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Low Technology Kilns and Drying Schedules for Hardwood in Small-scale Operations

INFORMATION NOTE

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SUMMARY

TRADA Technology has, on behalf of the Forestry Commission, recently completed a study of hardwood drying in the UK. The study concentrated on drying methods and schedules for UK hardwood species and the availability of low technology kilns in the UK for small-scale operations. The aims of the study were:

- **to conduct a brief literature review to ascertain existing information on current kiln schedules and drying practices applicable to the drying of small volumes of hardwood timber (of species commonly found in the UK) and;**
- **to conduct a trade search of kiln manufacturers and suppliers to establish the availability within, and suitability for, the UK of low technology timber drying kilns.**

LITERATURE REVIEW

1. The literature review identified recently published (1985 onwards) and readily accessible information on small-scale kiln drying of timber with a particular emphasis on kilning schedules for UK hardwood species such as beech, birch, oak and sycamore. Additional articles looked at considered wood moisture relations, drying schedules, drying methods and practice, kiln types and economics, sampling levels, sorting of timber prior to drying and planing of timber prior to drying, the principles of air-drying, forced air-drying, pre-drying, kiln drying, dehumidifier drying and vacuum drying.

Kiln schedules

2. Many of the schedules found in the literature review were conservative in terms of drying conditions and drying time and do not reflect recently reported developments in drying practice. The most appropriate of the currently available publications for drying schedules and practice for use with UK hardwood timber species, in small-scale drying operations, is the recently revised *Timber Drying Manual* (Pratt, 1997). Common UK hardwood species for which drying schedules are reported are: alder, ash, beech, birch, cherry, elm, oak, poplar, sweet chestnut and sycamore (schedules for all of these are found in the *Timber Drying Manual*). A number of North American schedules are now available on the internet, as is a computer-based drying schedule programme for hardwood species.

3. The *Timber Drying Manual* provides the core details of drying method and practice for UK hardwoods. However, a number of other authors (see references) provide additional details on good stacking and stickering of timber packs, temperature and relative humidity control, good air flow speed with minimal air bypass and methods for monitoring kiln performance. The need for different drying schedules for use with dehumidifier kilns and heat & vent kilns, to reflect differences in the drying method and control, are also stressed.

Timber preparation

4. Recent North American research has looked at changes in timber preparation methods and practices and the selection of drying schedules. This includes reports on mixing species of similar density in a kiln load, pre-sorting timbers on a density/specific gravity/moisture content basis, planing prior to drying, critical sampling levels for accurate monitoring of the drying process and differentiating drying schedules for dehumidifier kilns from those for heat & vent kilns. The result of this work is the modification of some drying schedules to reduce drying time without compromising drying quality. While the North American schedules may not be directly applicable to UK species, they do present potentially

advantageous modifications which are not reflected in the information currently available to UK timber dryers.

Kiln types

5. The majority of kilns in use are either heat & vent kilns or dehumidifier kilns with a few specialist vacuum drying operations. Heat & vent kilns control temperature and relative humidity by way of heaters, roof vents and steam input. Dehumidifier kilns, however, control temperature by heaters, heat recovery from the dehumidifier and vents, and relative humidity through removal of moisture from the kiln atmosphere by way of a refrigeration system (dehumidifier). Dehumidifier kilns have become more popular in recent years, particularly for smaller drying operations, largely due to their ease of operation, low capital costs, low energy requirements and high quality of output. Dehumidifier kilns traditionally have longer drying schedules than most heat and vent kilns and therefore they can tie up capital in large stock holdings. Recent advances in refrigerants for cooling systems and good insulation of walls, ceilings and floors are, however, making dehumidifier kilns quicker and more efficient. Air-drying to a moisture content of 25–30% prior to kiln drying to the final moisture content required is also common place.

KILN AVAILABILITY

6. The trade search identified a number of manufacturers and suppliers of low technology timber drying kilns. Ten manufacturers and suppliers of particular relevance to the study were identified who could

Table 1 Summary of small-scale kiln suppliers to the UK market for the drying of hardwood timbers

Company	Kiln type	Capacity	Drying schedules	Drying chambers	Price*
Kiln Services	Dehumidifier Dehumidifier Head & vent	4 – 20 m³ 4 – 20 m³ 4 – 25 m³	Supplied Supplied Supplied	Self-supply Supplied Supplied	£7,800 £11,200 £12,300
Arrowsmiths	Dehumidifier Dehumidifier Dehumidifier	2.5–5.0 m³ 9–18 m³ 9–18 m³	- - -	Optional Self-supply Supplied	£512/unit – no chamber £1,320/unit £4,089
Cubbage	Dehumidifier	5 – 20 m³	Supplied	Optional	£4,500–£9,700 – no chamber
Calorax	Dehumidifier	10 – 20 m³	-	Supplied	£4,500
Koetter	Heat & vent	9.8–12 to 14.6–18 m³	Supplied	Supplied – self assembly	£5,277–£6,629 ■
Incomac	Dehumidifier Dehumidifier Heat & vent Heat & vent	12 m³ 20 m³ 10 m³ 30 m³	- - Supplied Supplied	- - Supplied Supplied	£9,573–£14,482◆ £14,275–£17,221◆ £15,480–£29,290◆ £15,480–£29,290◆
Tekma Wood	Heat & vent	10 – 20 m³	Supplied	Supplied	£25,000–£31,000
Dryfinn	Dehumidifier	12 – 25 m³	-	Supplied	£15,220●
Ruskol	Dehumidifier	10 m³	-	Self-supply	£6,293▲
Wooddryer System	Heat & vent	25 m³	Supplied	Optional	£8,969 ■

*Prices are plus VAT and ex-works.
The following exchange rates were used to derive costs in £: ■ US$ 1.667, ● FIM 8.4102 and ▲ Dkr 10.5147 (Financial Times, 1998); ◆Lit 2,648 (Thomas Cook, 1998).

supply a range of dehumidifier and heat & vent kilns (see Table 1). In many cases the manufacturers could also supply recommended kiln schedules. Drying capacity starts from as little as 2–3 m^3 for dehumidifier kilns and 4–5 m^3 for heat & vent kilns, though some suppliers of heat & vent kilns indicate minimum viable capacities of 25 m^3 while others not listed indicated they had a real interest only in kiln capacities of > 100 m^3. Six of the manufacturers and suppliers are UK based and can offer a good range of options in terms of price, equipment and drying times. The remaining four manufacturers and suppliers are based overseas and offer little extra choice to the UK based companies.

7. Dehumidifier kilns are generally cheaper to purchase, more portable, less complex and therefore simpler to maintain than heat & vent kilns. However, they generally offer slower drying times than heat & vent kilns, particularly when drying to below 15% mc, with the smaller models being particularly slow. Drying temperature and water extraction rates vary from 45°C and 68 litres/day to 60°C and 576 litres/day. Drying chambers are normally supplied as part of the package though some manufacturers and suppliers can provide equipment for use in a self-supplied chamber, e.g. a shipping container. Capital costs also vary from as low as £500† for a small dehumidifier only, i.e. no chamber, to around £10,000† for a set of large dehumidifiers with prefabricated chamber and appropriate control panel. One manufacturer is also reported to be working on using a new refrigerant to provide higher operating temperatures and faster water extraction rates.

8. Compared with dehumidifier kilns, heat & vent kilns are more expensive to purchase and operate, with prices starting from £5,300† without a chamber and ranging from £10,400† to £31,000† with a chamber. Against this, heat & vent kilns offer faster drying times and more automated monitoring systems with control panels. All of the kilns come complete with the drying chamber, with one supplier offering a self-assembly chamber and another supplier offering equipment for use in a self-supplied chamber. Some manufacturers also offer water/steam spray systems for use during the warm up, equalising and conditioning stages of the drying process, while others have schedules pre-programmed into the microprocessor control panel. A variety of fuels can be used to heat these kilns, e.g. gas, oil and wood residues, thus removing the need for 3 phase electricity. All bar one of the kilns, which has an integral panel floor, need to be sited on a permanent concrete base and are therefore not portable.

9. The scope of the current work did not permit a detailed assessment for either type of kiln or the influence of variables such as, species, initial moisture content, size variation, drying history, drying schedules, and operator input regarding desired quantity and quality of output.

CONCLUSIONS

Drying schedules and practices

10. A good range of drying schedules is available for use with UK hardwood species, many of which are conservative in terms of drying conditions and drying times. The most comprehensive and appropriate currently available drying schedules for the small-scale drying of UK hardwood species are those published in the *Timber Drying Manual*. However, the schedules do not differentiate between dehumidifier and heat & vent kiln drying. Several other guides are available on the subject of drying timber, those specialising in hardwoods all being from overseas. These overseas drying schedules and practices reported suggest a number of innovative advances have been made in the drying of hardwoods. They may be appropriate for UK hardwood species but have not yet been assessed.

Kiln availability

11. The two most common types of kiln available for drying hardwoods such as those in the UK are heat & vent kilns and dehumidifier kilns. Dehumidifier kilns are generally cheaper to purchase than heat & vent kilns though running costs are reported to be similar. There is a wider range of drying times with dehumidifier kilns and they generally dry timber more slowly than heat & vent kilns.

Full details of information reviewed for this study are given in Table 2 for Dehumidifier Kilns and Table 3 for Heat & Vent Kilns.

† All prices are approximated to the nearest £100 and are correct as at project completion (November, 1998).

Table 2 **Dehumidifier kilns** (A '- -' indicates no specification given.)

Dehumidifier kilns	UK manufacturers and suppliers					
Specifications Supplier/agent/country:	**Kiln Services Ltd** as above	**Arrowsmiths Ltd** as above		**Cubbage Machinery Ltd** as above		
Kiln model	DH300	Junior	Senior	SC 3000	SC No.2	SC No.4
Kiln capacity	4–20 m³	1": 2.5 m³– 2": 5.0 m³	1": 9 m³– 2": 18 m³	5–7 m³	7–10 m³	15–20 m³
Chamber included	Optional	Optional		Optional		
Chamber size, external (length, width, height)	- -	5.0x2.5 x2.5 m	10.0x4.0 x2.5 m	- -	- -	- -
Power source	Mains electric	220/240v 13amp/50Hz	220/240v 10amp/50Hz	200–220v/ 50Hz single phase	380–420v/50Hz 3 phase	
Heat source	9.0 Kw resistance heater	450W drier & 500W heater	1.0Kw drier & 1.1Kw heater	1.5 Kw heater	4.5 Kw heater	9.0 Kw heater
Temperature range	Max 60°C	Max 45°C	Max 40°C	Max 50°C	Max 60°C	Max 60°C
Temparture control	High temperature ventilator	Thermometer, thermostat multistage timer		- -	High temperature ventilator	
RH control	Dehumidifier			- -	- -	- -
Dryer unit size	- -	0.615x0.32x 0.365 m	0.96x0.32 x 0.96 m	1.07x0.29x 0.82 m	1.1x0.46x 1.19 m	1.1x0.46x 1.53 m
Dryer unit weight	- -	26kg	63kg	76kg	128kg	190kg
Fan type & number	2x500 mm axial	1–2x300 mm	1–2x300 mm	4x400 mm	5x400 mm	10x400 mm
Air flow speed	1 m/s	0.24 m/s	0.38 m/s	0.83 m/s	1.67 m/s	1.67 m/s
Water removal	500 l/day	18 l/day	68 l/day	51 l/day	216 l/day	432 l/day
Trolley & track	Yes	- -	Extra	- -	- -	- -
Corrosion resistance	- -	Copper coils & cathode protection		- -	Stainless steel coils optional	
Schedules available	200 species	- -	- -	Supplied and adapted for dehumidifier kilns		
Monitoring system	Optional 4 point mc display	- -	- -	- -	- -	- -
Control panel	Automatic: airflow, temperature & relative humidity	- -	- -	Proportional controller	Master control panel	
Price (+ vat, ex-works) drier and chamber	£11,200	- -	£4,089	- -	- -	- -
without chamber	£7,800	£512	£1,320	£4,500	£8,300	£9,700
chamber	- -	- -	£1,200	- -	- -	- -
Control panel	- -	- -	£299	- -	- -	- -
Extra driers	- -	- -	- -	- -	£645	£1,220
Optional mc display	£380	- -	- -	£880, 1st kiln; £480 each additonal kiln		
Fans	- -	2x10" £62	2x18" £290	- -	- -	- -
Trolley kit	- -	£26	£26	- -	- -	- -
Moisture meter	- -	£276	£276	- -	- -	- -
Installation kit			£73			
Notes Other models	- -	- -	- -	- -	- -	2xSC No.4: 30–40 m³: £16,940
Drying time (days)	50–10% mc, oak, 1¼" 41; 2" 58 beech, 1¼" 23; 2" 45 35–10% mc, oak, 1¼" 30; 2" 46 beech, 1¼" 16; 2" 30	50–10% mc, oak, 1" 40; 2" 95 30–10% mc, oak, 1" 22; 2" 50		45–12 % mc, medium density hardwood, 1.5" 12–14		

			Overseas manufacturers and suppliers		
Calorax as above	**Incomac** Stewart Lumber		**Dryfinn (also Eurotec)** Finland		**Ruskol** Denmark
DH 300BH Timber	MAC 15/5g	MAC 25/5g	DF K12	DF K25	IS 125 HT
Stack length 2.75 x 2.75 x (kiln length -0.6 m)*	12 m³	20 m³	12 m³	25 m³	10 m³
Supplied	Supplied	Supplied	Supplied	Supplied	Self-build
length variable x4.1x3.75 m*	- -	- -	1.65x1.43x0.63 m	1.65x1.8x0.68 m	- -
- -	Electric 11.8 Kw	Electric 15.2 Kw	380v/15A 3 phase	380v/15A 3 phase	220v/50Hz
9.0 Kw electric heater or 15.0 Kw hot water boiler	4.8 Kw heater	6.0 Kw heater	15Kw heater	22.5Kw heater	18.9 Kw heater
Max 55°C–65°C from early 1999	Max 60°C	Max 60°C	Max 60°C	Max 60°C	Max 50°C
Overheat protection device	- -	- -	- -	- -	Ventilator
Dehumidifier 10–99 % rh	- -	- -	- -	- -	Dehumidifier/ Ventilator
1.435x0.98x0.72 m	- -	- -	- -	- -	0.91x0.56x0.515 m
220kg	- -	- -	- -	- -	90kg
450 or 500 mm	- -	- -	4x500 mm	4x600 mm	- -
1.38 m/s	3.61 m/s	4.17 m/s	- -	- -	0.34 m/s
300 l/day	336 l/ day	576 l/day	400 l/day	800 l/day	192 l/day
Optional	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	Stainless steel coils
No	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	Electronic controller
Temperature & relative humidity reading & setting	Manual through to fully automatic		- -	- -	Electronic controller
- -	Tunnel £9,573, Box £14,482	Tunnel £14,275, Box £17,275	£10,820	£15,220	- -
£4,500	- -	- -	- -	- -	£6,293
- -	- -	- -	- -	- -	- -
£1,500	- -	- -	- -	- -	- -
£4,500	- -	- -	- -	- -	- -
		- -	- -	- -	- -
- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -
DH 600 *Kiln length is designed to suit customers own requirements	- -	- -	- -	- -	- -
50–12% mc, 1.5" oak, 38; beech, 16.2; sycamore, 19.3	- -	- -	70–8% mc, beech, 1" 12; 2" 20 60–8% mc, beech, 1" 20 60–20/25–10% mc, beech, 1" 11		80–6% mc, oak, 1" 22; 2" 31 beech, 1" 15; 2" 19

Table 3 **Heat & vent kilns** (A '- -' indicates no specification given.)

Heat & vent kilns	UK manufacturers and suppliers			
Specifications Supplier/agent/country:	**Kiln Services Ltd** as above	**Koetter Dry Kiln** WMS Consulting		
Kiln model	Mini	KDK-4150	KDK-5000	KDK-6200
Kiln capacity	4–5 m^3	1":9.8 m^3–2":12.1 m^3	1":11.8 m^3–2":12.9 m^3	1":14.6 m^3–2":18.1 m^3
Chamber included	Supplied	Flat pack	Flat pack	Flat pack
Chamber size, external (length, width, height)	5.0x2.2x2.2 m	5.6x3.2x2.4 m	6.5x3.2x2.4 m	8.05x3.2x2.4 m
Chamber portable	Possible	Possible	Possible	Possible
Power source	3 phase electric, gas, oil	gas/wood waste boiler 230v/50–60Hz single phase	gas/wood waste boiler 230v/50–60Hz single phase	gas/wood waste boiler 230v/50–60H single phase
Heat source	Electric heater, hot water/steam boiler	Hot water	Hot water	Hot water
Temperature range	Max 70°C	Max 60°C	Max 60°C	Max 60°C
Temparture control	Ventilators	Ventilators	Ventilators	Ventilators
Relative humidity control	Ventilators	Ventilators	Ventilators	Ventilators
Fan type & number	2x500 mm axial	8x300 mm	10x300 mm	12x300 mm
Air speed	1.5 m/s	- -	- -	- -
Steam/water spray	Mist sprayer	None	None	None
Trolley & track	Yes	Optional	Optional	Optional
Schedules available	200 species	Supplied	Supplied	Supplied
Monitoring system	4 point mc display	Manual relative humidity check	Manual relative humidity check	Manual relative humidity check
Control panel	Micro-processor display panel	None	None	None
Price (+ vat, ex-works) drier and chamber	£12,300	£10,372	£11,910	£13,424
without chamber	- -	£5,277	£6,140	£6,629
Notes	Other models: SMK-2: 8–12 m^3, £21,240 SMK-3: 16–25 m^3, £26,020	Prices are for parts and instructions, not assembly		
Drying times	50–10% mc, oak, 1¼" 24; 2" 42 beech, 1¼" 12.5; 2" 21 35–10% mc, oak, 1¼" 16.5; 2" 33 beech, 1¼" 8; 2" 15	60–12% mc, oak, 1" 21, 2" 80; beech, 1" 18, 2" 65		

		Overseas manufacturers and suppliers		
Incomac Stewart Lumber		**Tekma Wood** Finland		**Wooddryer System** United States
ICD-J10	ICD 30	- -	- -	Wooddryer system
10 m³	30 m³	10 m³	20 m³	25 m³ +
Supplied	Supplied	Supplied	Supplied	Optional
7.6x2.8x2.15 m	5.1x5.0x5.4 m	7.6x2.8x3.7 m	7.6x2.8x5.6 m	8.5x4.8x5.8 m
- -	- -	- -	- -	- -
- -	- -	gas/oil/electric/ wood fuel boiler	gas/oil/electric/ wood fuel boiler	gas, oil, wood waste or 3 phase electric
Hot/superheated water or steam	Hot/superheated water or steam	Hot water at 110°C	Hot water at 110°C	Hot water
100°C +	100°C +	60–70, Max 80°C	60–70, Max 80°C	Max 65°C
Ventilators	Ventilators	Temperature sensor water control valve	Temperature sensor water control valve	Electronic sensor
Ventilators	Ventilators	Ventilator/steam spray	Ventilator/steam spray	Electronic sensor
- -	- -	Included	Included	- -
- -	- -	- -	- -	- -
Steam spray	Steam spray	Steam spray	Steam spray	Steam/water spray
Yes	- -	Included	Included	Included
Pre-programed	Pre-programed	Supplied	Supplied	Supplied
Microprocessor/sensors	- -	Basic kiln controller	Basic kiln controller	Industrial PC
Semi-automatic – PC control	Semi-automatic – PC control	Micro-processor	Micro-processor	PC control
£15,480 - tunnel kiln £29,290 - box kiln	- -	£25,000	£31,000	£8,969
- -	- -	£25,000	£31,000	- -
- -	- -	An additional pc monitoring system is available for an extra £3–4,000		Computer link for pc supervision of monitoring system £353
- -	- -	At a wet bulb temperature of 40°C: 60–12% mc, oak, 1" 16, 2" 33; beech, 1" 9, 2" 19 At a wet bulb temperature of 50°C: 60–12% mc, oak, 1" 14, 2" 28; beech, 1" 8, 2" 17		60–10% mc, oak, 1" 30–35, 2" 60–80; beech, 1" 14–18, 2" 35–40

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