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Technical Course on Criteria for the
Selection of Woodworking Machines

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TIMBER DRYING 1/

by

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*) Translation from the Italian prepared by the organizer of the Course.

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In the last 30 years, wood industry has considerably grown, and by a systematic study of timber properties and characteristics, very important knowledges, as far as technology is concerned, have appeared.

As far as this growth is concerned, the artificial seasoning of timber has got a vital importance whether for the connected mechanical workings or for the enormous economic implications consequent on air seasoning of big stocks of timber.

The most important problem to be solved was to dry the timber artificially, by means of a cheap and practical system, without the problems and the risks connected to the matter.

It is not possible, however, to deal with the matter of hygrothermic treatments of timber without an introduction describing the characteristics and the structure of the wood.

In fact, what does drying the timber mean?

It is necessary to know what happens to the timber when it is submitted to a drying process.

WOOD : Structural characteristics and substances of which it is composed

Fig. 1 shows the cross-section of a hardwood. It is composed of a group of channels closed to one another and of varying dimensions. These channels are called vessels. They consists of a chain of cylindric cells welded to one another, forming a system of continuous conduction which allows, during the vital cycle of the tree, the passage of limph (water + mineral salts). The vessels are very large during the tree's period of re-awakening in spring, while they get smaller in size during autumn and winter.
Side by side with the vessels exist the fibres, which, scattered among the vessels, are cells having the function of sustaining the tree, and still other types of cells, generally in a radial position, which serve the purpose of acting as

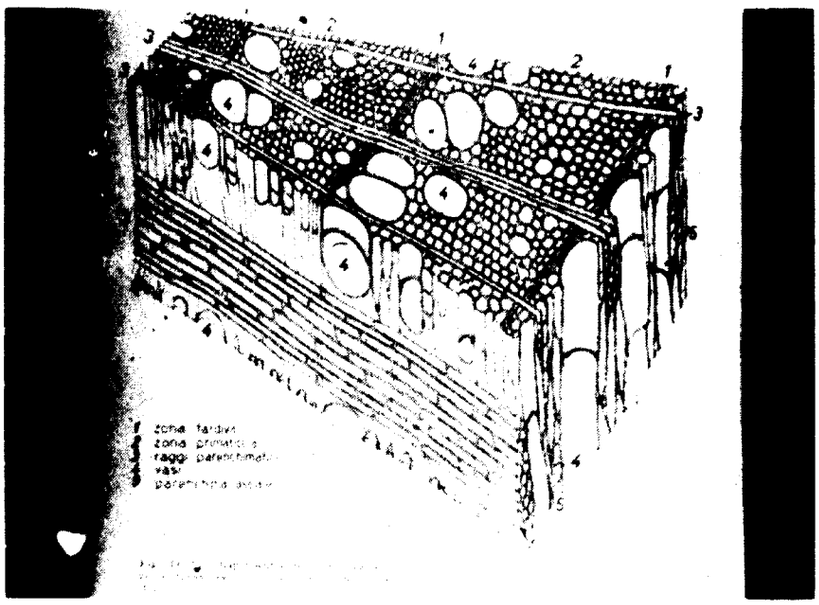


FIG. 1 : Cross-section of a hardwood (Prof. Giordano)

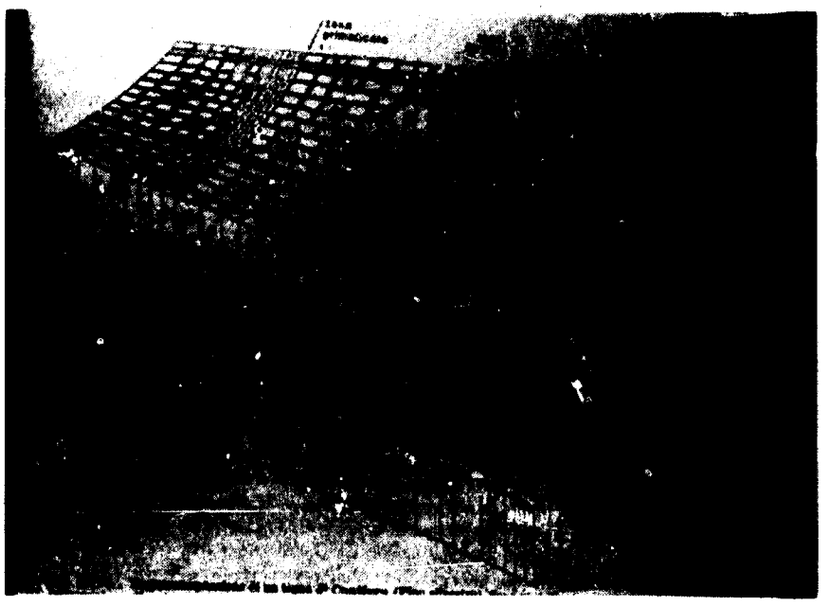


FIG. 2 : Cross-section of a softwood (Prof. Giordano)

reserves for the tree.
That is to say, they contain matter within, which serves as reserve feeding material for the tree during periods of special hardship (for example dought). These cells as a whole are called parenchimatic rays.

Fig. 2 shows diagram of a section of a coniferous log (soft wood).
As can be seen, the vessels which we consider previously, assume a completely different form (they consist of rectangular section).
In this case they are no longer called vessels but tracheides.
In the case of tracheides, too, we find intermixed supporting fibres and parenchimatic rays serving as reserves. However, something different appears: resiniferous channels, big openings, through which the resin flows. (We remark that channels and gumniferous pockets, comparable to resiniferous channels, are present also in hardwoods).
Of what are these cells, which we have seen, made?. Basically, they are made of cellulose and lignine. If we compare the cell to a building in reinforced concrete, cellulose is the reinforced content, and lignine the cement.
It could appear therefore, that timber, apart from the shape, is always the same.

In practice, the situation is different because inside the empty spaces of the cells there are many other substances which change from species to species.

The first and most important substance contained in the wood is water. In wood structure it is shared as follows:

- Free water : contained in the big cellular cavities filled as a container full of water. It doesn't influence the properties of wood, but only its weight.
- Saturation water : which is absorbed by the cavities and the spaces of the cellular walls.

It is also interesting to remark that the juices circulating in the living tree are watery solutions of acids, mineral salts, various other substances, also not dissolved, as terpenes, phenols, tannins, carbohydrates, azote compounds, fats, resins, gums, etc.

All these substances, generally called "extractives", are often the characteristics to distinguish one species from another.

When the tree is cut down, due to a dehydration process the

water content of the wood tends to diminish and, indeed, the water disappears almost completely.

If this process is properly carried out, during the going out of the water evaporating from the timber, this one doesn't suffer any damage, as far as its cellular structure is concerned, and all the above mentioned substances remain in the form of a thin coating over the cells, some salts can crystallize inside the empty spaces in the cells, so that some characteristics of timber remain unalterated, as, for example, colour.
If the drying process is not properly carried out, the timber is doubly damaged: it suffers in fact serious alterations to its structure, and a lot of its extractives may be extracted together with the water. As a consequence, many phisical properties may change.

DRYING PURPOSE

The reasons for which the timber has to be dried are the following:

1. To lessen its weight, so that it can be easily worked and transported. Fresh timber, in fact, contains big quantity of water: from 150 to 300 Kgs/cu.mt. about.
2. To protect it from fungus and from xylophagus insects. The fungus, which cause changes in colour of timber and weaken its structure, usually do not attack the timber if it has less than 20% moisture content.
3. So that shrinkage and the eventual consequent splittings and strains end before the timber is worked.
4. To increase timber's strenght and hardness and to make it fit to mechanical workings (as, for example, turning and smoothing).
5. To make it fit to be glued.
6. To make it fit to finishing processes (preservatives, and varnish).

What is, therefore, to be done in order that during the drying process the important structure just observed can remain intact and the substances contained in the wood can remain inside, whereas the water goes away ?

METHODS OF DRYING

The drying process can be performed by means of two basic methods:

1. Open-air seasoning process
2. Artificial drying process

1 - NATURAL SEASONING PROCESS

Natural seasoning, generally, begins as soon as the tree is cut down but, above all, after the sawing, with the spontaneous evaporation of the free water through the pores and the cellular walls.

To aid natural seasoning, sawn timber is generally placed, duly piled up with lacks, in open yards (see fig. 3).
The piles have always to have weathered covering, to protect them from the rain, the sun and, eventually, to have protections on the heads.
It is opportune that the distance from the ground is not less than 30 cm.

Anyhow, since open-air climatic conditions vary during the seasons, it is not possible to expect to achieve, by means of air seasoning, any moisture content of timber (in european zones it can get 12-20%).

The final moisture content will depend on different factors, such as piles' exposition to winds, stacking method, foggy or wet zone, ground humidity, the season or, quite, the year.

It is evident, at once, that the operator has to keep costly stocks of timber for long periods, since this process of seasoning takes more than one year.
From the financial point of view, this means an immobilization of capital which is difficults to sustain. Moreover, to satisfy the demands of the market, the timber must be prepared in a great range of commercial sizes which, later, may not to be corresponding to specific size requirements.

In any case, the most serious damages are the following:

1. Damages of stacks which, due to inclement weather, are darkening, warping and splitting more and more. (Fig. 4)
2. Attacks of fungus which, besides to cause spots and changes in colour, damage the mechanical strenght of sawn timber,

FIG. 3 : Timber piles in open-air seasoning

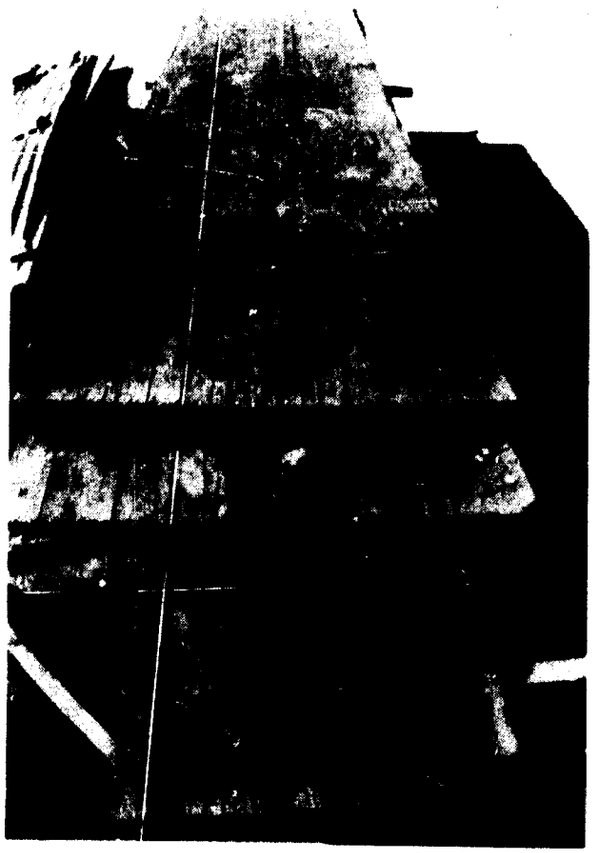


FIG. 4 : Damages due to open-air seasoning
(Experimental yard of NATIONAL WOOD INSTITUTE Italy)

destroying its cellular structure.

3. Attacks of xylophagus insects, responsible for irreparable damages of whole stacks of timber.

ARTIFICIAL SEASONING

There are different methods to artificial dry the timber, but the most used by the most qualified industries from the point of view of technology are:

1. Traditional drying process by steam (classic system)
2. Drying process by condensation

Both these systems use two different types of driers, according to their operation system:

- Chamber driers
- Tunnel driers

The characteristics of chamber driers is the discontinous operation, owing to the fact that the timber is stacked in drying chambers, where it remains for all the drying cycle. These units can dry any species of timber, with any thickness, any initial and final moisture content.

Tunnel driers, on the contrary, are used to dry big quantities of coniferous, having the same thickness and constant initial moisture content.
In any case, they can be used also to dry european hard woods and tropical timbers.
The continuous movement of the piles in the tunnels is performed by means of trucks.

DRYING PROCESS BY STEAM

In this process a mixture of warm air and steam is used.

Warm air (abt.80°C.) transmits to the timber the necessary heat to give rise to the evaporation of water and, at the same time, it becomes saturated of steam. The saturated air is then ejected, and fresh air takes its place.

In fig. 5 we show a drier of small capacity, while in fig. 6 we show a high capacity one.

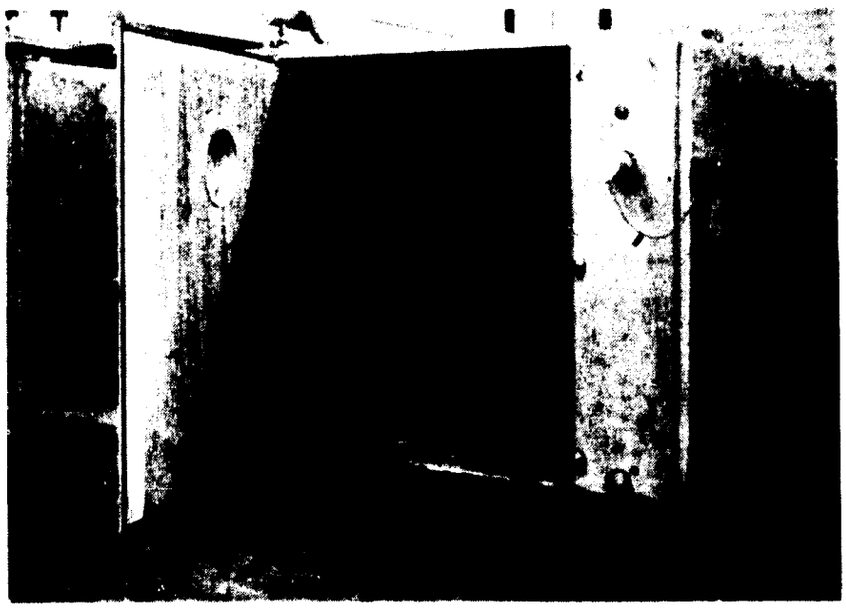


FIG. 5 : Small capacity steam-drier

FIG. 6 : High capacity steam-drier

The principal tools of steam-driers are the following ones:

- Heating device
- Humidification device
- Air circulation and change device
- Electronic device for cycle programming

Heating device

It consists of a boiler, to produce warm air and steam and an ensemble of finned or smooth pipes, where the above mentioned warm air or steam pass through.
The boiler can be stocked by fuel, gas-oil, gas or by wooden shavings.

Humidification device

It consists of one or more pipes having holes in different points, to spray steam in drying chamber, in order to humidify the air.

Air circulation and change device

It consists of an ensemble of fans with electric motors equipped with variator.
Tne air of the drier is changed through stacks and openings from which the air saturated of steam is ejected out of the chamber, and fresh air go in.
The inlet and outlet of air is adjusted by proper air locks.

Electronic device for cycle programming

Only the most sofisticated units are equipped with such a device. It is used to program a fully automatic drying cycle.

The initial conditions of timber to obtain a good drying result are the following: uniformity of species, of thickness and of initial moisture content. The drying program has to be choosen on the ground of the above mentioned data, bearing also in mind the eventual presence of crusts, the content of extractives and other substances such as oils, and faths.

When the above mentioned steam-drier is properly used by qualified and experts engineers, it supplies very good results, above all whether it is equipped with electronic device for cycle programming.

The reasons which has interfered with its capillary diffusion is above all its high investment cost. In fact it consists

of complex and expensive devices such as, for example, the ensemble of boiler and the electronic automatic control device.

Furthermore, the management and maintenance cost cannot be disregarded, above all when the stocking is made by fuel or gas-oil and not by wooden shavings.
The utilization of specialized staff can creates serious problems in emergent countries.

In fig. 7 we shows the example of a drying process not properly carried out: there are collapses caused by the enormous tensions due to a too swift drying of the surface in comparison with the inside.
Often this defect remains inside and is discovered only when boards are cut.

In fig. 8 we show a set of steam-driers placed side-by-side; we can observe smoke and exhaust steam going out from outlet air locks.
Vapours and the condensate drained from a steam drier are generally dirty and polluted: due to high temperature not only the water evaporates from timber, but also all the other components (or extractives) of wood, like acids, fats, oils, starch, tannin, resin, and gummy substances, which are poisonous in part.
Keeping in mind that each cubic meter of timber contains as an average 250 liters of water, anybody can imagine the problems linked to dispersing daily such a great amount of polluting condensate and vapours, especially where anti-pollution regulations have to be observed.

We have also to remember that as the vapours full of extractives are very corrosive, the engineers will be obliged to perform a continous and careful maintenance of drying chambers, whether they are metal or masonry made, to allow a longer duration of the drier.

There is a lot of processes that can happen during the heating to high temperature, especially as far as hardwoods are concerned (european and tropical).
When they are fresh, in fact, they contain many substances water-soluble (sugars, starchs, fats etc.) which, stimulated by high temperature, or are extracted, as already described, or create new substances, having different colour, which modify the normal colour of timber (above all acids and glucosides).
The beech, for example, which is pink, becomes dark red, the oak yellow with blackish spots, the walnut and the mansonia blackish brown, the balsa is darkening with grey-black spots on all thickness.

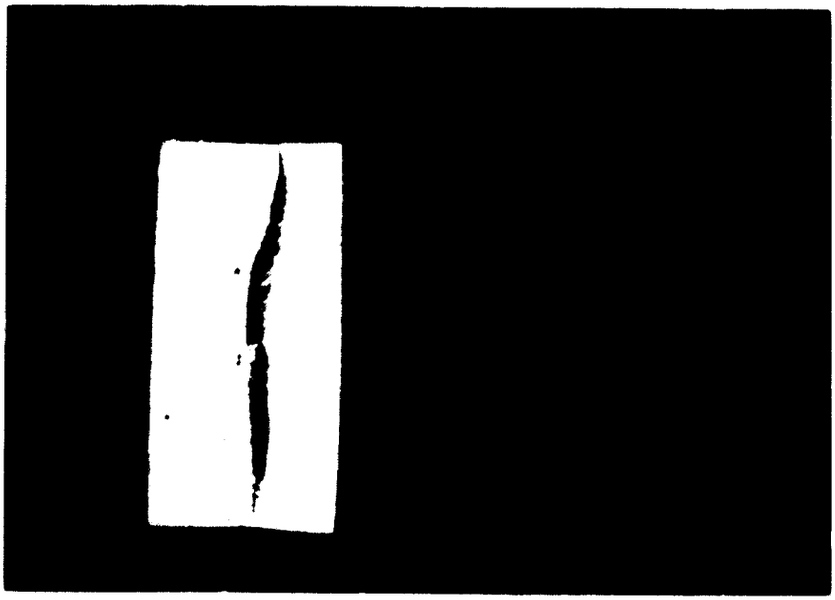


FIG. 7 : Collapses caused by a drying process not properly carried out

FIG. 8 : Steam-driers

At the end, total volumetric shrinkage of timber thermically treated is furtherly increased whether by the loss of the cellulas walls of the above mentioned extractives, or due to a ligh collapse of the cells during the treatment.

THE DRYING BY CONDENSATION

In the last years a modern drying method has developed and diffused all over the world.
This method can be described, without fear to be wrong, as revolutionary.

It is the principle of drying by condensation.

As any new method, it has met on its way many difficulty from technological point of view, and also opposition as far as sale is concerned; it is obvious in fact that many industries, that at present are converting to this method, were scheduled to manufacture steam-driers and suddenly they have had to face an unexpected competition.

We should like to briefly illustrate what is the method to dry the timber by condensation and which are the result obtained.

PRINCIPLE OF OPERATION

In drying by condensation the timber is placed in a hermetic chamber, and is dried by means of a circulation of the same air, constantly recirculated, whose temperature progressively variates between 10° and 40°C., and with a relative humidity variating between 40 and 15%.
This process, made in closed circuit and at the atmospheric pressure, is performed by a refrigerating machine (fig. 9- air circulation scheme).
The air, full of the moisture absorbed from the timber placed in the chamber, pass over the cold surface of the refrigerating machine's evaporator, and its temperature is brought under condensing point, in order to obtain the deposition of the moisture, which is collected in a drain pipe.
The air is then heated, by means of the refrigerating machine's condenser.
The air flow, passing again over the timber to be dried, absorbs again its moisture and the same cycle begins again. (see machine scheme in fig.10).

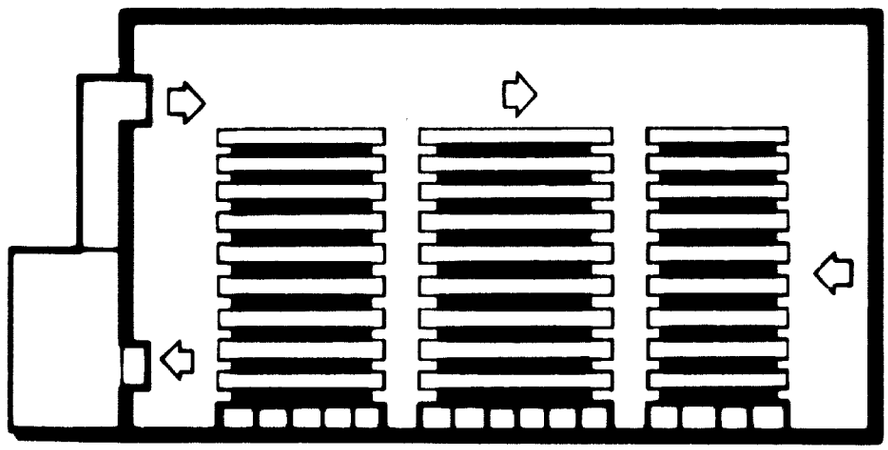
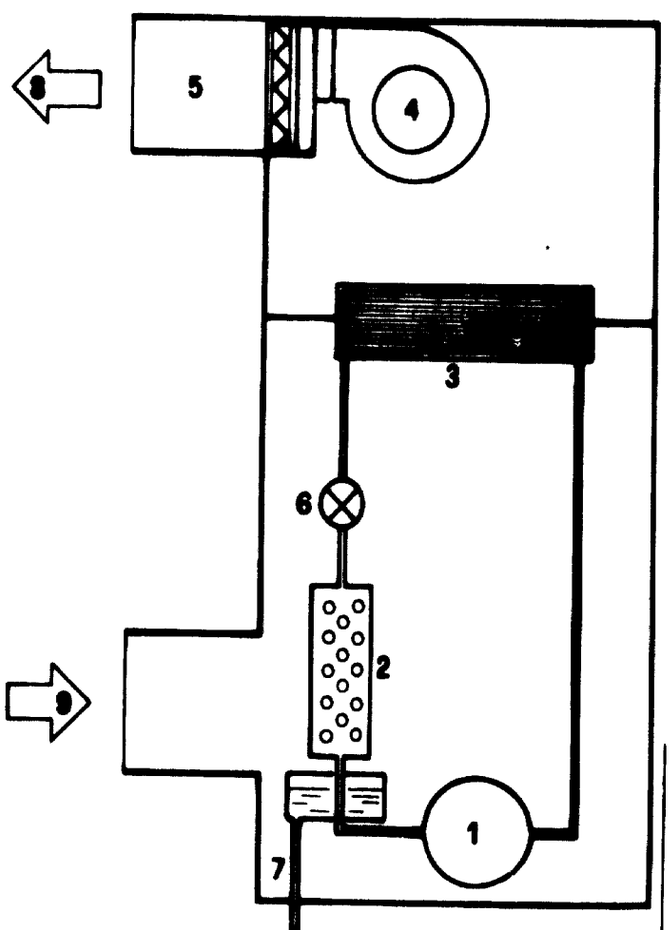


FIG. 9 : Drying by condensation: air circulation scheme



1) Compressor
2) Condensing battery
3) Heating battery
4) Ventilator
5) Supplementary heating
6) Expansion valve
7) Condensed water
8) Dry air
9) Moist air

FIG. 10 : Drying by condensation: Machine scheme

PLANT'S DESCRIPTION

On the whole, the plant consists of:

- a drying chamber
- a refrigerating machine with air recirculating system

Drying chamber

Any available room can be used: a garage, a shed or any other room where a certain insulation has been made, by some adaptation works.
In any case, the most suitable room must have a good insulation, in order to save electric energy for heating, and have waterproof walls, ceiling and floor, to avoid to external moisture to sink.

Drying chamber can be built by three methods:

- Prefabricated drying chamber by insulating modular panels;
- Double masonry drying chamber having insulating air space;
- Single masonry drying chamber, made by foam clay or other equivalent material.

Refrigerating machine

It consists of:

- External sheet structure.
- Complet refrigerating circuit, having gas compressor, a set of heating exchangers and all the accessories necessary for the good running of the circuit.
- A set of heating exchangers consisting of an evaporator, a condenser and an auxiliary condenser, where wet air is cooled, dehydrated, heated again while the auxiliary condenser eliminates the excessive heat, if any.
- A supplementary heating unit, to preheat the timber.
- A ventilation system for air circulation from the timber to the machine and from the machine to the timber.
- A cooling fan.
- An electric control unit.

- A set of air manifolds to throw dry air and to suck wet air.

Fig. 11 shows an installation of a condensation drying unit. It is the one with machine compartment.
Fig. 12 shows the one which is placed inside the drying chamber, together with the timber.

By using a condensation drying unit, thanks to the great simplicity of the method, people totally untrained can obtain very good results. In fact, with the temperatures and humidities used during the process it is virtually impossible to force the drying process over a certain limit, thus avoid ing any possibility to damage the timber.
No day or night overseeing is required; it is enough to control at intervals the timber moisture content.

Whether different species of timber are dried at the same time there is no problem to particularly study the drying program.

Splittings, strains, collapses, discolorations, spots, are fully absent, thanks to a dehydration process absolutely natural: this is why also semifinished products can be dried easily.

In case of loss of electricity, or breakdowns, there is no risk for the timber. In the drying chamber only an increase of hygrometric state will happen. The drying cycle can then go out again, without any damage to the timber.

The low temperature used and the absence of boiler avoid any risk of fire. It often happened that great industries have suffered serious damages caused by fire due to classic driers.

We point out at the end the important ecologic matter of the environment defence, radically solved by condensation system: complete absence of noxious exhausts (drained water is distil led water), absence of smokes and steams impregnated of timber's extractives.
The progress achieved in the last years by condensation drier has shown its undoubted efficaciousness: short drying times, uniformity of final moisture content on all thickness.
It has been shown that the final moisture content achieved in competitive times is 7-8%.
In comparison with steam-driers, it appears that drying times are lightly longer for timber having small thickness till to 30 mm.; for timber having medium thickness the drying times are the same and to dry timber having big thickness drying times are shorter.

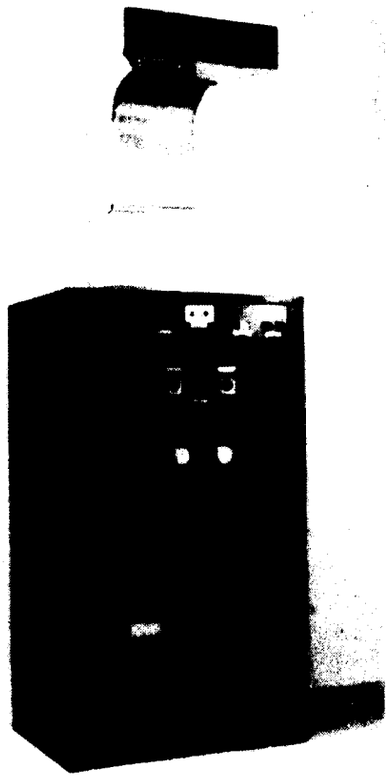


FIG. 11 : Small capacity condensation drying unit

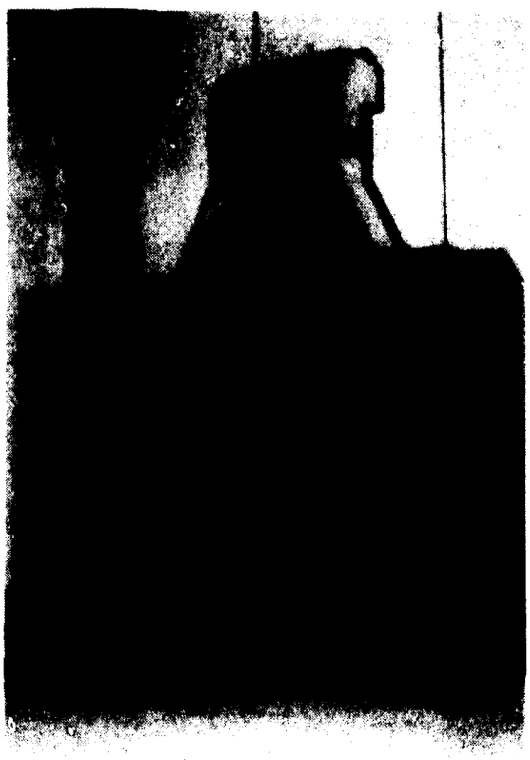


FIG. 12 : High capacity condensation drying unit

As far as investment, management and maintenance costs are concerned, it is easily realizing that the investment cost of a condensation drier is rather low, as it is a question of a simple refrigerating machine, equipped with particular electric control devices, but not so much refined to require complicate manufacture engineering.

As far as management cost is concerned, it is well known that a refrigerating machine, used as a heat pump (which is the specific case of timber drying) is a very high efficiency machine.
Besides, thanks to the closed circuit operation, which does not require inlet of fresh air from the outside of the chamber, the energy consumption consists only of the heat necessary to evaporate the water from timber, which is then partially restored during the condensation; the losses of heat for transmission through the chamber are the lowest, thanks to the low temperature of drying (about 30-35°C.).

The closed circuit operation makes this drying system independent of external climatic conditions, which do not influence the process. This is why the unit can be used in any climate and, besides, the settings to be made by the operator are much reduced, thus proportionally limiting management costs.

As far as maintenance costs are concerned, it can be remarked that a refrigerating machine for air conditioning requires periodic maintenance very simple. Any frigorific engineer can perform an eventual repair.

OTHER ARTIFICIAL DRYING METHODS

We briefly mention other drying methods which, even if they have not got a great diffusion, may have important characteristics and in the future may have an unforeseeable development:

- Liquids method
- Organic solvents vapours method
- Infrared rays method
- High frequency method
- Overheated steam method
- Vacuum method

We fix our attention only on the last two, as they are the only ones which are rather diffused at present.

Drying with overheated steam

Overheated steam is not saturated and therefore it is suitable to produce water's evaporation from the timber. Almost always, the driers are metal built and must be absolutely hermetic. Generally they have small dimensions, till to a 5 cu.mt. capacity.
Drying times are short, but in spite of this, they have not got a large industrial application.

Vacuum driers

By vacuum, water boiling temperature is reducing, this is why it is long since this method is used in medicine, biology and food industry, to dry that materials which can easily deteriorate.
Likewise, the vacuum method has been used to dry timber sensible to high temperatures. It must have, anyhow, a medium permeability.
The problem to be solved was to transmit the heat to the timber, because the vacuum is a very good thermic insulating. This is why heating by convection cannot be used to cause water evaporation.

At present there is an industrial application of an Italian patent (Ing. Pagnozzi) which performs contact heating by means of heating plates placed into an autoclave.
The results obtained are good, whether for moisture uniformity (also for timber having big thickness) or for quality. Drying times also are competitive.
Anyhow, autoclaves capacity is not very high, and this fact has interfered with its diffusion.
Another inconvenience is that the vacuum, besides to cause water evaporation, causes also the evaporation of timber extractives, which remain on the surface of the timber, on the plates or go out with the drained water.

C O N C L U S I O N

Before to conclude, we remember that timber is a very hygroscopic body, and this allows changes of humidity with open air, within the limits of a moisture content between 0% and 30%.
The result is that an equilibrium settles between timber moisture and air humidity.
The timber having a water content more than this equilibrium humidity will dry, while the timber having a water content less than the equilibrium humidity will absorb air steam till to achieve that equilibrium humidity.

What, therefore, will be the final moisture value to be given to the timber during the drying process ?

It is obvious that the hygrostatic state of the air is very variable, therefore it is very difficult to give values which can be actual in any region or country, having different climates.
Anyhow, bearing in mind the table 1 (Prof. Giordano) where there are the equilibrium values of timber moisture, compared with air temperature and relative humidity, it is possible to establish some indicative value, keeping also in mind the final destination of the timber as finished product.
A product destined to outside as, for example, doors or windows, must have a final moisture content much higher than a product, as furniture, destined to a chamber heated by means of radiators.
Table 2 shows some recommended final moisture value for some finished products.

It is also recommended to store the timber artificially seasoned so that it is not submitted to climatic variations.

We have to remember that industries require drying times more and more shorter, anyhow we point out that a not proper reduction of drying times can be prejudicial to timber quality and can cause serious damages.
However, to foresee the duration of a drying cycle is very difficult, due to the quantity and the complexity of the factors influencing its proceeding.
Drying times, therefore, whatever the calculation method may be, have to be considered as an average estimate.
Therefore, drying of timber is a technologic process to be carried out much carefully, much more than any other working or treatment of timber.

TABLE "1" (Prof. Giordano)

Timber equilibrium moisture in relation to air temperature and humidity

Air relative humidity %		Air temperature °C							
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
from	to	Timber equilibrium moisture %							
20	25	5	5	5	5	5	5	5	5
25	30	6	6	6	6	6	6	5	5
30	35	7	7	7	7	7	6	6	6
35	40	8	7	7	7	7	7	7	7
40	45	8	8	8	8	8	8	8	7
45	50	9	9	9	9	9	9	8	8
50	55	10	10	10	10	10	9	9	9
55	60	11	11	11	10	11	10	10	10
60	65	12	12	12	11	11	11	11	11
65	70	13	13	13	12	12	12	12	12
70	75	14	14	14	14	13	13	13	13
75	80	16	16	15	15	15	15	14	14
80	85	18	18	17	17	17	17	16	16
85	90	20	20	20	19	19	19	18	18
90	95	23	22	22	22	22	21	21	21
95	100	27	26	26	26	26	26	25	25

TABLE "2"

RECOMMENDED FINAL MOISTURE CONTENTS	
Timber final destination	Moisture percentage
Boards	16 - 20
Buildings	12 - 18
Furnitures for rooms heated by means of stoves	11 - 13
Furnitures for rooms heated by means of central heating	9 - 10
External frames	13 - 16
Internal frames	9 - 10
Wood blocks	7 - 9
Boats	12 - 16
Shoulder pieces	10 - 12
Pictures frames	8 - 10
Wine casks	12 - 16
Instruments	6 - 9
Sports articles	10 - 12

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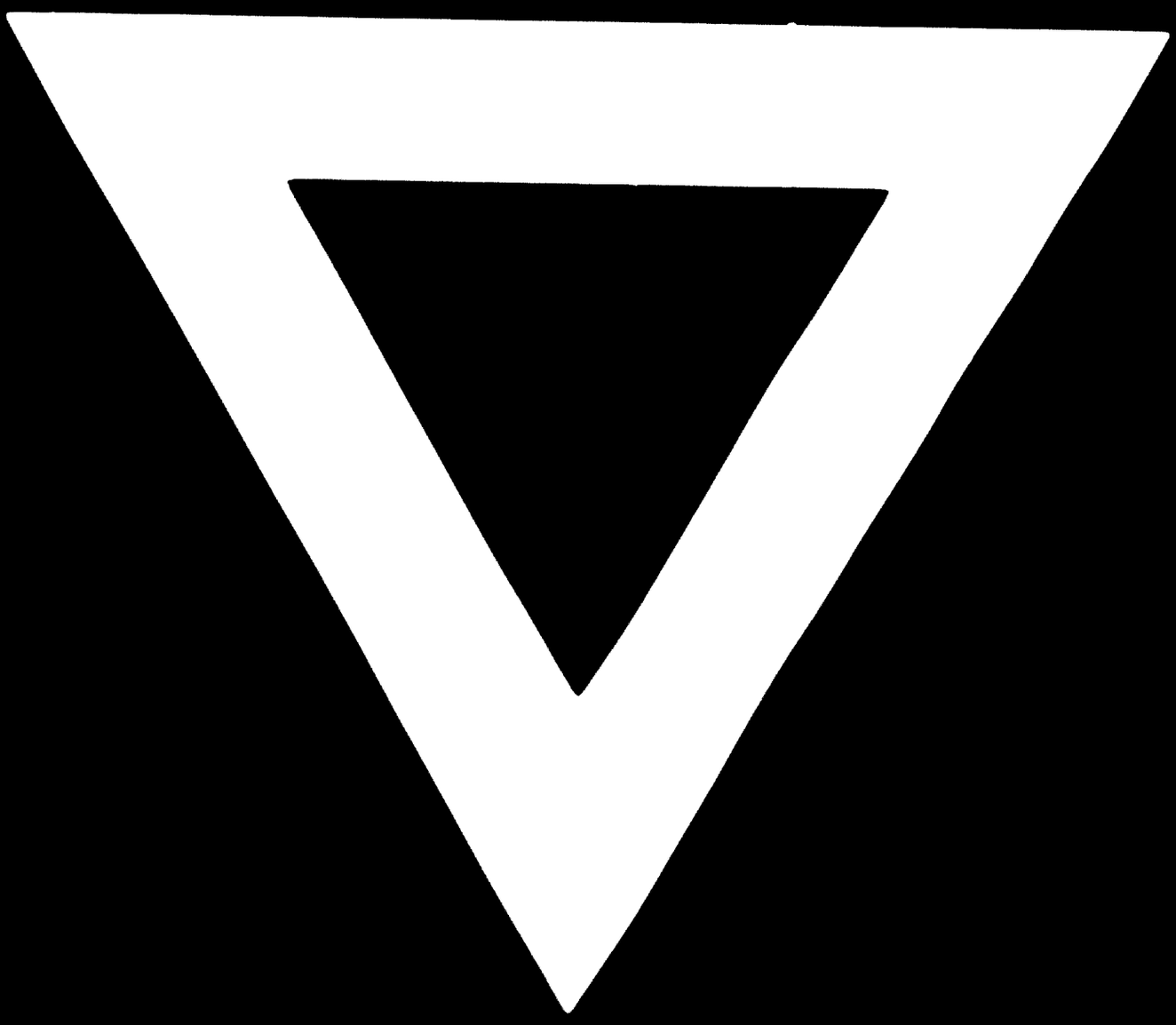

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