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Timber Drying by vacuum or by conventional methods?

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Central Timber Journal

(independent organ of
the forestry and timber trade)

Stuttgart 14 May 1993
119th year,

no. 58

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For many operators an important step in the rationalisation of timber drying may be the introduction of vacuum drying – with drying times which may be 2 to 6 times shorter than in conventional processes. If the correct method is selected better timber quality and lower drying costs will also be obtained. The following notes provide clear, concrete help in deciding which option to take.

I. New Ideas from the New World

An article entitled "Secret lumber-drying process remains shrouded in mystery" appeared recently (February 1993) in the US journal "Woodshop News". The inventor, Eugene Sexton of Tennessee, claims that his "ESP '90" process can dry whole trees naturally, cheaply and without special equipment, with little or no timber reduction. Eugene Sexton has declared his intention of cutting a large tree (red oak) into three equal sections and drying only the two end parts. All three sections are then to be examined for moisture, discoloration and other changes by scientists from the US Department of Agriculture's Forest Products Laboratory (FPL) in Madison, Wisconsin. The parties are so far in agreement; but no-one has yet declared himself willing to cover the costs of transporting the three pieces (each 3 m long, 1/2 m in diameter and weighing 450 kg) from Tennessee to Wisconsin. The three pieces of trunk have already been stored for over a year on Sexton's premises. The two dried sections are in "good condition", says Sexton, but the central part is "away from the window" and may possibly split right through.

This "heavenly" drying method has not yet reached Europe; we realists still have to rely on conventional fresh air/exhaust air drying and increasingly on vacuum drying. Nevertheless this article shows that new drying methods are being considered all over the world, in research laboratories and industrial development centres. At a time when rationalisation measures are characterised more and more by terms such as "just in time" and "lean production", oak drying times of one or even six months sound rather antiquated and can hardly be justified economically.

Fig.1 Hot steam vacuum drier High Vac B40/10

II. A survey of alternative drying techniques

Even in the past there has been some variety in the vacuum driers available, in respect of the basic process (continuous or discontinuous) and the type of heating – by convection, heating plates or microwave. As drying terminology is now well known, only extremely important features will be mentioned, briefly. More space will be devoted to a less well known method, microwave heating.

In discontinuous vacuum drying (always with convection heating, i.e. with heat transfer by circulating air) the wood undergoes repeated changes, first being heated at atmospheric pressure then demoi-
 sturised at low pressure without any heat. This saves on fan capacity in the design of the chamber; however there is considerable risk of discoloration owing to the presence of a high oxygen component during the heating phase.

In continuous vacuum drying there is simultaneous heating and demoi-
 sturising most of the time, at reduced pressure; external air is excluded. With convection heating the air speed, i.e. the fan capacity, must be suitably high owing to the low density of the drying agent. With direct heating no fans at all are required but there are serious problems: heating plates are only used individually and only for small useful volumes owing to their limited size and the very laborious, time-consuming job of stacking and removing from the stack.

The other direct heating method, viz the use of microwaves, is at present being tried out on miniature driers in Japan. Apart from the comparatively high capital costs and greater likelihood of malfunctioning it is very difficult to obtain homogeneous intensity distribution over the whole stack, i.e. the risk of local overheating of the timber is relatively high when rapid drying is carried out. But the main drawback of microwave heating at the moment is that all the energy required for drying has to come from the electricity network. Nor is the efficiency of ordinary power oscillators all that high (e.g. it is less than 70% for continuous wave magnetrons); the excess operating heat of the "transmitter" has to be dissipated by intensive cooling. At any rate "waste heat" from chip or bark combustion cannot be utilised with this type of drier.

III. Some details of the vacuum drying process

The distinctive features of vacuum driers described above can no longer provide the designer with a basis for costing models specifically to customer requirements. Plate or microwave heated installations no longer meet (or do not yet meet) the high demands which the rapid technological developments of recent years have brought with them. They are also inappropriate for large chambers; yet there is more and more demand in the market for these particular installations.

The old classification takes too little account of the importance of physical state variables in a low vacuum; these are a decisive factor in determining the drying result (drying time, quality and cost, degree of discoloration, final moisture dispersion) and purchase price.

Limits reflecting the effect of state variables on individual stages of the process and drying targets must therefore be drawn so that the vacuum drier models and drying methods of the future can be regrouped.

The distinction between continuous and discontinuous vacuum drying should be retained so long as both methods are widely used in practice. But the distinction according to the type of heater can be dropped, since heating by forced convection (fans) has clearly gained acceptance and is almost universal.

Drying in pure superheated steam or a steam-air mixture

Selection of the drying agent is of great importance, since design, control and drying targets are equally concerned with it. Either pure superheated steam or a steam-air mixture is used. Residual quantities of air can never be completely discharged, so there is no clear division between the two versions, especially at very low operating pressures below 100 mbar. The difference should therefore be defined a bit more accurately: in superheated steam drying an attempt is made to keep the partial pressure of air as low as possible; in drying with a steam-air mixture dosed quantities of air are systematically fed in for specific purposes.

Table 1

With pure steam high demands are made on the vacuum pump and the tightness of the drying chamber in respect of the lowest partial pressure of air obtainable (less than 30 mbar). However the demoi-
 sturising rate can be increased almost at will by appropriate cooling of the condenser, since the steam on the way to the condenser is not slowed down by any appreciable resistance caused by diffusion.

If a mixture with air is used instead of pure steam, and if there is the same partial pressure of steam and an unchanged temperature, there will be the same relative moisture, i.e. the climatic values will remain unchanged. Owing to the higher total pressure prevailing and the accompanying higher gas density, there are no problems with conventional heat transfer to the timber: the required fan capacity or speed is reduced. But the higher total pressure simultaneously reduces the mobility of the water in the timber (coefficient of circulation) and thus increases the risk of drying stresses. The diffusion resistance which the air molecules set up to the steam must also be taken into account. It impedes compensation of the partial pressure of steam in various stacking areas and limits the demoi-
 sturising rate upwardly, without additional apparatus. But even at the conditioning stage it may be helpful to use this impediment systematically, e.g. in order to slow down dispersion of wood moisture (more on this in Section V).

Drying agent	Vacuum drying in				Conventional fresh/exhaust air drying
	pure superheated steam		steam-air mixture		air
Operating process	continuous	discontinuous	continuous	discontinuous	continuous
Total operating (low) pressure [mbar]	from: 50 200 50 200		from: 100 200 100 200		atmospheric
Drying time	1	2	3	3	5
Drying risk	1	3	2	4	4
Final moisture dispersion (unawn)	4	3	2	2	1
Timber colour	1	3	2	3	4
Electricity consumption (with speed control)	2	2	2	3	4
Heat consumption (without recovery)	1	2	2	3	4
Water consumption	2	3	2	3	1
Total costs per m ³	1	2			4
Purchase price	3	2			1

Table 1 Rough criteria for assessment of timber driers (drawn up for material requiring a drying time of at least 10 days in the fresh air/exhaust air process).

Assessment:

1 = good, 5 = poor.

Adapting the operating pressure to the job

A third distinctive feature – the pressure range used for drying – is primarily concerned with the type of woods to be dried and also affects the cost price. The lower the operating pressure the more expensive is convection heat transport, with a large number of fans designed specially for low pressure. The higher demands made on seals and the vacuum pump have already been mentioned, and in addition the running times of the pump are longer and the resultant wear greater.

However, this extra expense is inevitable for a company wishing to dry deciduous woods quickly but gently. For example, if we consider the use of pure steam at an operating pressure of 200 mbar, we know that this level represents saturation point at 60 °C. That is to say, it is essential for the chamber temperature to be higher, since only unsaturated steam can absorb moisture from the timber. So obviously the only woods that can be dried at 200 mbar (or over) are those which can tolerate temperatures of 65 °C or higher from the outset (even when freshly sawn). But this is not generally the case with deciduous timber.

Although the temperature limit predetermined by the operating pressure can be reduced in a steam-air mixture this has disadvantages, particularly a greater risk of discoloration. Drying at too high a pressure should also be avoided so that transportation of moisture – which is especially critical in hard woods – is not slowed down unnecessarily.

For strong material (building timber) optimum conditions can always be found at pressures from 200 to 1 000 mbar in a continuous process. For weak softwoods a clear increase in drying speed in a vacuum – over that of conventional driers – can only be obtained in a discontinuous process.

Subdivision according to the operating pressure range is not necessary in a discontinuous process (with any kind of timber), since one will want to make up the time lost in the evacuation phase as a result of the separate heating phase, with the lowest possible final pressure.

IV. Cost comparison based on moist oak

Critical scrutiny of the assessment given in Table 1 reveals that continuous vacuum drying in pure superheated steam offers particular advantages, assuming that the material needs to be vacuum dried for economic reasons. (The criterion used for vacuum drying was that the minimum drying time by the conventional method would be 10 days.)

The cost comparison in Table 2, between conventional fresh air/exhaust air drying and the superheated steam vacuum process, provides a more detailed picture of the cost situation. The basis for the comparison is an annual output of 1 300 m³; the calculation is based on investment and cost estimates made in 1993.

Independently of these absolute figures, vacuum superheated steam drying solves the problem of tying up capital as a result of the extremely long drying times. Today thick oak boards are still largely predried in the open for about 2 years (and sometimes 3 to 6 months in pre-driers) before being dried in a chamber, owing to discoloration and drying risks. With oak costing say 1 200.00 DM per m³ this means an extra cost of 70.00 DM per m³ for conventional drying (assuming 1 year open air/pre-drier, 8% interest, drying time previously 90, now 60 days). So in the example given the total costs are 126.35 DM per m³ (vacuum) as against 237.20 DM per m³ (conventional).

Table 2 Cost comparison between two sawn timber drying units

1. Basic conditions	Vacuum drier high-Vac*	Conventional drier HTR 100**
Type of timber	European oak, sawn	
Thickness of timber	mm	50
Stacking strip thickness	mm	20 24
Initial moisture	%	70-80
Final moisture	%	8
Widthways layout	%	85
Stacking factor		0.6 0.57
Stacking dimensions:		
- width	mm	2 x 1 200 5 x 1 200
- height	mm	2 x 1 150 3 x 1 200
- length	mm	19 600 10 000
Gross useful content	m ³	108 3 x 216
Net useful content	m ³	65 3 x 123
Drying time	days	16 90
Drying days in year		320
Annual output	m ³	approx. 1 300 approx. 1 300
Heating medium	°C	PHW 110/90
Installed heating power	kW	180 3 x 250
Connected wattage:		
- fans	kW	14 x 3.0 3 x 5 x 3.0
- vacuum pump	kW	11.0 ---
- cooling fans	kW	11.0 ---
Annual energy consumption:		
- heating (oil)	l	approx. 60 000 approx. 100 000
- electricity	kWh	approx. 120 000 approx. 175 000
- water	m ³	approx. 600 approx. 50
Space requirement without driveways	m ²	200 330
Assembly time/hands	days/h	15/150 40/1200

* Mfr: Brunner Trockentechnik GmbH

** Mfr: Hildebrand Holztechnik GmbH

2. Investment costs	High-Vac	HTR 100
Unit size/ useful content	m ³	1 x 55 3 x 123
Additional supplies, suitable for outdoor installation, incl. computer & printer, stepwise speed control (incl. pump & cooling system for High-Vac), incl. packaging, erection, commissioning	DM	455 000.00 438 000.00
Operating room	DM	8 500.00 20 000.00
Transport costs (300 km) with unloading at site	DM	17 000.00 7 000.00
Building assembly hands	DM	5 250.00 42 000.00
Erection aids	DM	3 000.00 10 000.00
Foundations, building work, rails	DM	13 500.00 33 000.00
Land without driveways (30.00 DM/m ²)	DM	6 000.00 9 900.00
Installation of water, electricity, compressed air and compressor	DM	21 700.00 34 000.00
Building & operating permission, architect	DM	— 10 000.00
Total	DM	530 000.00 604 000.00

3. Summary	High-Vac	HTR 100
3.1 Depreciation investment costs x 0.1	DM	53 000.00 60 400.00
3.2 Interest on capital 5% of investment costs	DM	26 500.00 30 200.00
3.3 Operating costs (average over 10 years)		
a) oil consumption	l	60 000 100 000
	DM	36 000.00 60 000.00
b) electricity	kWh	120 000 175 000
	DM	45 600.00 66 500.00
c) water consumption	l	600 50
	DM	3 150.00 263.00
Total annual costs	DM	164 250.00 217 363.00
Annual drying output	m ³	1 300 1 300
3.4 Total cost/m ³ (annual average over 10 years)	DM/m ³	126.35 167.20
3.5 Current operating costs (a+b+c, based on 1993)	DM/m ³	43.15 64.56

Basic figures

Depreciation	10% p.a. (10 years)
Interest on capital	10% p.a. (regular repayment)
Heating oil costs	1993: 0.40 DM/l 2003: 0.80 DM/l; average 0.60 DM/l
Electricity costs	1993: 0.25 DM/kWh 2003: 0.50 DM/kWh average 0.38 DM/kWh
Water costs	1993: 3.50 DM/m ³ 2003: 7.00 DM/m ³ average 5.25 DM/m ³
Land costs	30.00 DM/m ²
Unskilled worker costs	35.00 DM/h (incl. incidental expenses)

Not included in calculations: Investment costs heating unit, tax and insurance, stacking battens and other aids, stacking costs, handling and supervision, maintenance, repairs, replacement parts. These items are regarded as neutral in the cost comparison.