case, the finishing is done using a curtain coater.)

IX. MAIN DEFECTS OF VARNISHING PRODUCTS DURING STORAGE: CAUSES AND REMEDIES

A. Viscosity highly increased

Causes: 1. Containers kept open or not properly closed.

Remedies: 1. Solvent must be added till the required viscosity is reached.

B. Solidification of the product's superficial layer

Causes:
1. Container not properly closed.
2. Too long a storage time.
3. Storage temperature too high.

Remedies:
1. The container situation must be checked; before use, the solid film should be skimmed off and the product filtered.
2. The storage time should be reduced and the products stored at a temperature of about 20°C.

C. Gelatinization of product

Causes:
1. Too long a storage time.
2. Too high a storage temperature.
3. If the product is Polyurethane, absorbtion of air moisture is due to improperly closed container.

Remedies: In all cases, the product has to be rejected, its eventual use could lead to serious troubles.

D. Dirty products

Small extraneous particles mixed with the varnish. The defect is easily noticed by pouring some product on a glass surface.

Causes:
1. This defect occurs mainly with matt varnishes and is due to the precipitation of matting particles or to an improper filtration.
2. Formation of rust on the surface of metallic containers.

Remedies: The product must be filtered and rejected if it is too damaged.

E. Sedimentation

Heavy varnish components settle at the bottom of the container.

Causes:
1. Too long a storage time.
2. Too low a viscosity due to the high solvent content; the lower the viscosity, the higher the rate of sedimentation.

Remedies: The product must be stirred carefully before use.

X. DEFECTS DURING VARNISHING OPERATIONS: CAUSES AND REMEDIES

A. Greater varnish absorbtion from varnishing surface

The defect is characterized by a high absorbtion in wood with great absorbtion variations.

Causes:
1. Bad quality of material (particle board or fibreboard).
2. Glues used during veneering operations not suitable.
3. Too smooth a surface obtained with inadequate sanding paper. (This defect affects mainly the staining process.)

Remedies:
1. Depending on the type of surface, a proper number of undercoats should be used.
2. The viscosity of the glue should be increased with appropriate additives.
3. If the surface is too smooth, an appropriate sanding paper should be used to obtain the correct varnishing conditions.

B. Poor grain penetration

Causes:
1. Product with too high a viscosity.
2. Product not suitable to the type of wood being dried.

Remedies:
1. The appropriate quantity of solvent should be added.
2. A product more suitable to the situation or an insulating undercoat should be used.

C. Blisters in the varnish film

Causes:
1. Too thick a product, the film surface dries and traps solvent inside and this creates blisters.
2. Product viscosity not correct, too high or too low.
3. Moisture of wood or of the environment too high (polyurethane components reacts with the air's moisture and carbon anhydride is produced, which creates blisters).
4. Pressure of compressed air too high.
5. Low quality of solvent.

Remedies:
1. Only the correct quantity of product should be used according to the instructions provided by the varnish maker.
2. The product must be used with the right viscosity according to the instructions.
3. The moisture of the wood has to range between 8 and 14 percent and the air's moisture should not exceed 75 percent.
4. The pressure of the compressed air should be reduced.
5. Only good and appropriate solvents should be used, and cheap products avoided.

D. Formation of waves and drops in the varnish film

Causes:
1. Too thick a film.
2. Viscosity of the product too low.
3. Solvent having too slow a rate of evaporation.
4. Spray gun too close to the wood surface.
5. The compressed air pressure is too low.

Remedies:
1. The quantity of product applied per coat should be reduced.
2. The viscosity should be checked.
3. A faster solvent should be used.
4. Spraying with the gun should be done from the proper distance to the surface (15 to 30 cm).
5. The pressure should be augmented tc 4-5 atm (58-73 PSI) and a fast coat, then, after a few seconds, a slower second coat should be applied.

E. Film not uniform

Spots in which the varnish cannot grip properly are present, the varnish tries to avoid them.

Causes: The causes can be numerous and it is difficult to find the right one immediately:
1. Surface not properly cleaned.
2. Presence of fatty substances.
3. Presence on the panel surface or in the air of silicones.
4. Use of gloves treated with silicone during the working operations.
5. Presence of varnish or other substances not compatible with the product used.
6. The air flow inside the spraying room is too high.
7. Small particles of abrasive material from sanding paper.
8. Existence of oil and water in the compressed air network.
9. Use of dirty containers during the spraying operations.

Remedies:
1. The surfaces should be cleaned carefully before painting.
2. Cleaning should be done with solvent.
3. The origin of the silicone substances should be checked and a remedy found.
4. Gloves should be changed.
5. The origin should be checked, found and remedied to.
6. The air flow should be reduced.
7. The surfaces should be cleaned and washed (if possible).
8. Proper maintenance should be provided to the air compressor and to the compressed air network.
9. The origin of the extraneous substances should be found as well as a remedy.

XI. MECHANICAL, OPTIMAL AND CHEMICAL DEFECTS OF DRIED VARNISH FILMS: CAUSES AND REMEDIES

A. Colour of grains turning into grey or silver

The grain has a grey-silver colour along the wood fibre direction due to the impossibility to ensure a deep product penetration into the wood's structure.

Causes:
1. Great presence of urea glue in the grains. This glue prevents a deep product penetration.
2. Compatibility problems between staining and varnishing products.

3. Veneers containing fat substances which prevent the polymerization process of veneers containing particles of silicon or tannin. These difficulties appear in varnishing some types of briar or species like Teak. These problems are mainly related to the use of polyester and sometimes also to the use of polyurethane.
4. Powder in the grain.

Remedies:
1. The glue viscosity should be augmented to prevent its filtering through the veneer stain the glue according to the colour of wood.
2. An appropriate isolation product (normally polyurethane) should be used.
3. One or more coats of appropriate isolation product should be used.
4. The surfaces should be cleaned properly.

B. <u>Insufficient gripping</u>

The defect consists in insufficient adhesion between two different coats or between the varnish film and the wood surfaces.

Causes:
1. Normally, the defect depends on the type of surface material (like melamine paper, plastics, etc.)
2. Wood moisture too high (up to 14 percent). (This defect occurs mainly with the use of polyester varnish.)
3. Staining coat not completely dried.
4. Incompatibility between different products used (a nitrocellulose undercoat with a subsequent U.C. coat).
5. Inadequate sanding operation. The gripping of the products is due to the presence on the wood's surface of micro-grooves from sanding. Problems can arise if the surface is too smooth.
6. Too long a time elapsed between different coats: formation of two different films. These problems mainly occur when using polyester, but sometimes fast drying polyurethane can create the same problem.
7. Excessive product catalysation, consequently high drying velocity, so that it is not possible to have a chemical reaction between different coats. This problem affects mainly P.U. products.

Remedies:
1. The specific process most suitable for each material other than wood should be used.
2. The wood moisture should be reduced.
3. Longer drying times should be used.
4. Only compatible products should be used in the same varnishing cycle.
5. Sanding paper and sanding operations should be checked and the grit number appropriate to the species should be chosen.
6. The correct time between two different coats should be followed strictly. These may not be exceeded. Sanding operations between coats improve mechanical gripping of products.
7. Sanding should be done with sanding paper rougher than usual to obtain a physical gripping of products.

C. Film not dry and sticky surface.

The film does not dry or the drying process takes longer, so that the surface is sticky when touched.

Causes:
1. Environmental temperature too low (cold countries).
2. Too high a concentration of solvent in the air (for varnishes which dry by evaporation of solvents).
3. Too high a thickness of film.
4. Product not properly catalyzed.

Remedies:
1. The ambient temperature should not be less than 18°C. The higher the temperature, the lower the drying time.
2. The air flow and extraction of overspray should be improved.
3. The quantity of product per coat should be reduced.
4. The catalysts should be used as prescribed.

D. Defects due to the sanding process

Fast wear of sanding paper, presence of particles of varnish or scratch on varnished film. Normally, the defects are due to an improper hardening of the film; but there are also some other aspects to take into account like the use of the correct types of sanding papers and their proper use according to the grit numbers.

Causes:
1. Film not hard enough.
2. Sanding paper not properly used.
3. Sanding paper damaged by moisture.

Remedies:
1. Depending on the chemical characteristics of the product used, the catalysts are altered to improve the sanding properties of the film
2. The sanding paper should be used as per the following rules:
   - Polyesters: Silicon carbide (a blue-black colour).
   - Polyurethanes: Open coat sanding paper (light-grey colour). In this sanding paper, there is more space between the grain of grit.
   - Nitro-cellulose: Normal aluminum oxide sanding paper (brown or yellow in colour).

   In choosing the grades of grits the following should be taken into account:
   - For a closed grain finish, grades of grits 100-120 should be used according to the species of wood.
   - For an open grain finish, grades of 150 to 220 should be used according to the species of wood.
   - For sanding P.U. between different coats, grade of grits 280 should be used, and for finishing 320-360.

E. Dried varnish film not smooth and regular enough

This defect is commonly known as "orange-peel" and is due to an imperfect diffusion of the varnish upon the surface.

Causes: 1. Incorrect quality or quantity of solvent used. Usually, the use of a solvent with a fast evaporation (almost all these solvents are cheaper) prevents a good diffusion of the varnish film, it traps air between the surface and the film and prevents a deep penetration of the product in the structure of the grains.

2. Errors due to an improper use of spraying equipment:
- The spray gun is kept too far from the surface and the pressure of the air is too high so hat when the product reaches the surface, its fluidity is not sufficient for good diffusion.
- The nozzle of the spray gun is not appropriate, generally, it is smaller than necessary.
- The use of products not suitable for air gun spraying systems.

Remedies: 1. Only the type of solvent and the quantities suggested by the product maker should be used. The necessity to use appropriate products to improve their diffusion should be taken into account.

2. The product's specifications should be strictly adhered to, and the spraying equipment should be used correctly. "Orange-peel" finish occurs more easily when spraying vertical surfaces. So whenever possible horizontal surface spraying should always be preferred so that it may be "orange-peel" free (if viscosity and application techniques are correct).

F. Spots and stains due to irregular film gloss

This defect is due to an imperfect homogeneity of the film when matt products are used. The surface is not identically matt but spots with different gloss occur. Normally, this defect is evident on regular and big vertical or horizontal surfaces.

Causes: This defect occurs mainly when using a conventional air spraying system.

1. The air gun is held too far from the surface.
2. The product is sprayed in an irregular way so that the thickness of the film is not regular. This happens when the operator sprays many times on the same spot.
3. The product is not suitable for air spraying or a solvent having a too fast evaporation is used.

Remedies: 1. and 2. The defect is due to an improper use of the equipment.

3. Only suitable products and solvents should be used. The producer's instructions should be strictly adhered to.

G. Weakness of solid film with poor adhesion properties

Solid film flaking and cracking under mechanical actions of small intensity. The elasticity of film is lower than the elasticity of the surface material and the variation in dimension of the film and of the surface are not of the same magnitude.

Causes: 1. Use of an unsuitable product, e.g. use of hard polyurethane films on surfaces having a high elasticity.

2. The ratio between the two polyurethane components is not correct.
3. The drying temperature (10°-11°C) is too low for polyurethane.

Remedies:

1. Only products having a good elasticity should be used. If not, the appropriate additives should be used to improve this characteristic.
2. The quantities of components recommended by the product specifications must be strictly adhered to.
3. The problem of too low a temperature is restricted only to cold countries.

H. Colour of surfaces turning yellow

This defect comes out after some time and is due to the changing in colour both of the film and of the material of the surface of the wood under the effect of ultra-violet rays.

Causes: Little by little, the light affects the film of varnish and the wooden surface. There are products and species that react more sensitively to the action of light; for example, nitrocellulose and polyurethane products turn yellow faster than polyesters.

1. Turning to yellow of the wooden surface.
2. Turning to yellow due to the varnishing product.
3. Sometimes, the turning to yellow is due to some particular substances like hydrogen peroxide, oxalic acid or ammonia used for bleaching the wood. When the wood is varnished with polyurethane products, the presence of this bleaching substance, even in very small quantities, accelerates the reaction, turning the surface colour to yellow-orange.

Remedies:

1. In order to eliminate or reduce this defect due to the action of U.V. rays on wooden products, it is necessary to add to the varnish (normally N.C. or P.U.)(a substance able to absorb U.V. radiations, in effect acting like a light filter.
2. Products have been studied to reduce this defect. Mainly for P.U., it is possible to find retardants that reduce or eliminate the action of light on varnish film. Not all the P.U. products are compatible with these retardants. To solve this problem, one should consult with the technical laboratories of varnish products.
3. When the wood is bleached, it is necessary to wash it carefully with water. It is only after a perfect drying (a minimum of 24 hours) that the products can be sprayed.

I. Small craters in the varnish film

This defect manifests itself in the form of small holes appearing like numerous small craters in the film. Small particles of air trapped below the film are the cause of this defect. This defect becomes evident after the drying process.

Causes:

1. Too fast drying of the products due to the high temperature of the environment as well as to the high presence of solvent particles in the atmosphere.

2. Viscosity too high. The air trapped by the varnish film cannot come out because of the resistance of a too viscous product.
3. Too high a quantity of product per coat. The excess thickness of the film prevents the air trapped inside to come out.
4. Use of solvents having too high a velocity of evaporation. Their fast evaporation increases the viscosity of the product so that the air is trapped inside.
5. Use of cheap low quality solvents.

Remedies:
1. The temperature inside the drying areas should be reduced and the ventilation improved.
2. More solvent should be used to reduce the viscosity of the product.
3. Less product should be applied per coat.
4. A solvent with a lower evaporation rate should be used to allow the air to come out of the film and avoid too fast a film drying.
5. Only the solvent suggested by the producer of the varnish should be used.

J. Dissolution of undercoat

This defect occurs when the product of the undercoat is dissolved by the next coat. As a result of this, the surface is not regular and the imperfections of the surface are put in evidence.

Causes:
1. The undercoat has not dried properly.
2. When polyurethane is used this defect can be related to the use of too little catalyst.
3. The undercoat was covered with the next coat containing very powerful solvents.
4. The use of non-compatible products (e.g. when a matt N.C. coat is covered with a coat of P.R.).

Remedies:
1. Drying times should be respected.
2. The correct quantity of catalyst should be used according to the product's specifications.
3. The type of product should be changed.
4. Different types of products should not be mixed.

K. Film too rough

This defect is due to the presence of small particles in the film that create an uneven and rough surface. This defect is very easy to notice by touching the surface.

Causes:
1. The surfaces were not cleaned properly before spraying.
2. Particles from sanding operations adhered to the surface.
3. Dust inside the spraying environment.
4. Panels stacked after sanding without cleaning.
5. Presence of extraneous particles in the product.
6. Rust on the internal surfaces of the can containing the varnish.
7. Spraying equipment not properly cleaned.

Remedies:
1. The surfaces should be brushed carefully before spraying.

2. The sanding machine's dust extraction system must be checked. In any case, the surfaces should be cleaned carefully after sanding.
3. The spraying environment must be kept clean. For best results a pressurized spray booth should be used. The spraying sector must be insulated from the rest of the factory, and, if there is no spray booth, the floor must be kept wet by pouring water on it.
4. The panels should be resanded to eliminate all the particles that have adhered firmly to the surface under the effect of the weight of the stacked panels.
5. After adding solvent, the products should be filtered.
6. The can should be changed.
7. The hoses and the spraying equipment should be kept clean and substitute hoses and product containers too when they become too dirty.

L. Bleeding

This occurs when a finishing material tends to dissolve the stain or undercoat under it. The colour from the stain or from the undercoat blends with the top finishing coat and spoils the final result.

Causes:
1. The undercoat or stain contains colouring substances that can be dissolved by the topcoat's solvent creating moulds and spots of different colours.
2. Sometimes, the defect is due to a specific extractive substance from the wood material such as tannins. The end result is as described above.

Remedies:
1. The stain or pigmented undercoat should be combined in such a way as to avoid the use of the same solvent as for the top finishing coat.
2. The appropriate products must be used to isolate the wood from the finishing material.

M. Bleaching or clouding of a transparent film

The transparency of the film is reduced or eliminated by a white "cloud". This defect can manifest itself either immediately or after some time.

Causes:
1. If the defect is noticed just after the application of the finishing material, the reasons could be due to a very high humidity inside the working spaces (the defect appears more often when using N.C. products). The environmental moisture condensation on the surface of the panels is the reason for this defect. The fast evaporation of solvent s creates a drop in temperature on the surface and this facilitates the condensation of moisture.
2. The defect can also appear after a more or less long period. This occurs mainly when P.U. materials are used. The reasons are the following:
   - The second components of the two-component P.U. has deteriorated.
   - Too high a moisture content in the product.
   - Presence of incompatible substances.

- Too thick a film, so that the solvent is trapped inside.

3. If the defect occurs after a long time, the cause is due to some incompatible substances from the wood or from the glues employed that react little by little and affect and spoil the finish.

Remedies:

1. The relative air humidity of the spraying environment should be lowered and solvents having a lower evaporation velocity should be used.
2. The products must be changed.
3. The item should be sanded to eliminate all the old varnish film and sprayed again.

M. Cracking

If the varnish film cracks, it results in numerous splitting and flakings. This defect is due to the different degree of elasticity between the wood's surface and the finishing film so that the film generates abnormal stresses that, after a certain period of time, result in the cracking of the film.

Causes:

1. The finishing material is too hard because of the excessive quantity of catalyst used with the P.U. products. This defect results in a lot of cracks resembling a cobweb.
2. Too much product is used.
3. Sometimes, the cracking is generated by the wood material splitting. In this case, the film of varnish cracks along the wood cracks. This defect mainly occurs with plywood and the cracks are generally along the grain direction and have the same length as the panel.

Remedies:

1. When this defect occurs, the item should be sanded and the varnishing processes repeated, paying attention to the quantity of catalyst used. In any case, the product's instruction sheet must be referred to.
2. The quantity of product applied per coat should be reduced.
3. The wooden materials should be selected carefully, the thickness of finishing materials reduced and products with a good elasticity must be used.