INDEX

NYLE WARRANTY

LIMITED WARRANTY: The equipment supplied by Nyle is warranted to be free from defects in workmanship and materials for a period of one year from the date of the original installation or 15 months from the date of delivery, whichever comes first. In addition, the cold coil and the compressor will be warranted for an additional year or for a total of two years. A new or remanufactured part will be supplied by Nyle providing the defective part is first returned to Nyle for inspection. The replacement part assumes the unused portion of the warranty. The warranty does not include labor or other costs incurred for diagnosis, repairing or removing, installing or shipping the defective or replacement parts. Nyle makes no warranty as to the fitness of the equipment for a particular use and shall not be liable for any direct, indirect or consequential damages in conjunction with this contract and/or the use of its equipment. Buyer agrees to indemnify and save harmless Nyle from any claims or demands against Nyle for injuries or damages to third parties resulting from buyer's use or ownership of the equipment. No other warranties, expressed or implied, will be honored unless in writing by an officer of Nyle Standard Dryers, Inc.

Model ____________________ Serial Number ____________________

Date Purchased ____

Mail:

Nyle Standard Dryers, Inc.
P.O. Box 1107
Bangor, ME 04402

Shipping:

Nyle Standard Dryers, Inc.
72 Center Street
Brewer, ME 04402

TEL: 207.989.4335 1.800.777.NYLE FAX: 207.989.1101

Operating Instructions
Wood-Mizer ***DH4000*** Controller

Different species and thicknesses of wood need to be dried at different rates in order to prevent damage such as checks from forming in the wood. Different species have different maximum drying rates, and some species, such as softwoods have no "maximum" drying rates. Refer to table on page 2-5 for the rates for many hardwood species. As a general rule, 8/4 (50mm) thick hardwoods have to be dried 2 to 2½ times slower than 4/4 (25mm) thick lumber. For example, 4/4 Red Upland Oak, (Upland is identified by the growth rings being less than ¼" (6m) apart,) has a maximum drying rate of 3.8%/day while 8/4 has a maximum rate of 1.5%/day. So when you are drying 4/4 Oak, you will aim for a target of 3% per day to allow for any variances in the drying within your chamber, stacking, etc. If you exceed this rate while drying from green down to 40%, checks will form in the lumber although you may not see them until the lumber is drier. If you dry too slowly, that can result in mold forming on the lumber.

Softwoods, while generally not having a maximum drying rate, must be dried fast enough to prevent mold growth, blue stain, brown stain, and other cosmetic damage. For this reason, the maximum recommended load size for the ***DH4000*** is 1500 board feet of softwoods and fast drying hardwoods such as Poplar. The drying times are much faster for these woods, so while the individual loads are smaller, the annual production will be about the same for fast drying woods or slow drying woods.

Refer to the species groupings on the following pages. It is preferable not to mix different species in a kiln charge, but if they are in the same group, it is easily managed. *Do not mix dried and green lumber!* If you have some lumber wetter than others that you want to put in the same load, if the difference is more the 5%, put the wetter lumber in first and dry that until it is close to the moisture content of the rest of the lumber. Whenever you are mixing species, you must use the maximum dry rate for the slowest drying species in the load.

Your kiln has a temperature controller that operates the electric heater, and a humidity controller that operates the compressor. There is a lockout that prevents the compressor from operating if the temperature in the kiln is less than 80°F. (27°C.). There is also a 2% differential in the controls to avoid short-cycling.

Operating the Dryer

After you have familiarized yourself with the machine during the check out procedure, and you corrected loaded your lumber into the chamber, you can start the drying process. First you must determine the moisture content of the lumber by either using a high-quality moisture meter or by using the oven-dry sample method described elsewhere in this manual. Even if you are using a moisture meter, you should become familiar with the oven-dry method, as that is considered the most definitive method.

1. Start the circulating fans.
2. Turn the system switch to "ON".
3. Set the temperature control and the humidity control according the drying schedule for the type of wood being dried. Use the up and down arrow buttons to change the settings.
4. Daily, at roughly the same time as the day before, check the moisture content at 4 or 6 places within the kiln. Don't worry about opening the kiln door to go inside, most of the heat inside the chamber is stored in the lumber and is not lost in the few minutes it takes to take your samples out or to take your moisture meter readings. Write down the readings and compare those readings to the previous day's.
5. If the moisture removal rate was lower than the maximum allowed value, lower the humidity setting by using the drying index listing in Section 3 of this manual to adjust the drying rate to a different humidity setting. As you gain experience with your chamber, and how you saw and stack you lumber, you will develop a feeling about how the changes in the settings affect the drying rate. Keep in mind that temperature also affects drying rate. Conversely raise the humidity setting if the lumber is drying faster than the safe allowed rate.
6. Follow the Drying schedules to change the temperature settings and humidity settings as various drying stages are met. However, the moisture loss per day is more important to control than following a fixed schedule.
7. The system has two manual vents to be used if the temperature inside the kiln gets too high. Keep in mind that if you are venting, moisture and heat are going out the vents. The temperature control only turns on the electric heater. Your chamber will gain heat from the compressor motor, the blower motor, and the circulating fans.
8. Continue checking the moisture content daily, keeping a record. Adjust you schedules based on the fastest drying, not an average. The lumber will equalize its moisture content the longer it is in the kiln. When you reach your desired moisture content, turn the system switch off. If the lumber is not equalized, keep the fans running in the closed kiln for another day to equalize the load. If you are drying Pine, or other species where setting pitch may be required, keep the system on, but raise the humidity control setting to 99% so the compressor will not run and raise the temperature to 160°F. overnight to set the pitch. To sterilize the lumber to insure the death of any bugs, do the same but 140°F. would be sufficient.

Please don't hesitate to call with any questions you have.

System Check Out Procedure

The system is initially activated by turning the system switch "ON". This will start the blower fan in the unit and also power up the controller. If the blower does not start, check to make sure there is power to the unit and all connections are secure. Do not proceed if the blower is not running.

The temperature inside the kiln is indicated in the top display of the controller. This is the "Dry Bulb" temperature. At the initial start up, the kiln temperature will be displayed. Until the temperature inside the kiln reaches 80ºF, the lower display on the controller will show "Pre Heat" and the heat light will be on. The heat light will also be on when you are using the electric heater to raise the temperature in the kiln. To change or check the set point temperature, press the "Mode" key until the "Set Point" indicator light comes on. You can then change the set point by using the up or down arrows on the controller. Check to see that the air coming out of the top of the dehumidifier is being warmed. It will only be about 5ºF. Warmer than the air entering the unit.

The percentage timer for the compressor is activated when the temperature in the kiln has reached 80ºF(26ºC). The compressor should not be run if the temperature in the kiln is below 75ºF(24ºC), or if the temperature is above 130ºF. Outside of the recommended temperature range of 80º-120ºF. (24º-49ºC) the refrigerant pressures in the system will be either too high or too low, and the system can be damaged. (*There are pressure safety switches in the system to prevent damage*) Set the percentage timer by pressing the "Start/Reset" key, and using the up and down arrow keys to change the setting. Press the "Start/Reset" key again to start the cycle. The percentage timer cannot be set from 91 to 99 percent in order to prevent short-cycling of the compressor, and allowing enough off time, if the compressor is running less than 100% of the time for the refrigerant pressures to equalize.

The timer window on the controller will either be showing the amount of time the compressor will be running, or the amount of time until it starts again. The compressor runs fairly quietly, and it may be hard to tell if it is running. The easiest way to check may be to have a helper push the "Start/Reset" switch while you are next to the unit, feeling vibration and listening closely for changes as the compressor goes on or off. *Make sure you wait at least 6 minutes after you turn the compressor off before turning it on again, and the temperature is at least 75ºF.*

Loading The Drying Chamber

The USDA Dry Kiln Operators Manual describes, in Chapter 5, the proper method of stacking and stickering the lumber. Nyle recommends that these steps be followed carefully. Stickers should all be at least 3/4" thick and all sticks in any load must be the same thickness. Thick lumber (10/4" and thicker) should be dried using double stickers. Sticker placement is very important. The end stickers should be as close to the ends of the boards as possible. Sticker spacing should be approximately 18". This spacing can be reduced to 12" if excessive warping, cupping, and bow are a problem. Keep stickers in a vertical line and always support the load under each sticker. If you have some wide boards, or other pieces that you want to keep as straight as possible, pile them on the bottom as the weight of the lumber above will constrain the wide boards and give the best result.

When the lumber is fully loaded, the baffles should be lowered to the top of the lumber and the side baffles should be carefully positioned. If no side baffles are installed, the space could be closed off with plywood or boards. Do not use plastic sheeting as it may come loose and become entangled in the fans. If the load supports are thicker than normal stickers, the extra space should be blocked with a narrow board or lathe. Close off any large openings that will let air go around the lumber. A small amount of time spent doing this correctly will pay back in more even, faster, and less expensive drying. Air will always take the path of least resistance, and you must force it through the stickered pile.

If a less than full load is anticipated, it is better to reduce the depth rather than the height or width. This will obviously leave the stickers "hanging out", but will result in better drying.

INTRODUCTION TO DEHUMIDIFICATION LUMBER DRYING

Dehumidification lumber drying with a Nyle Lumber Drying system is similar in many ways to drying lumber in a conventional dry kiln. The lumber is stacked in a chamber and air is circulated through it at controlled temperatures and humidity's in accordance with a schedule, which is developed for the species and thickness being dried.

The basic difference with a dehumidification system is that when the water evaporates from the wood and increases the humidity of the air, a refrigeration system is energized to remove the water from the air by dehumidification rather than exhausting moisture laden air to the outdoors. By removing the water on a dehumidification coil in a refrigeration system, the energy that was used to turn the water into vapor can be recovered and reused. By eliminating the need to vent to remove the water vapor, no energy is required to heat the ventilation air.

The Nyle system includes a method of heating the number supplemental to the refrigeration system and that system is used during initial warm-up and, sometimes, when temperature increases are desired.

The Nyle system includes a circulating fan system. This system establishes airflow within the chamber. This airflow is the medium by which the heat energy is carried to the lumber, and also how the evaporated moisture is carried back to the machine. The evenness of drying is related to this airflow.

The Nyle system also includes an exhaust vent system. This vent is to be used to keep the maximum temperature from exceeding that required by the schedule.

The dryers are installed in insulated chambers, usually built from standard construction materials. Details on construction can be found elsewhere in this manual or on drawings provided by Nyle.

It is important to remember that the dehumidifier and the chamber together form a dry kiln, and that successful and efficient drying will depend on an air tight and well-insulated chamber.

KILN CONSTRUCTION

The kiln chamber should be built from standard construction materials. The walls, floor, and ceiling should be a 2″x4″ framework, with blue or pink styrofoam (extruded polystyrene) friction fitted between the studs. The interior face of the studs should be covered with a 1″ layer of Celotex Thermax (or, better, two overlapped ½″ layers). Celotex Thermax is foil faced polyisocyanurate (urethane) board, which is orange or yellow in color and is available in 4′x8′ sheets in various thickness′. Celotex Thermax is a trade name and similar and acceptable products are available under other trade names.

The joints and nailheads should be caulked with high temperature silicone and then optionally, with aluminum tape. The Thermax should now be covered with one or two layers of 6 mil polyethylene, and finally covered with ½″ CDX or marine grade plywood. The interior service can now be coated with "mobile home or metal roofing aluminum paint". This is an asphalt based coating with powdered aluminum and fiber for strength. It is available in hardware stores. It should be recoated as necessary or every year. The exterior can be finished to suit your tastes, but avoid galvanized steel or other ferrous sidings.

Because the floor will carry the weight, it should be built stronger, by using at least 2″x6″ and a minimum of ¾″ plywood. The floor should be similarly insulated. A concrete floor can also be used, the concrete floor profile should be as follows: A gravel base, a 2″ layer of rigid blue or pink styrofoam, a layer of polyethylene, and 4″ of reinforced concrete. Install a slight pitch in the floor back to a drain or trough. The dryer can also empty into this drain as well.

If the kiln is a freestanding outside building, the attic space must be well ventilated through the eaves. This is done to avoid any moisture buildup in this space, which will condense on the cold roof, dripping onto the insulation. An interior kiln can have the ceiling insulation open to the atmosphere.

The doors should be built in the same manner as the walls, but could be lightened by increasing the stud spacing and using 3/8" plywood. The lighter weight will reduce the load on the hinges. A vapor barrier must be installed. Two side hinged doors usually works best, but a top hinged door or a lift off door is also a consideration. Gaskets should be placed wherever the door meets the kiln; this will give a good, airtight fit. If no door sill is used, a scraper type weatherstrip can be used to reduce air leakage. The door can fit together in the center with a lap fit. The door should close tightly against the gasket using turnbuckles, tarp straps, lag studs with wingnut, etc.

Air deflectors and baffles must be used to control the airflow within the kiln chamber. The corner deflector is used to help turn the airflow, and is usually made of plywood. A hinged baffle should fall from the fan wall, and be held up during loading with a nylon rope. This baffle is hinged to compensate for different load sizes, and also allow for shrinkage of the board pile. Also, lumber that does not fill the entire width, should have a baffle that closes in the open space. This baffle can be fixed or portable. Do not underestimate the effect of this baffling, as correct baffling will pay off in more even drying and faster drying. This more than offsets the extra effort and time to place the baffles.

An access door should be placed in the chamber to allow for service of the dehumidifier and/or lumber monitoring. While outside electronic moisture meters can be used to avoid entering the kiln, during the drying cycle, Nyle strongly recommends regular checks inside the kiln to visually inspect for surface or end check, mold or stain, and to spot check with a hand held meter.

EQUIPMENT INSTALLATION

1. Place the dehumidifier at the center of the long wall with the inlet filter facing the boardpile. Connect an appropriate length drain hose as shown in the FIGURE 1. The dehumidifier can be elevated any reasonable amount to help the drain gravity feed. The drain must have a trap. If the drain hose extends outside (not to a floor drain in the kiln) the wall opening should be sealed around the hose.

2. Place the controller at a convenient point outside the chamber near the dehumidifier. Remove the cover.

3. Drill a hole in the kiln wall to allow control cables and the sensor wire (coiled up inside the controller) to be carefully routed into the chamber.

4. Mount the temperature sensor 6 to 12 inches from the wall. 4' off the floor, for an accurate reading. Do not place the sensor near the blower outlet.

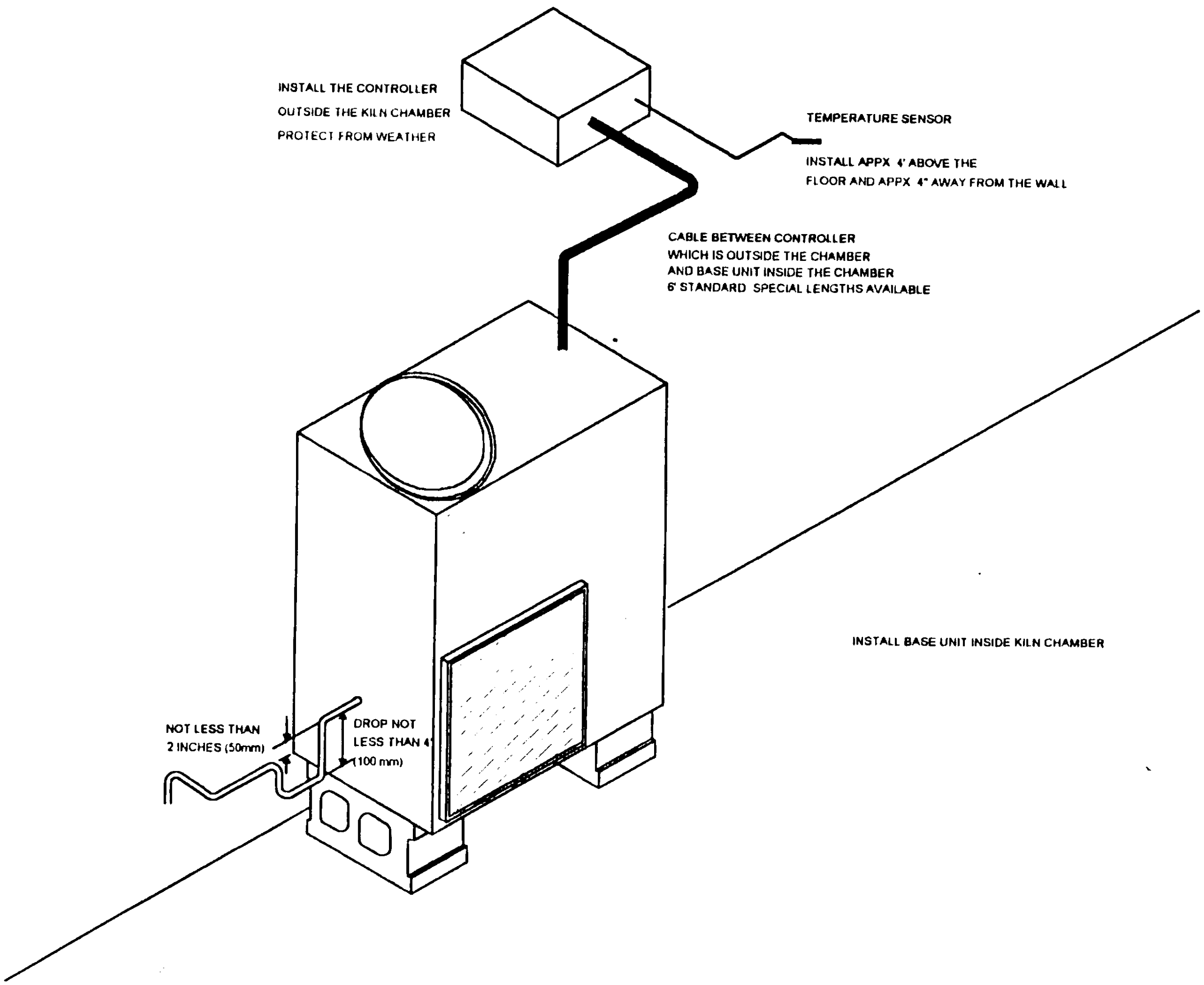
5. Remove the right side panel of the dehumidifier gaining access to the compressor and terminal strip. Securely connect control cable to the dehumidifier. Note that each wire is marked with the terminal number to which it is to be connected. Carefully connect each wire to the similarly marked terminal. Do not stretch or overstress the cable. Seal the hole in the kiln wall after the system check out is successfully concluded.

6. Install and caulk the vents so that they are on opposite sides of the fans and at opposite ends of the kiln. The vents can be mounted to open to the inside or the outside. It is usually more convenient if it opens from the outside. On the L50, the vent location is different and should be located as shown on the chamber drawings.

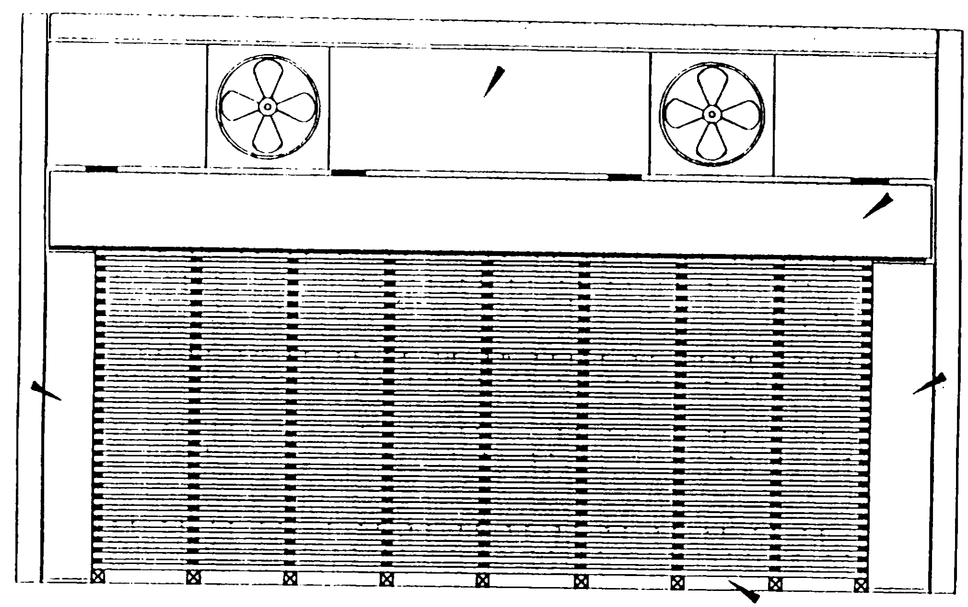
7. With the "SYSTEM" switch in the "OFF" position, plug in the power cable (the special receptacle for the L200 is supplied by Nyle.)

8. Install the fans in locations over the lumber as on the suggested chamber drawings.

9. The unit is now ready for the check out procedure.



DRAWN BY:	**NYLE CORPORATION** P. O. BOX 1107 BANGOR, MAINE 04402 USA TEL: 207 989 4335 FAX: 207.989.1101 EMAIL: dlewis@nyle.com		
APPROVED BY:			
	FIGURE 1		
	SCALE	DRAWING	REV



STACKING & BAFFLING

CLOSE ALL LARGE AIR GAPS SO THAT AIR CAN ONLY PASS THROUGH THE STICKER SPACE

CAREFULLY ALIGN STICKERS VERTICALLY

HINGED BAFFLE FROM FAN WALL TO FRONT EDGE OF LUMBER STACK

NYLE CORPORATION

FIGURE 3

L200 POWERED VENT KIT INSTALLATION INSTRUCTIONS (OPTIONAL)

Parts Included:

1 Johnson Thermostat
2 Aluminum Damper/Louvers
1 Vent Fam

Installation Steps:

The fan is installed on the suction side of the circulating fans so the opening that shows on the drawings as the intake becomes the exhaust and the opening that shows on the drawings as the exhaust becomes intake.

1. Install one louver over the vent on the inside of the chamber on the pressure side of the fans. Put it so that when the louvers are open, air is coming into the chamber. Leave the manual vent in place as a screened rain protector and leave it in the open position. This will now be the intake vent.

2. Remove the manual vent on the intake side (the same side as the L200 base unit). Install the aluminum louver provided with this package on the outside so that when the shutters are open, air is leaving the kiln. This will now be the exhaust vent.

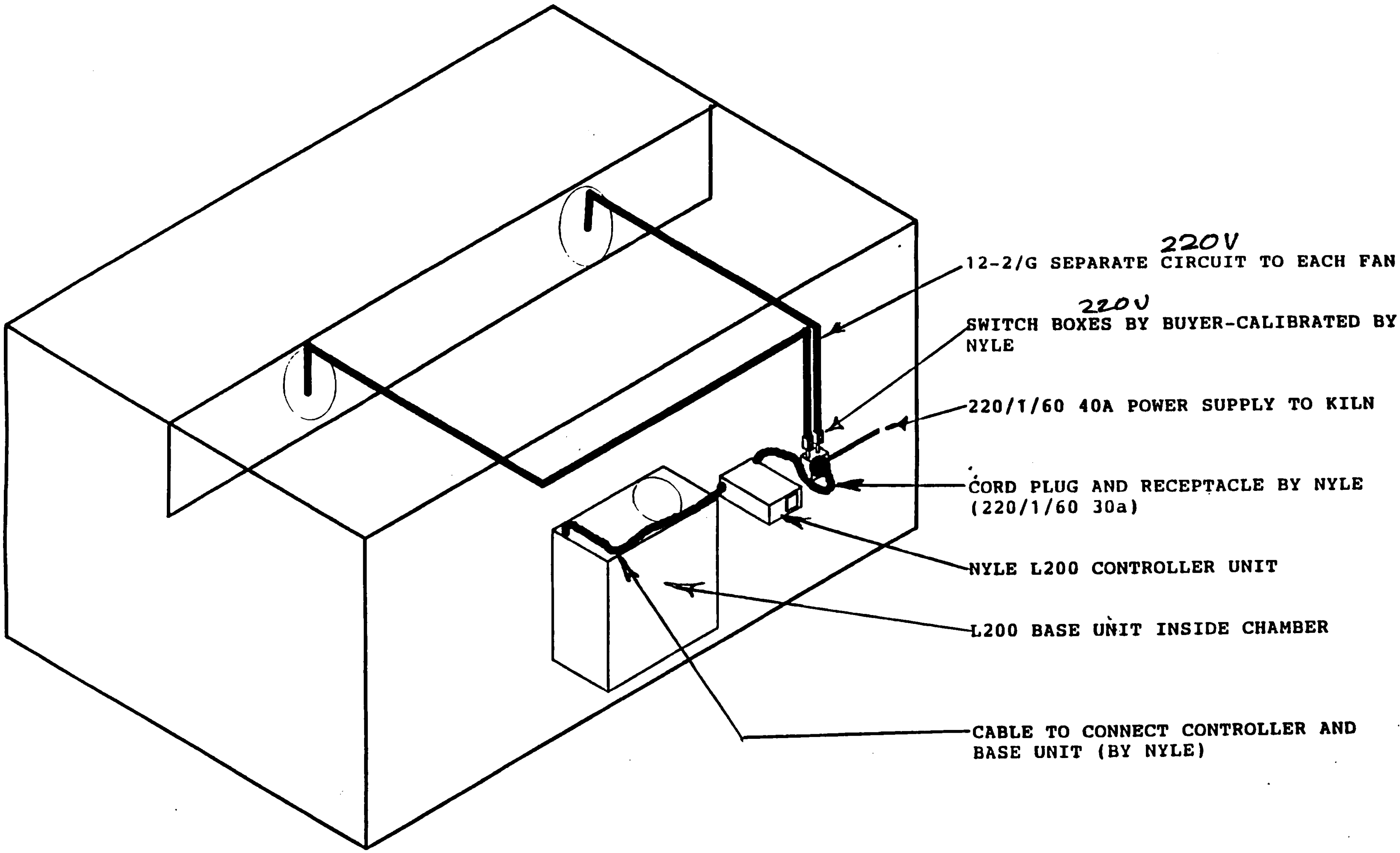
3. Install the exhaust fan in the new exhaust vent opening. The exhaust fan is inside the chamber blowing to the outside. The square aluminum box on the end of the fan is made to fit the opening.

4. Mount the thermostat outside the kiln with the sensor inside the chamber. Connect the sensor wires to the thermostat.

5. Wire from terminal 240 on the thermostat to terminal 6 on the terminal strip in the control unit of the L200. Wire from the terminal marked AC COM to terminal 3 on the terminal strip in the control unit of the L200.

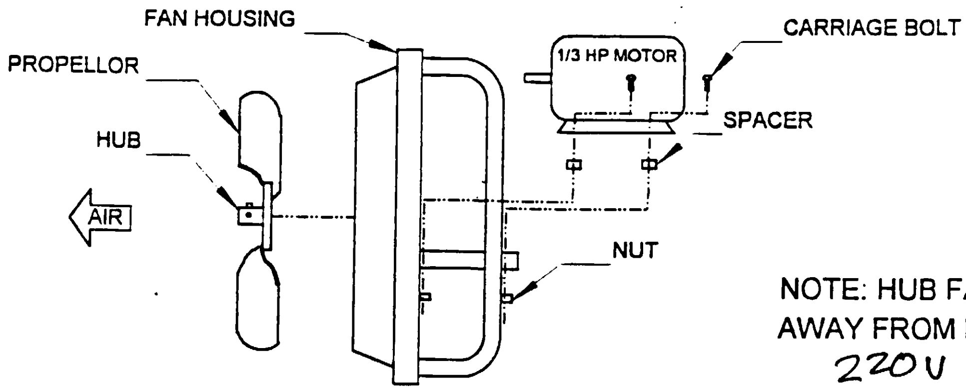
6. Be sure there is a jumper from terminal 240 on the thermostat to terminal C on the thermostat.

7. Run two wires from the thermostat to the new exhaust fan. Connect one wire from the motor to terminal NO on the thermostat and the other to terminal AC COM on the thermostat.



NYLE L200 FIELD WIRING

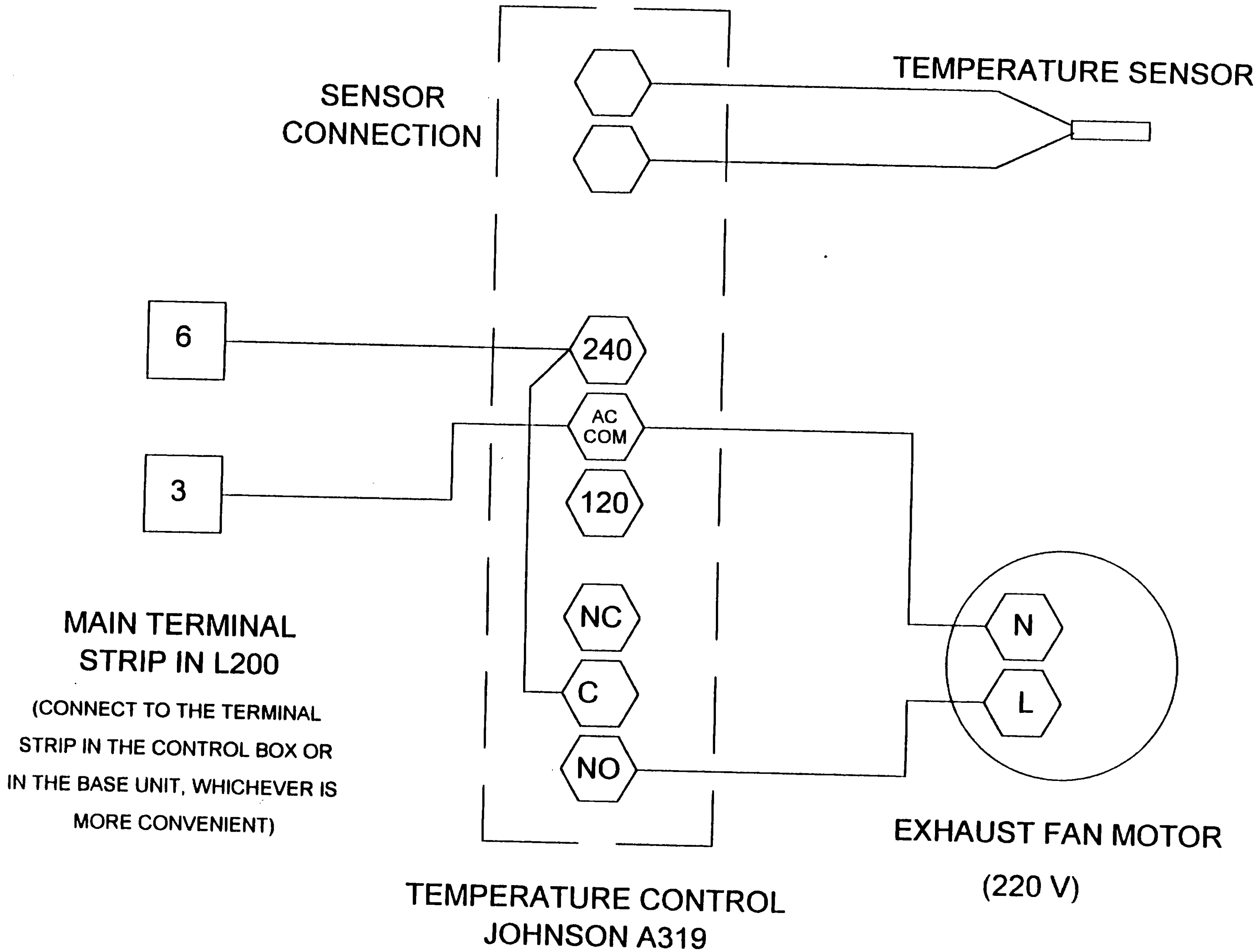
L-200 Fan Kit $225.00
− 10% OEM
202.50



NOTE: HUB FACES AWAY FROM MOTOR
220V 1ph 3A

1. MOUNT MOTOR ON BASE USING SPACERS, BOLTS AND NUTS PROVIDED
2. PLACE FAN ON MOTOR SHAFT SO THAT ONE SET SCREW MEETS THE FLAT OF THE SHAFT. TIGHTEN BOTH SET SCREWS.
3. ADJUST THE MOTOR SO THAT THE TIP OF THE BLADE IS EVENLY SPACED AND AT THE THROAT OF THE VENTURI

DRAWN BY:	**NYLE CORPORATION** P. O. BOX 1107 BANGOR, MAINE 04402 USA TEL. 207 989 4335 FAX 207 989 1101 EMAIL: [illegible]@nyle.com
APPROVED BY	
	L200 FAN ASSEMBLY
	SCALE / DRAWING / REV



WIRING DIAGRAM FOR POWERED VENT KIT WITH 220V L200

TABLE A

<u>LUMBER GROUPS</u>

Group 1		
	4/4 Softwood	Cedar, Eastern White Fir, Balsam Hemlock, Eastern Larch, Eastern Pine, Red (Norway) Pine, Eastern White Spruce, Black Spruce, Red Spruce, White
	4/4 Soft Hardwoods	Aspen Basswood Cottonwood Poplar
Group 2		
	4/4 Medium Hardwood	Ash, Black Ash, White Beech Birch, White Birch, Yellow Cherry, Black Elm, White Hickory Maple, soft Maple, Hard Sweetgum (Red gum) Tupelo (Black gum) Walnut
	8/4 Group 1 Woods	
Group 3		
	4/4 Hardwoods	Elm, Rock Oak, Red Oak, White
	8/4 Group 2 Woods	
Group 4		
	8/4 Group 3 Woods	

Sec 2

Drying Schedules Group I & II Woods

Moisture Content	Temp. °F.	Rh
Above 35%	90°	80%
35%–25%	100°	60%
25%–Final	120°	30%

Drying Schedules Group III Woods

Moisture Content	Temp. °F.	Rh
Above 35%	90°	85%
35%–25%	100°	60%
25%–Final	120°	40%

Note: With group II and III hardwoods, monitor the maximum drying rate limits for the species and thickness being dried. Adjust the Rh settings to change the drying rate, use the drying rate index (section 3 of this manual) for reference. For example, if the lumber is drying too slow or too fast, find a temperature or humidity where the index is higher or lower that the current settings.

TABLE B

NORTH AMERICAN MEASURE

NORTHEAST LUMBER - Based on 4/4 (1" OR 25 mm)

SPECIES	Oven Dry Weight #/MBF	Ave. Green MC %	Green Weight #/MBF	# Water per %MC	Max MC% loss/day
Eastern White Cedar	1578	93	3046	16	11
Fir, Balsam	1739	118	3790	17	20
Hemlock, Eastern	2161	111	4558	22	20
Larch, Eastern	2532	52	3849	25	20
Pine, Red (Norway)	2051	83	3747	21	15
Pine, Eastern White	1950	90	3705	20	12
Spruce, Black	2110	80	3798	21	20
Spruce, Red	2000	89	3781	20	20
Spruce, White	1840	115	3967	18	20
Ash, Black	2532	95	4937	25	07
Ash, White	3055	45	4431	31	05
Basswood	1899	107	3933	19	12
Beech	3114	63	5089	31	05
Birch, White	2692	73	4659	27	05
Birch, Yellow	2954	69	4996	30	05
Cherry. Black	2633	58	4161	26	07
Elm, Rock	3165	50	4760	32	3.5
Elm, White	2692	93	5207	27	10
Hickory	3325	64	5452	33	06
Maple, Soft	2692	93	4389	27	07
Maple, Hard	3165	68	5317	32	05
Oak, Red Upland	3277	74	5703	33	3.8
Oak, White Upland	3518	70	5981	35	2.5
Oak, Southern Red	3092	80	5567	31	02
Sweetgum (red gum)	2740	100	5480	27	5.3
Tupelo (black gum)	2740	100	5480	27	11
Walnut	2851	85	5274	29	08
Poplar, Cottonwood, Aspen	1899	154	4819	19	15

To estimate maximum MC loss per day for other thickness', multiply % Max MC loss per day from above table by 0.6 for 6/4 and 0.4 for 8/4.

TABLE B (METRIC)

NORTHEAST LUMBER - Based on 4/4 (1" or 25 mm)

Species	Oven Dry Weight	Ave. Green MC	Green Weight	Kg Water per	Max MC %
	Kg/M3	%	Kg/M3	% MC	loss/ day
Eastern White Cedar	315.6	93	609.2	7.27	11
Fir, Balsam	347.8	118	758	7.73	20
Hemlock, Eastern	432.2	111	911.6	10	20
Larch, Eastern	506.4	52	769.8	11.36	20
Pine, Red (Norway)	410.2	83	749.4	9.55	15
Pine, Eastern White	390	90	741	9.09	12
Spruce, Black	422	80	759.6	9.55	20
Spruce, Red	400	89	756.2	9.09	20
Spruce, White	368	115	793.4	8.18	20
Ash, Black	506.4	95	987.4	11.36	7
Ash, White	611	45	886.2	14.09	5
Basswood	379.8	107	786.6	8.64	12
Beech	622.8	63	1,017.8	14.09	5
Birch, White	538.4	73	931.8	12.27	5
Birch, Yellow	590.8	69	999.2	13.64	5
Cherry, Black	526.6	58	832.2	11.82	7
Elm, Rock	633	50	952	14.55	3.5
Elm, White	538.4	93	1,041.4	12.27	10
Hickory	665	64	1,090.4	15	6
Maple, Soft	538.4	93	877.8	12.27	7
Maple, Hard	633	68	1,063.4	14.55	5
Oak, Red Upland	655.4	74	1,140.6	15	3.8
Oak, White Upland	703.6	70	1,196.2	15.91	2.5
Oak, Southern Red	618.4	80	1,113.4	14.09	2
Sweetgum (red gum)	5,480	100	1,096	12.27	5.3
Tupelo (black gum)	548	100	1,096	12.27	11
Walnut	570.2	85	1,054.8	13.18	8
Poplar, Cottonwood, Aspen	379.8	154	963.8	8.64	15

To estimate maximum MC loss per day for other thickness', multiply % MC loss per day from above table by 0.6 for 6/4 and 0.4 for 8/4.

DRYING SCHEDULES

Each species of lumber has a maximum rate of drying (expressed as % loss/day) that can be tolerated without damage. Through experimentation by the U.S. Dept. Of Agriculture, and various Universities and others, these rates have been determined. Schedules have been developed based on time, dry bulb-wet bulb temperatures, and even automatic moisture content devices. Due to the many important variables that affect drying such as kiln chamber heat loss, air velocity, ambient temperature and humidities, vapor leaks, etc., the most important consideration of a schedule is that you do not exceed a safe drying rate.

The L50 and L200 drying systems dry lumber by controlling the temperature of the kiln and operating the compressor a known amount of time to remove a projected amount of water. If more water needs to be removed over 24 hours, then the compressor should operate proportionally longer during that 24 hours to remove the correct amount. The following schedules are therefore based on temperature and operating time. The compressor operates on one hour cycles, and can run none or all of that hour or almost any amount in between. It is very important to remember that water can leave the kiln by other means than the compressor. If the vent must be open to remove surplus heat, or there is a crack around the door gasket, or the floor is not insulated (allowing water to "sweat" and run down a drain or under a wall), moisture will leave at an uncontrolled rate. The following schedules are very conservative for these reasons. If your kiln is tight and well insulated, you will find these recommended drying rates to be slower than necessary.

The schedules are just starting points, with the actual drying rates determining the modifications. The drying rates in TABLE 1 are the rates to follow when first using the machine. These rates can be safely exceeded by an additional 50% (i.e., 1.0% can be raised to 1.5% and 3.3% can be increased to almost 5%) given careful judgment and operating experience for Groups 1, 2, and 3. Top quality moisture meters or weight samples must be used at these higher drying levels to avoid lumber damage. Some hardwoods, such as Southern Red Oak, White Oak, and Group 4 hardwoods should not use any sort of accelerated schedule.

Later, in this manual, is a section regarding degrade and a section on reducing degrade. While you are reviewing the sections, remember that these systems do not dry according to wet bulb schedules. If you are experiencing drying problems that cannot be pinpointed, a wet bulb hygrometer is available to give you the wet bulb and dry bulb readings in the kiln chamber. If references are made to lower the wet bulb temperature, take that to mean increasing the compressor running time. Also, to raise the wet bulb temperature is analogous to reducing the compressor running time.

Kiln Sample Boards

To measure moisture content on a daily basis, it is best to use sample boards. Moisture meters are not accurate enough for most hardwood dry kiln operations when the wood is above 30% MC and there is a need to keep a close watch on the drying rate. In Oak, for example, all checks and honeycombing occur when the wood is drying from green down to 40% MC, so that is when the drying rate needs to be closely controlled.

Sample boards are used:

- To estimate the MC of the load in the chamber, so that kiln conditions can be regulated according to drying schedules.
- To measure the drying rate, which allows control of drying quality
- To check on any degrade development.
- To check on final MC and drying stresses.
- To develop a MC vs. time curve.
- To study variations in drying within the kiln.
- To monitor changes in MC after drying (during storage and shipping) Note: It is a good idea to keep sample boards with dried lumber so that they can be used to track moisture content changes in storage.

When selecting sample boards, keep in mind that they need to represent a "sample" of the lumbar in the kiln. Do not select junk boards, and try to have both the slowest and the fastest drying boards of the load. Generally, you would have six sample boards.

1. Cut 30 inch sample boards no closer than 12 inches from the ends of the board. Avoid having knots, splinters, or bark in the sample board.

2. Number the sample boards.

3. Cut two 1 inch sections off each end of the sample board, and mark them with the number of the board they came from. For example, the two sections that came from sample board 3 would be labeled 3A and 3B.

4. Weigh all the 1inch sections, accuracy to 0.1 gram is suggested. Write down these "green weights".

5. End coat the sample board. This assures that the sample board will dry as though it were a larger piece of lumber.

6. Also weigh the rest of the sample board itself, to an accuracy of 0.025 pounds or 1 gram is recommended, and record these values.

7. Put the sample boards in the lumber stacks in places where they can be reached and will dry at the same rate as the rest of the lumber. Do not place the sample

boards where they will receive more air flow than the rest of the lumber.

8. Place the small sections in an oven at 215°F (101°C) until the section stops loosing weight, usually 24 hours. When the section weighs the same in one hour separate weighings, it is oven dry. OR use a microwave oven <u>with a carousel tray</u>. Put the sections on a paper towel around the outside of the tray. Use low power (to avoid smoking the sections) for 20 minutes. Weigh the section, and put back in the oven for 1 minute. If the section has not lost any weight, it is oven dry, if not, continue drying in 5 minute increments until a constant weight is achieved.

9. Calculate the moisture content of each section separately using the following formula:

   %MC= (wet weight/oven dry weight - 1) X 100

10. Average the moisture content of the two sections from each sample board to calculate the estimated moisture content of the sample board when it was cut.

11. Calculate what the oven dry weight of the sample board is using the following formula and the average moisture content (MC) from the previous step:

    Calculated OD weight = (wet weight/100 + MC) X 100

12. Write the calculated OD weight on the sample board so that it is readily available

13. At about the same time each day, weigh the sample boards and calculate the current moisture content with this formula:

    % MC = (current weight/calculated oven dry weight - 1) X 100

14. Place the sample board back in the same place in the kiln it came from.

15. Calculate the daily drying rate for each section. Keep all the figures written down as a record of the load. Make any adjustments to the schedule based on the fastest drying sample.

16. Once the moisture content of the kiln is below 20%, it is often a good idea to cut new moisture sections from the center of the sample board (1 section per board). Perform steps 4 to 13 only using 1 section (no need to average 2 sections per board). You will then have new oven dry weights calculated for the sample boards. This midcourse correction often provides more accurate results. Moisture meters are more accurate at this level also.

Example:

Two 1 inch sections are cut from 30 inch sample board 1, and labeled 1A and 1B. They are weighed on a balance, and the weights are: A=2.5g and B=2.3g. The sections are placed in microwave on low power for 20 minutes and weighed, weighing A=1.7g and B=1.6g. They are put back in the microwave for 1 minute and weighed again. The weights did not change, so these values are now the Oven Dry Weights. Calculate the moisture content using the formula in step 9.

A=2.5/1.7 - 1 x 100 = 47.06 B=2.3/1.6 - 1 x 100 = 43.75

Average the two calculations together (47.06 + 43.75)/2 = 45.40%. This is the calculated moisture content for the rest of the sample board.

Calculate the Oven Dry Weight of the sample board 1. Use the formula in step 11. The green weight is 1.64 kilograms.

ODW = 1.64/145.4 x 100 = 1.13 kg.

After a day in the kiln, weigh sample board 1 and it weighs 1.58kg. Using the formula in step 13, the moisture content is:

%MC = [1.58/1.13 - 1] x 100 = 39.8

The daily change in moisture content is : 45.4 - 39.8 = 5.6%.

FPRS

WOOD DRYING NEWS DIGEST

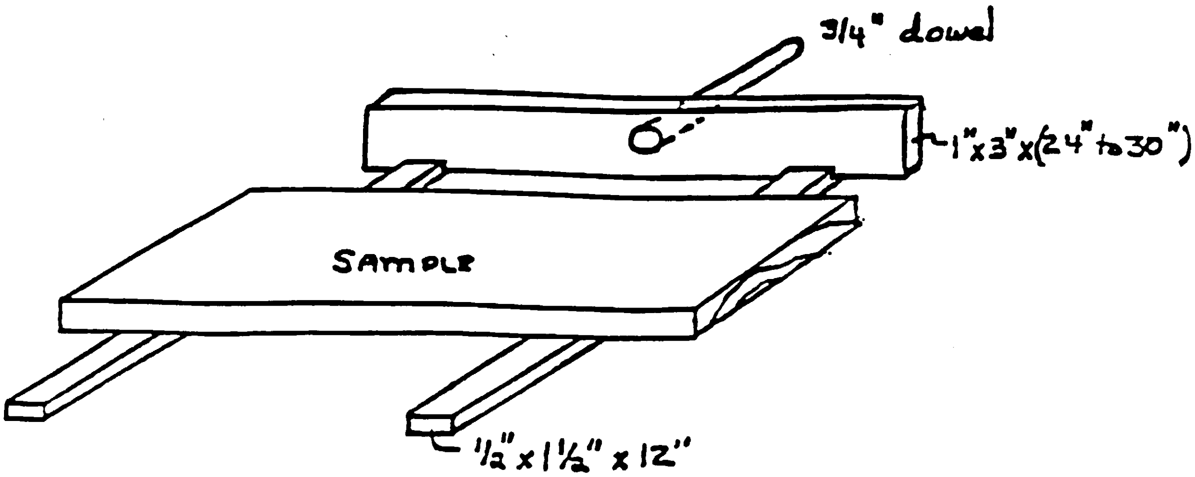
linking industry and research through effective technical communication since 1947

Feb. 1985 F-7.6

A SAMPLE BOARD HOLDER by Eugene M. Wengert, Department of Forest Products, Virginia Tech. Blacksburg VA.

Q: Where can I put the sample board in the kiln or pre dryer if I don't cut the sample pocket suggested in "the book'?

A. The greener the lumber, the more critical it is to put the sample in a pocket, as that procedure is what the schedule is based on. In lieu of this, although the results are not good with green lumber, the sample can be placed in the 4 x 4 space if the air flow is somewhat blocked off. A sample board holder is an effective way to use the 4 x 4 space without much error and thereby automatically block off some of the air. Generally, the sample will need to be cut when the MC is below 25 percent. The sample may also check more, but warp and stain less than the rest of the load. (Note: The sample may be either cross wise or parallel to the airflow.)



SIDE VIEW

Published by: Drying & Storage Technical Committee
Forest Products Research Society, 2801 Marshall Court, Madison Wisconsin 53705 USA 608/231-1361

Wet Bulb Depression (Dry Bulb - Wet Bulb) °F

Bulb °F		2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	25°	30°	35°	40°	45°	50°
55°	RH	88	76	65	54	44	34	24	14	5							
	EMC	19.5	15.1	12.2	10.1	8.4	6.8	7.3	3.6	1.3							
	DRI	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4							
60°	RH	89	78	68	58	48	39	30	21	13	5						
	EMC	19.9	15.6	12.7	10.7	9.1	7.6	6.3	4.9	3.2	1.3						
	DRI	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5						
65°	RH	90	80	70	61	52	44	36	27	20	13						
	EMC	20.3	16.1	13.3	11.2	9.7	8.3	7.1	5.8	4.5	3.0						
	DRI	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.5						
70°	RH	90	81	72	64	55	48	40	33	25	19	3					
	EMC	20.6	16.5	13.2	11.6	10.1	8.8	7.7	6.6	5.5	4.3	0.7					
	DRI	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7					
75°	RH	91	82	74	66	58	51	44	37	31	24	10					
	EMC	20.6	16.8	14.0	12.0	10.5	9.3	8.2	7.2	6.2	5.1	2.3					
	DRI	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8					
80°	RH	91	83	75	68	61	54	47	41	35	29	15	3				
	EMC	21.0	17.0	14.3	12.3	10.9	9.7	8.6	7.7	6.8	5.8	3.5	0.3				
	DRI	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.9	1.0				
85°	RH	92	84	76	70	63	56	50	44	38	33	20	9				
	EMC	21.2	17.2	14.5	12.5	11.2	10.0	9.0	8.1	7.2	6.3	4.3	1.7				
	DRI	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.8	1.0	1.1				
90°	RH	92	85	78	71	65	58	52	47	41	36	24	13	3			
	EMC	21.3	17.3	14.7	12.8	11.4	10.2	9.3	8.4	7.6	6.8	4.9	2.8	0.9			
	DRI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.1	1.2	1.4			
95°	RH	92	85	79	72	66	60	55	49	44	39	28	17	8			
	EMC	21.3	17.4	14.9	12.9	11.6	10.5	9.5	8.7	7.9	7.1	5.3	3.6	1.9			
	DRI	0.1	0.2	0.3	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.2	1.4	1.5			
100°	RH	93	86	80	73	68	62	56	51	46	41	30	21	12	4		
	EMC	21.3	17.5	15.0	13.1	11.8	10.6	9.6	8.9	8.1	7.4	5.7	4.2	2.8	0.7		
	DRI	0.1	0.3	0.4	0.5	0.6	0.7	0.9	0.9	1.0	1.1	1.4	1.5	1.7	1.9		
105°	RH	93	87	80	74	69	63	58	53	48	44	34	24	16	8		
	EMC	21.4	17.5	15.1	13.2	11.9	10.8	9.8	9.0	8.3	7.6	6.1	4.6	3.3	1.8		
	DRI	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.7	1.9	2.1		
110°	RH	93	87	81	75	70	65	60	55	50	46	36	26	19	11	4	
	EMC	21.4	17.5	15.1	13.3	12.0	10.8	9.9	9.2	8.4	7.7	6.3	4.8	3.8	2.5	1.1	
	DRI	0.2	0.3	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.7	1.9	2.1	2.3	2.5	
115°	RH	93	88	82	76	71	66	61	56	52	48	38	29	22	14	8	2
	EMC	21.4	17.5	15.1	13.4	12.1	10.9	10.0	9.3	8.6	7.8	6.5	5.2	4.1	2.9	1.7	0.4
	DRI	0.2	0.4	0.5	0.7	0.9	1.0	1.2	1.3	1.4	1.6	1.9	2.1	2.4	2.6	2.8	2.9
120°	RH	94	88	82	77	72	67	62	58	53	49	40	31	24	17	10	5
	EMC	21.3	17.4	15.1	13.4	12.1	11.0	10.0	9.4	8.7	7.9	6.6	5.4	4.4	3.3	2.3	1.1
	DRI	0.2	0.4	0.6	0.8	1.0	1.1	1.3	1.4	1.6	1.8	2.1	2.4	2.6	2.9	3.1	3.3
125°	RH	94	88	83	77	73	68	63	59	55	51	41	33	26	19	13	8
	EMC	21.2	17.3	15.0	13.4	12.1	11.0	10.0	9.4	8.7	8.0	6.7	5.5	4.6	3.6	2.7	1.6
	DRI	0.2	0.5	0.7	0.9	1.1	1.3	1.5	1.6	1.8	1.9	2.3	2.7	2.9	3.2	3.4	3.6
130°	RH	94	89	83	78	73	69	64	60	56	52	43	35	28	21	15	10
	EMC	21.0	17.2	14.9	13.4	12.1	11.0	10.0	9.4	8.7	8.0	6.8	5.6	4.8	3.8	3.0	2.0
	DRI	0.3	0.5	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.6	2.9	3.3	3.6	3.9	4.1
140°	RH	95	89	84	79	75	70	66	62	58	54	46	38	31	25	19	14
	EMC	20.0	16.9	14.8	13.2	11.9	10.9	10.0	9.4	8.7	8.0	6.9	5.8	5.0	4.1	3.4	2.6
	DRI	0.3	0.6	0.9	1.2	1.5	1.8	2.0	2.2	2.5	2.7	3.2	3.7	4.1	4.4	4.8	5.1
150°	RH	95	90	85	80	76	72	68	64	60	57	48	41	35	28	23	18
	EMC	20.2	16.6	14.5	13.0	11.8	10.8	9.9	9.2	8.6	8.0	6.9	5.8	5.1	4.2	3.6	2.9
	DRI	0.4	0.8	1.1	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.9	4.5	5.0	5.5	5.8	6.2
160°	RH	95	90	86	81	77	73	69	65	62	58	50	43	37	31	25	21
	EMC	19.8	16.2	14.2	12.7	11.5	10.6	9.7	9.1	8.5	7.9	6.8	5.8	5.1	4.3	3.7	3.2
	DRI	0.5	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.7	4.1	4.8	5.5	6.1	6.7	7.2	7.6

Dry Bulb is the temperature as measured by a thermometer.

Wet Bulb is the temperature of a thermometer with a wet wick over the sensor.

Wet Bulb Depression is the difference between the dry bulb temperature and the wet bulb temperature. For example, if the dry bulb is 105° and the wet bulb temperatures 98°, the depression is 105-98, or 7°.

RH - Relative Humidity. The ratio of the amount of water in the air to what the air could hold. At 50% RH, the air has 50% as much water in it as it would hold at 100% RH. 100% is a 0° depression.

EMC -Equilibrium Moisture Content. This is the average moisture content all wood will reach eventually when exposed to these conditions. For example, at a dry bulb of 115° and a wet bulb of 101°, a 14° depression, the EMC is 10%. This means that eventually all wood will average 10%. Wood drier than 10% will pick up water and wood that is wetter than 10% will give up water.

DRI - Drying Rate Index. This is an index of relative drying rate. For example, if a dryer is operating at 120° and a wet bulb depression of 12°F, and drying the load at a rate of 1.5% per day, at the DRI is 1.1. If the conditions were changed to 130° and a 20°F depression, DRI is 2.2. The wood will dry at 2 times the rate (2.2/1.1=2), or 3% per day. This assumes that other conditions remain the same (airflow, stacking etc.)

Sec 3

DRYING RATE INDEX (DRI)

The dry kiln industry has never had a method of predicting drying rates. This is remarkable as one main reasons for having a kiln is to bring about predictable production rates. The EMC values give and end point of what the moisture content of the lumber would eventually become but it does not give any indication of how long it will take to reach that moisture content.

Drying schedules developing dehumidification drying in the late 1970's. It became obvious that a method of adjusting kiln schedules to meet drying time objectives within the limitations of the operating range of the dehumidifiers, had to be found. It was common to look up a drying schedule in the *Dry Kiln Operator's Manual* or some other reference, and then find a set of conditions at which dehumidifier could run using the same EMC. This resulted in unnecessarily long drying cycles and was quickly shown to be an ineffective method of doing kiln schedules.

Nyle developed the Drying Rate Index in response to that but time has shown that the Drying Rate Index is very useful in both conventional and dehumidification kilns. With the trend to control kilns by monitoring drying rate to get maximum productivity and quality, the Drying Index becomes a very valuable tool.

The drying rate is a function of the vapor pressure deficit. Everyone knows that things dry faster in hotter, drier air. Every fluid has a vapor pressure associated with it that varies with the temperature of the fluid. Air has a vapor pressure that is a function of temperature and humidity. The difference between the two determines the rate of drying. This is how everything in the world dries whether it is paint, the ocean, lumber or perspiration. When the humidity of the air is 100% no evaporation takes place regardless of temperature. As the relative humidity drops, the rate that fluids evaporate increases. The problem is that a way of predicting the change in drying rate with changes in temperature and humidity was needed.

The Drying Rate Index is a relative number. For example, if a kiln is operating at 120°F dry bulb and 110°F wet bulb, that means the depression is 10° (120°F - 110°F =10°F). According to the Nyle Drying Chart, the relative humidity is 71%, the Equilibrium Moisture Content (EMC) is 12.1% and the Drying Rate Index (DRI) is 0.9. The EMC indicates where the lumber will end eventually. The EMC is also an indication of where the surface moisture content of the lumber will go fairly quickly. The whole board will eventually be 12.1% but the surface will reach 12.1% much quicker.

In the above example, the lumber might be drying at 3% per day but it could be dried at 5% per day. In order to change the drying rate from 3% per day to 5% per day, it would be necessary to find a DRI that is 1.67 times the existing drying rate.

Desired Drying Rate/Existing Drying Rate=Multiplier. (5/3 = 1.67)

Multiplier x Existing DRI = Desired DRI

The existing DRI is 0.9 so the new DRI should be 1.5(0.9 x 1.67)

Referring to the Nyle Drying Chart, it can be seen that if the temperature were increased to 130°F and the depression 15° (read between 14 and 16 on the chart), the DRI will be 1.5. Other combinations of dry bulb and depression will give the same result. For example, the dry bulb could be left at 120° and the depression increased to 17°, or the dry bulb could be raised to 140°F and the depression left at 10°. All of these would result in a 1.5 DRI and thus would dry the lumber at 5% per day.

Note that in the above three choices, 130/15, 120/17 and 140/10, the EMC is 9.7, 9.1 and 11.7 respectively. It is clear that EMC has nothing to do with how fast lumber dries but it does mean that low temperatures and bigger depressions may mean the surface moisture content will be lower. In some cases, were this pressed to an extreme, it may make the surface shrink too much so that factor should be considered.

The best way to use the drying chart is to check the kiln each day. Calculate the moisture loss and then adjust the kiln temperature and humidity each day to achieve the drying rate desired. Each charge of lumber will be different and will result in a different drying schedule. For this reason, it will be clear that drying schedules are of little use except as a starting point. None of the drying schedules published state at what airflow they were developed. So running a schedule from a manual or another operation is ineffective as the airflow in the kiln may be different and may change through the cycle if variable speed fans are used.

REPRINTED FROM: *FPRS WOOD DRYING NEWS DIGEST* B-4.11 April 1984

"Using a Home Microwave Oven for Oven-Drying"

Gene Wengert. Department of Forest Products. VA Tech. Blacksburg. VA 24061

Many times in wood products manufacturing, we need to know the MC of wood The process of measuring MC accurately typically involves cutting a small sample. weighing it. oven-drying it for 24-hours and reweighing it. The microwave oven can be used in the process to oven-dry small samples or sections in order to obtain their MC in minutes rather than in hours or days. Tests we have conducted with oak show that the MC's from the microwave oven are identical to standard hot-air oven-drying at 217°F.

In the dry kiln operation, we have the sample board method of estimating MC using moisture sections. This microwave oven technique is not meant to replace the sample board method. Rather, with the microwave, the time involved in oven-drying the sections can be shortened to minutes, providing better information on MC's for kiln operation. especially for startup and shut-down.

The major requirement for this technique is that the microwave oven can only be used successfully by following special procedures. These special procedures are required because (1) microwave energy in the oven is not uniformly distributed resulting in non-uniform drying of the wood samples. and (2) overdrying is likely resulting in smoking and burning of the samples.

The correct procedures are:

(1) Cut a 1-inch along-the-grain moisture section or sample. as is typically done for hot-air oven-drying methods. Weigh this section immediately after cutting.

(2) Place the wood sections on a paper towel near the outside edge or the carousel tray. not in the center. (This prevents uneven drying.)

(3) Use a medium-low or low power setting. (This prevents smoking of the sections.) The time required for oven-drying is approximately 10-minutes for dry pieces and 20 minutes or longer for wetter pieces.

(4) Weigh the section after the initial drying and then dry for an additional minute. Reweigh the section. If the section weights are the same, then it is oven-dry.

(5) Use the same formula to calculate MC with a microwave oven as with a hot-air oven.

Published by: Drying & Storage Technical Committee
Forest Products Research Society
2801 Marshall Court Madison Wisconsin 53705 U.S.A.
608/231-1361

Cooperative Extension Service

University of Maine, Orono

EQUALIZING MOISTURE CONTENT AND CONDITIONING FOR STRESS RELIEF

by

Gregory Baker, Professor of Forestry

School of Forest Resources, University of Maine

This paper was presented at the Dry Kiln Operators Winter Meeting at Farmington State College, Farmington, Maine, December 19, 1967, sponsored by the School of Forest Resources and the Office of State Technical Services of the University of Maine. This is Dry Kiln Note No. 2 of the School of Forest Resources. Slightly revised by the author and Editor Lewis P. Bissell, Extension Forester, University of Maine, in March 1970.

Published and distributed in furtherance of Acts of Congress of May 8 and June 30, 1914, by the Cooperative Extension Service, Edwin H. Bates, Director - The University of Maine and the United States Department of Agriculture cooperating.

EQUALIZING MOISTURE CONTENT AND CONDITIONING FOR STRESS RELIEF

The term equalizing used in connection with drying is just what the word implies. We are attempting to narrow the range of moisture content between the inside and the outside of the pieces of lumber and to narrow the range in moisture content between different pieces in the charge.

Let us look a moment at the moisture distribution pattern in a piece of lumber which is drying. Moisture is evaporating from the surface. This lowers the moisture content of the surface below that of the interior, in other words, a **moisture gradient** is established and this is maintained as long as drying takes place, although the pattern of the gradient changes as the moisture content of the lumber is reduced. In the early stages of drying there is a large difference in moisture content between outside and interior, while in the late stages of drying the difference is much less.

If we cut a sample from a plank which has been partially dried and then split off thin sections, progressing from one face to the other, make moisture content determinations of each, and then plot these values we would have a curve somewhat like curve A in figure 1. Where the curve intersects the edges of the graph, which represents the board surface, the moisture content is equivalent to the equilibrium moisture content (EMC) of the surrounding air.

In order to maintain a satisfactory drying rate in a dry kiln the EMC is lowered from time to time. For example, if the final target moisture content was 8%, the EMC in the final stages of drying might be set at 3%. Some boards always dry faster than others, so when the target moisture content is being approached the driest should be watched in order to prevent them from reaching too low a moisture content. The rule of thumb used is: when the driest samples have an average moisture content 2 percent below the target moisture content, start equalizing. To accomplish this the EMC is set at this target moisture content **minus** 2 percent, or in our example, at 6 percent EMC.

Now what happens? First let us see what our moisture gradient is in these dry samples. If the average moisture content is 6% and the EMC is 2%, the moisture content at the center will be approximately 8%*, that is, there will exist a moisture gradient from 8% in the center to 2% at the surface. This is a much flatter moisture gradient curve than existed in the earlier stage of drying. See Curve B in Figure 1. Raising the EMC from 2% to 6% will result in some moisture pick-up at the surface of the boards thus narrowing the range of moisture content within the board. During this process the wetter boards are continuing to dry, at a slower rate, but still drying while the drier boards are being prevented from losing moisture.

---

*computed with the approximation equation:

$$Y = 3/2\ (A - EMC) + EMC$$

where Y equals moisture content percent at mid-thickness and A equals the average moisture content percent of the piece.

The equalizing process should continue until the range of average moisture content between boards comes within the tolerances which are satisfactory for the end use of the product. At the same time the moisture gradient within the boards is also reduced.

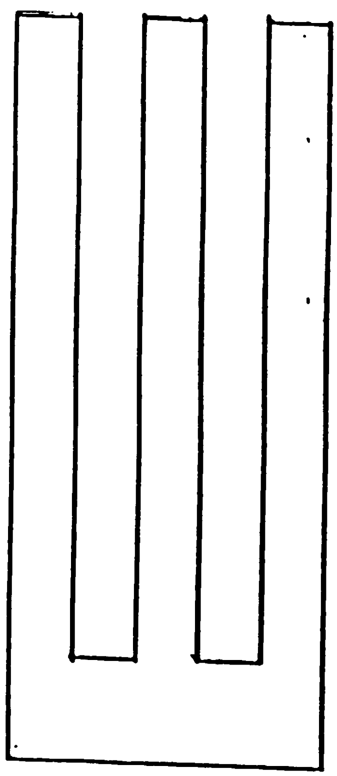
Once the charge had been equalized we are ready to relieve seasoning stresses. It is inevitable and unavoidable that stresses develop in lumber in the process of drying. Good drying practice attempts to keep these stresses low enough so that they will not damage the wood, notably through the development of checks.

In order to understand what we are doing when we condition we should also understand how these residual stresses come about. Actually the process is very complicated and does not lend itself well to mathematical analysis. It simplifies the matter (perhaps to the point of **over** simplification) if we think of the cross section of a piece of lumber as made up of two areas, i.e., the shell and the core. See Figure 2a. At the start of drying, moisture evaporates from the shell and it soon starts to shrink. Due to the moisture gradient, the core is still green and full size. Consequently, the shell becomes stretched over this core, that is, it develops a tensile stress perpendicular to the grain. If this stretching is carried on to the point of failure, checks will develop. The stretched shell exerts a compressive force on the core similar in nature to the compressive force that would be exerted on a piece of wood if a heavy elastic band were stretched around it. These internal stresses, compression and tension, are equal and opposite, that is, they are in balance within the lumber. The shell dries in this stretched condition and takes a permanent set. If it were sliced away from the rest of the wood it would become **somewhat** shorter but would also retain some of its stretched dimension. It has taken on a tension set. It is possible, under certain conditions, that the shrinking shell will exert enough pressure on the core to cause a compression set in that area.

Let us now consider the stage of drying where enough moisture has moved out of the core so that **it** starts to shrink. Now, visualize, if you can, what is happening. The shell is larger than normal due to the tension set it has acquired. The core tends to shrink normally but it will be resisted to some extent by the shell. The original balanced stresses of tension in the shell and compression in the core become reversed with tension in the core and compression in the shell. Fig. 2b. It is at this point that checks may close up and also where honeycombing may start in the interior.

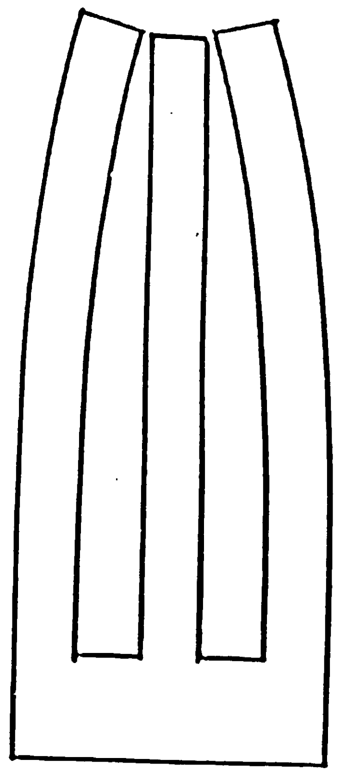
How does conditioning relieve this stressed condition? If we raise the humidity in the kiln the shell will absorb moisture and will swell. Swelling will be resisted by the core which has not changed in moisture. With swelling, the compressive stress in the shell is increased. If the shell is swelled just enough it will compress the wood and remove the tensile set developed in the early stages of drying and thus relieving the internal stresses in the wood. The usual recommendation is that the EMC used for conditioning be 2 to 3 percent above the desired final target moisture content. This higher EMC is necessary to overcome the natural lag in effect when wood reabsorbs moisture.

The standard test for drying stresses is to cut a cross section from a piece of lumber one inch or less along the grain and saw this into prongs. If the lumber is casehardened the outer prongs will turn inward. Fig. 3b. If the conditioning has been successful the prongs will remain straight on cutting. Fig. 3 a. Such stress-free lumber is ready for further manufacture or use with a minimum of loss.



Stress-free

Figure 3a



Casehardened

Figure 3b

Types and Causes of Drying Degrade

by

Gene Wengert

Prepared for:
Nyle Corporation
P.O. Box 1107
Bangor, Maine 04401

Dr. Wengert is well known in the lumber industry for his ability to translate complex scientific research into practical, common-sense ideas. He conducts many drying seminars for management and operators and conducts many in-plant quality assessments. He worked at the US Forest Products Lab for 15 years before joining Virginia Tech. in 1976.

Types and Causes of Drying Degree

Background

Drying degrade is the loss of value or the loss of quality that occurs during drying. Loss of **value** includes checks, splits, warp, and so on that reduces the NHLA grade of lumber. The loss of **quality** in drying may include both the losses recorded by NHLA grades and the losses that show up as subsequent manufacturing occurs, such as too wet lumber, casehardening and honeycomb. Quality losses are often difficult to measure. Quality losses may occur without a loss of NHLA grade. (For example, end splits and surface checks will often times not affect the grade but will affect the yield of furniture parts.)

The US forest Service has measured the losses in air drying in Pennsylvania. These losses vary with species, the heavier and more expensive species have more degrade.

Table 1 -- Value* Losses in Air Drying

Species	Loss
Basswood	8%
Birch	6%
Hard Maple	14%
Red Oak	13%
White Oak	15%

*Based on 1983 lumber prices and NHLA grading before and after drying.

In addition, the US Forest Service study shows that the losses are greater for the upper grades.

Table 2 -- Value* Losses in Air Drying

Grade	Red Oak	White Oak
FAS Select	6-10%	8-11%
No. 1 Common	7	10
No. 2 Common	2	4
No. 3A Common	4	7
No. 3B Common	1	2

These degrade losses become more important when it is recognized that degree losses can be expensive as the total operating expenses.

Table 3 -- Operating Costs for Drying

Item	Cost
Stacking	$20
Air Drying	$30-50
Kiln Drying	$20-50
Subtotal	$50-120
Degrade	$20-80

Based on a Va Tech drying cost assessment report for 1983.

The degree costs in Table 3 are only the value losses and do not include subsequent manufacturing problems due to improper drying such as excessive casehardening or too wet lumber. Also, another important concept is for the costs of drying listed above, degrade is the major item that can be controlled to reduce costs; the other cost items can be reduced only slightly with improved efficiency.

Causes of Degrade

There are five fundamental causes of drying degrade. It is as simple as this.

1. Drying too fast
2. Drying too slowly
3. Poor stacking
4. Operational errors
5. Wood-related factors

Let's relate these causes to the various types of degrade.

Drying Too Fast will result in surface checking, end checking, internal checks (honeycomb, fine hairline cracks, and bottleneck checks), splits and cracks, and collapse.

Drying Too Slowly will result in stain (both fungal stain such as blue stain, chemical stain such as sticker stain, brown stain, and the like), mold, mildew, decay, and warp, especially cupping.

Poor Stacking results in warp, especially bow and twist, and uneven drying.

Operational Errors result in lumber that is too wet (usually very serious) or too dry, drying stresses (casehardening) that are not removed, resin in softwoods that is not "set" and loss of aromatic odors (in red cedar).

Wood-Related Factors result in ring failure (or wind shake), bad odors, checked and loosened knots, box heart splits, fallen knots, and warp, especially crook. These defects are inevitable and are not controllable in drying. In addition to the above five categories, there are also manufacturing defects that occur in subsequent processing that are directly related to and a result of drying procedures. These processing defects include machining problems (including raised grain, chipped grain, fuzzy grain, torn grain, planer splits, saw pinching, non-straight cuts, flying out of lathe and kickbacks); gluing problems (including open joints and weak joints); and miscellaneous problems such as panel warping, panel end splits, and many finishing problems. Most processing defects are related to incorrect MC of the lumber; the lumber should be dried to a MC within 2% of the MC it will be at in storage., manufacturing, and use. The MC after drying is related directly to the relative humidity of the air.

Table 4 – Summary of Dominant Causes of drying Degrade

Type	Drying too Fast (Velocity too high) (RH too high)	Drying too Slowly (Velocity too low) (RH too low)	Poor stacking	Operational Errors	Wood Related Factors
Surface checks	X	X		X (1)	X (2)
End checks	X				
Internal Checks	X			X (3)	X (2)
Splits/cracks	X				X (4)
Collapse	X				X (5)
Blue Stain		X	X		
Mold, Mildew		X	X		
Decay		X	X		
Coffee or brown stain		X	X	X	X (2&5)
Sticker Stain			X	X (6)	
Pinking				X (7)	
Twist					X (8)
Cup		X		X (9)	X (10&11)
Bow			X		X (8)
Crook					X (4)
Diamond/oval					X (11)
Warp after drying				X (12)	
Uneven drying		X	X		X (13)
Too wet				X (14)	
Too dry				X (14)	
Casehardened				X (14)	
Resin not set				X (15)	
Ring failure/wind shake					X (2)
Loss of aromatic odor				X (16)	
Loosened knot	X				
Checked knot	X				
Heart split					X (11)
Raised grain					X (18)
Chipped, fuzzy, torn grain				X	X (19)
Planer splits				X (9)	
Bad smell					X (2)
End splits after drying				X (11)	

Notes:
1. Rewetting a dried surface; too high a temperature initially
2. Bacterially infected wood
3. Rewetting a dried surface; too high a temperature above 30% MC
4. Tension wood, compression wood, juvenile wood
5. Enzymatic oxidation reaction influenced by temperature, humidity, and MC
6. Wet stickers or wide stickers
7. Excessive temperature

9. Too dry or casehardened
10. Lumber from small diameter trees
11. Difference between radial and tangential shrinkage
12. Change in MC of lumber after drying; lumber MC not equal to air's EMC
13. Mixed species; heart/sap; thick/thin; lowland/upland;variable velocities
14. Poor samples; incorrect MC measurements; equipment problems; poor schedule or procedures
15. Softwoods only; use 160 degrees F or higher
16. Keep temperatures below 90 degrees F
17. Knot was held only by resin in tree
18. Density differences springwood to summerwood and equipment set-up
19. MC too high ot too low; equipmentset-up

Table 5 -- MC of Lumber after Long-term Exposure to Specified Relative Humidity

RH	MC of lumber
0%	0%
30	6%
55	10
77	15

Summary

Drying degrade is an expensive part of lumber drying, but wit exceptions is totally controllable. A well trained operator following specified procedures annd using common sense with proper equipment can limit degrade to within 2%.

CONTROLLING DRYING TO ACHIEVE ZERO DEFECTS

by

Gene Wengert

Prepared for:
Nyle Corporation
P.O. Box 1107
Bangor, Maine 04401

Dr. Wengert is well known in the lumber industry for his ability to translate complex scientific research into practical, common-sense ideas. He conducts many drying seminars for management and operators and conducts many in-plant quality assessments. He worked at the US Forest Products Lab for 15 years before joining Virginia Tech. in 1976.

Controlling Drying to Achieve Zero Defects

Degrade in lumber drying -- that is, the loss of value and/or quality during drying due to warp, splits, checks, stain and so on -- is not inevitable but can be controlled easily and effectively by the operator of the drying equipment. The first step in controlling degrade is to identify the type and the basic cause of the degrade. Then changes in procedures or equipment can be made to correct the problem. Because degrade losses can be very high and can affect subsequent processing, considerable effort should be made to run drying equipment properly and use accepted procedures. The key to degrade control is understanding how wood dries.

How Wood Dries.

There are three environmental factors* that influence the drying of wood. These are temperature (often called the dry bulb), humidity (often traditionally referred to as the wet bulb), and air velocity.

Temperature. Water in wood moves more rapidly (i.e., wood dries faster at higher temperatures. In most cases drying is more uniform at higher temperatures (for example, 85° F vs. 100° F). Also, higher temperatures in conventional kilns save energy , (Although heat loss through the wall is increased, faster drying, more efficient venting, and better equipment performance offset this loss.) As a result, higher temperatures are better then low temperatures.

On the other hand, wood is weaker at higher temperatures. (For example 100° F to 120° F can reduce some strength properties by over 10%.) Therefore, lower temperatures are preferred. As a result of weaker wood (and faster drying), for some species -- most notably oak and beech, but most all species are affected -- raising the dry bulb temperature will increase degrade when the wood is at MC's above 20%. The problem is worse when lumber is thicker. On the other hand, there are problems with temperatures that are too low as well, as mentioned above.

------

*In air drying two other factors -- precipitation and wind blown dust -- also influence degrade.

As a result, the drying procedures must use a compromise initial temperature, not too low -- usually below 90° F is too low -- and not too high-- not above

115° F for oak and up to 160° F for yellow-poplar, basswood, and soft maple. Below 20% MC, the strength loss due to higher temperatures is offset by drier wood, so elevated temperatures can be used.

Table 1 -- Temperature Sensitivity of 4/4 Lumber

Range of Recommended Initial Temperature

115° F and below	115-135° F	over 135° F
Oak	Apple	Aspen
Redwood	Ash	Basswood
	Beech	Paper birch
	Yellow birch	Cottonwood
	Cherry	Sap gum
	Elm	Yellow-popular
	Hickory	Fir
	Maple	Hemlock
	Walnut	Pine
	Spruce	

Note: Use standard schedules religiously when first drying a new species.

Humidity. Water in wood moves more rapidly as the relative humidity is lowered (which at a constant dry bulb temperature is the same as lowering the wet bulb temperature or increasing the depression. Similarly, drying is more uniform at lower relative humidities, both uniformity end-to-end and through the load. Also, warp is less at lower humidities. However, the faster drying rates for some species can, during the loss of the first 1/3 of moisture from the green condition, create increased degrade due to surface checking. Therefore higher humidities are preferred to control degrade.

As a result, the humidity in a kiln is a compromise between the benefits of low humidities and the benefits from high humidities. One inch oak and beech may use initial humidities as high as 88%, while basswood can tolerate initial humidities as low as 40%. The exact initial humidity recommended is based on the dry bulb temperature velocity.

Table 2 -- Sensitivity of Lumber to Initial Humidity

Range of Recommended Initial Relative Humidity

Above 85% RH	78 to 84% RH	Below 78% RH
Apple	Ash	Aspen
Beech	P. Birch	Sap gum
Hickory	Y. Birch	Fir
Oak	Cherry	Pine
	Elm	
	Maple	
	Walnut	
	Yellow-popular	
	Hemlock	
	Spruce	

Velocity. The velocity of air affects the drying of lumber when the MC is greater than 40%. The higher the velocity the faster the drying and the more uniform the drying. (Uniformity is greatly decreased at lower temperatures (below 90 F) and higher humidities (above 80%) such as conventional warehouse-type predryers).

On the other hand, higher velocities are likely to cause checking for some species if drying is too rapid. As before, the preferred conditions are a compromise between the benefits and the risks. In most kilns, a velocity of 300 -350 feet per minute through the load of lumber, measured on the "leaving air" side is desired, although higher velocities for some species such as aspen, gum, soft maple, fir, and pine are acceptable.

Operating Guideline

There is a complex relationship between RH and velocity. When velocities are below 300fpm, the humidities can be lowered safely; when velocities are in excess of 350 fpm, the humidity usually must be higher than typical. The overall effort in controlling degrade by manipulating humidity and velocity is to control the daily moisture loss.

Regardless of the species or thickness being dried, there is a maximum moisture content loss per day that the wood can tolerate. Exceeding this rate of loss for a piece of lumber will greatly increase the likelihood of degrade, such as checking. On the other hand, drying much slower than the maximum safe rate can result in stain and excessive drying costs. This rate should not be exceeded during the critical period of drying, the loss of the 1/3 of moisture from green. After this first critical stage, the rate may slow down somewhat due to the resistance that dry wood has to drying. The safe rates are based on losses measured from properly prepared kiln samples using typical FPL schedules.

Table 3 -- Drying Rates

Species	Maximum Daly Rate of loss	
	4/4	8/4
Beech	4.5	1.8
Y.birch	6.1	2.4
Cherry	5.8	2.3
Elm	10.4	4.1
Soft Maple	13.8	5.5
Hard maple	6.5	5.5
Red upland oak	3.8	1.5
White upland oak	2.5	1.0
Southern oak	1 to 3	-----
Sap gum	5.3	2.1
Walnut	8.	3.3
Yellow-poplar	25	10

Summary

The three variables that control the rate of drying and drying quality are temperature, humidity and velocity. These variables can be manipulated to provide uniform, rapid drying, provided established guidelines and rules-of-thumb are considered.

20 tips to drying success

By Gene Wengert

If you are running a small sawmill and selling green lumber, profits can sometimes look a little small. Should you kiln dry some of your lumber to increase your bottom line? You bet! Drying isn't as hard as many people say it is, it's financially attractive, and essential for good profitability for a small sawyer. In past issues of this magazine I have written about various aspects of drying lumber: different types of drying, ways to avoid ruining a load, stickering, moisture meters and even handling between your mill and kiln. It is easy, with proper attention to details, to make $150 per MBF profit selling kiln-dried instead of green. As a quick review, here are 20 tips for drying success.

1. Always use as fresh logs as possible. Older logs (as little as 6 weeks) are much more prone to developing a variety of discolorations and checking of the surface, ends and internally.

2. Always sort your green lumber into value classes. Do not put money and effort into drying low-quality, low-value lumber. Sell low value lumber ASAP. Spend your valuable time and money on the upper-grade, high value products.

3. Sticker your lumber carefully using dry, 3/4-inch thick stickers, spaced 18 inches apart.

4. Avoid open-air drying. Instead, put the lumber into whatever kiln system you are using right away. If this is not possible, put stickered lumber into an open shed, protecting it from the rain and sun. Use plastic mesh over the lumber pile to prevent excessively fast drying for critical species and thicknesses.

5. If you are drying less than 50 MBF a year, use a solar kiln. For more predictable results and for quantities up to 2 million BF a year, use a dehumidification kiln. Small kilns, up to 12 MBF capacity, are usually the most versatile.

6. Attend a three to five days beginner's drying training school. The knowledge you'll gain is essential for good operation of your kiln.

7. Contact your state forestry officials to see if they can look your operation over and male suggestions for improvement; or hire a consultant to do the same.

8. Do not accelerate kiln schedules. With 50 years of experience, the published schedules should be followed religiously.

9. Never put drying lumber in a humid location where it will regain moisture or where it will be exposed to liquid water. Rewetting causes warp, stain, and checking to increase.

10. Keep records so that if something does go wrong, you can analyze the situation and avoid the problem in the future.

11. When doing your taxes, a kiln is usually depreciated as a piece of equipment rather than as a building.

12. Follow the book when preparing kiln samples. Short cuts are very risky.

13. Keep kiln-dried (KD) lumber in a dry building- 38 percent relative humidity (RH) will maintain the lumber at 7 percent moisture content (MC), and is ideal for most lumber. Add a little heat to the building to lower the RH when needed. Without heat, an open storage shed will allow KD lumber to come back to 12 MC.

14. Always double check final MC. More than 75 percent of complaints involving KD lumber are about MC. Learn the MC requirements of your customers.

15. When shipping lumber to a customer, always check the MC again and put the values on the shipping documents.

16. You do not make any money sawing or drying lumber. You only make money when the lumber is sold. Attend a class on marketing. This will assure that you are getting good value for your products.

17. Good packaging goes a long way in defining the quality of your product. Consider a lumber pile to be similar to a package of strawberries in the store- which ones are on the top? The best! Packaging is part of drying.

18. Consider planing some of your KD lumber and doing a little remanufacturing to make it look great and also to meet the needs of smaller woodworkers. Small, high-quality pieces of planed walnut, cherry and oak lumber can sell for $7 per BF.

19. When planning your kiln, always plan for expansion. Many kiln drying operations double in size within two years.

20. Make sure you have the time to watch your kiln daily and make needed adjustments. If you don't have the time, hire someone to do it. Avoid disasters by catching them early.

Gene Wengert is and extension specialist and professor of wood processing in the Department of Forest Ecology and Management at the University of Wisconsin-Madison.

Independent Sawmill and Woodlot Mgmt.
Vol. 2 Issue No. 3 Feb/Mar 1999 p. 42

"NEXT STEP: NOW YOU'VE SAWN IT, NOW YOU DRY IT" THE DRYING OF WOOD WITH SMALL KILNS*

by Michael P. Folkema, R.P.F.

Paper presented at the YSC Wood Co-op Ltd.
Annual meeting, Fredericton, N.B.

June 29, 1994

INTRODUCTION

This paper explains how lumber can be dried with the use of small kilns. It is intended for small-scale lumber producers (e.g., owner-operators of portable bandsaw mills, or a group of such owners).

Both air drying and kiln drying of lumber are discussed. However, the emphasis of this report is on kiln drying.

AIR DRYING

If wood is to be used for outdoor projects, there may be no need to dry it. For some applications, green or air-dried wood is preferred, particularly since green lumber has less tendency to split when nailed. However, if wood is to be used indoors, it must be dried properly. Green lumber will shrink and warp. Methods of drying lumber are discussed below.

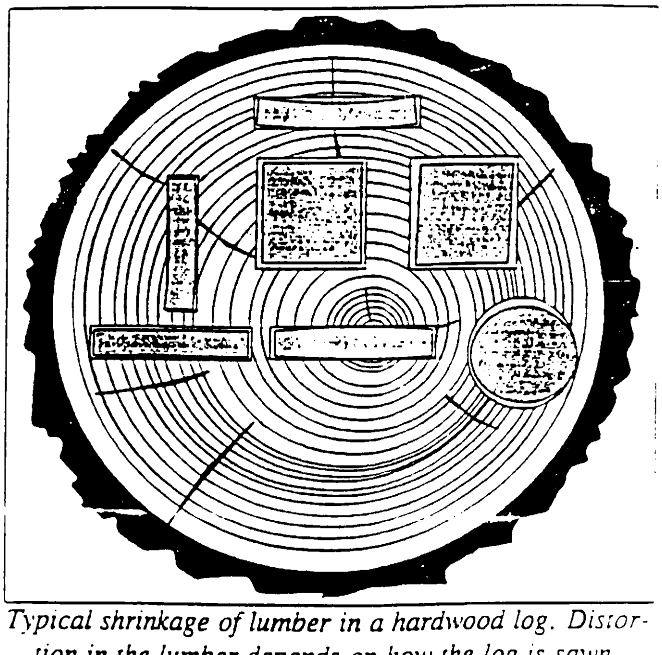
Air drying lumber outdoors requires that it be stacked with "stickers". Stickers in hardwoods are usually 1 1/4 to 1 1/2" wide and 3/4 to 1" thick. Stickers for softwoods are generally about 2" wide and 3/4 to 1" thick. For lumber, the moisture content is measured in percent of oven-dry weight:

$$MC = \frac{IW-OD}{OD} \times 100$$

where:

MC = moisture content in percent
IW = initial weight of the wood
OD = oven-dry weight of the wood

Freshly-cut wood has a moisture content ranging from 44 to 160 percent, but for most species it is 60-80%. Air-dried lumber has a moisture content of about 20%. When lumber is dried below the fiber saturation point (28-30% MC), it shrinks. Thus, for air-dry lumber, some shrinkage has already occurred. Table 1 indicates the time required to dry 1" lumber.



Typical shrinkage of lumber in a hardwood log. Distortion in the lumber depends on how the log is sawn.

* This paper represents an update/expansion of the "Drying Lumber" section within FERIC Handbook HB-10, "Handbook on Portable Bandsaw-type Sawmills" by the author.

NOTE: As opposed to wood chips (green-weight basis), the moisture content of lumber is usually measured on an oven-dry basis.

Table 1. Approximate time to air-dry green 1-inch lumber to 20 percent moisture content

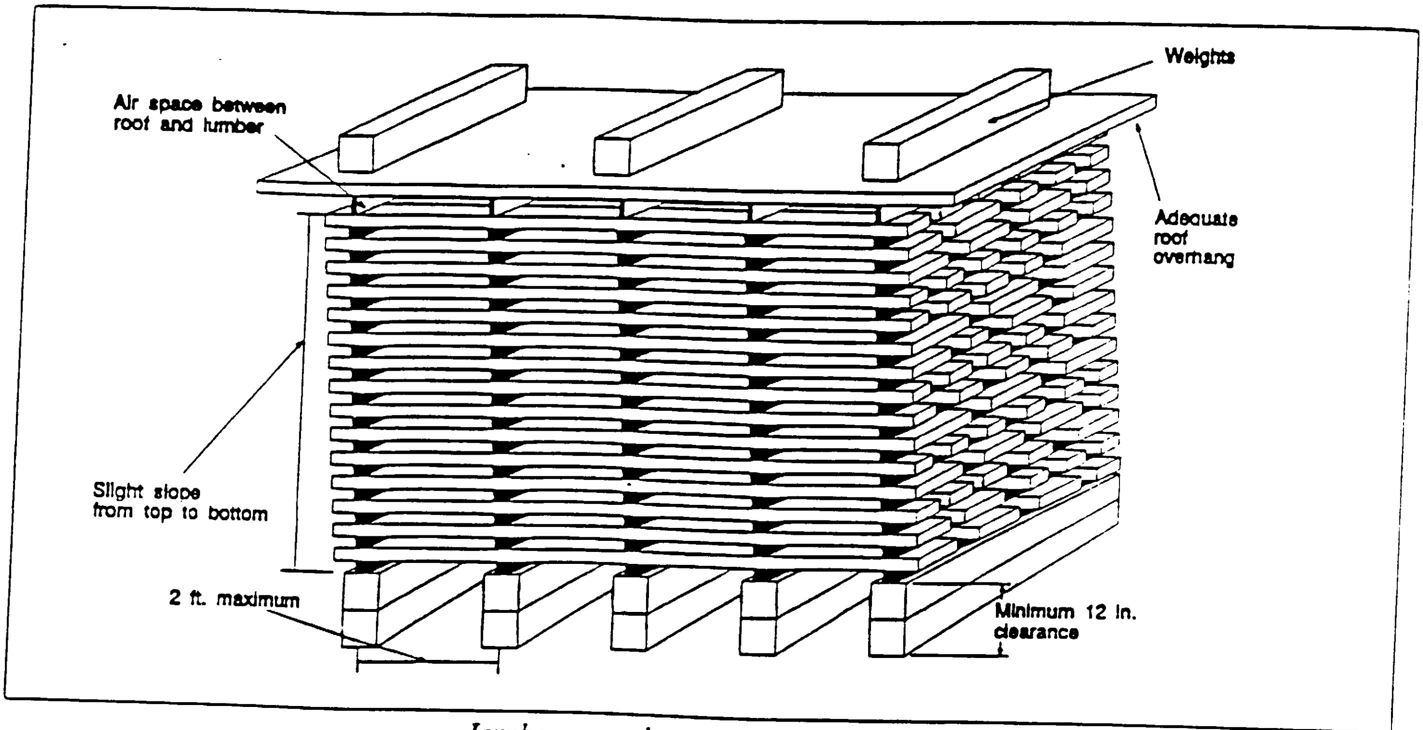
Species	Time* (days)
Ash (White)	60-200
Basswood	40-150
Beech	70-200
Cottonwood	50-150
Elm (American)	50-150
Hickory	60-200
Maple (Silver)	30-120
Maple (Sugar)	50-200
Oak (Red)	50-200
Oak (White)	80-250
Pine (White)	60-200
Spruce	30-120
Walnut	70-200

* Minimum days given refer to lumber dried during good drying weather, generally spring and summer. Lumber stacked too late in the period of good drying weather to reach 20% moisture content, or lumber stacked during the fall and winter, usually will not reach a moisture content of 20% until the next spring, which accounts for the maximum days given.

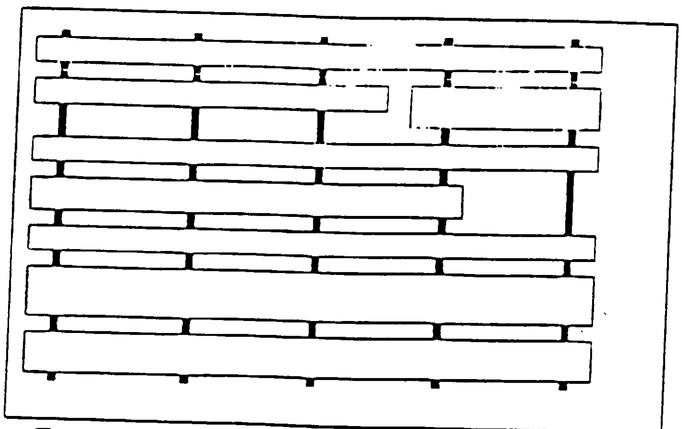
Lumber of interior use (e.g., flooring, furniture, interior trim) must have a maximum moisture content of 6-8%. NOTE: Small quantities of lumber can be dried from 20 to 6%, by moving it inside a heated room in a house. Stickers and weights are required for this additional drying. The additional drying will take one to four months.

For air drying of lumber, the following suggestions are offered:

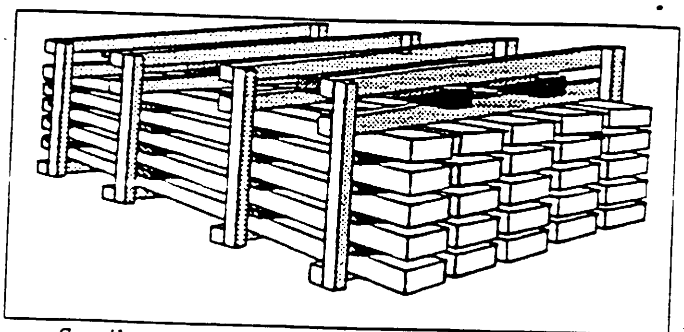
- When lumber is first sawn, it should be stickered immediately to avoid warping, checking and fungal stains.
- Stickers in hardwood lumber should be located approximately 40 cm apart, and at both ends of the boards. In softwoods, stickers are often 60 cm apart. All boards in an individual stack should be of the same length or pulled to opposite ends of the stack. In the latter case, the short end will be inside the pile and should be supported by a sticker to avoid cupping or twisting. All stickers should line up vertically to ensure the weight is distributed equally.
- Use light-colored, kiln-dried wood for stickers, especially when drying sensitive species that are likely to stain (e.g., white pine, red oak). Stickers should be of the same species of wood as the lumber, if possible.
- Heavy weights (e.g., timbers) should be placed on the tops of piles to reduce the effect of warping and cupping during drying.
- Air drying occurs most rapidly in the first few days. Even if it is to be kiln-dried later, lumber should be stickered and stored so it can air dry properly. Air drying reduces the cost of kiln drying because less energy is required.
- Take advantage of prevailing winds and high, unobstructed ground. Separate the stacks by 1 m or more, so that the wind can get between them. The air should go through the sides of the piles.
- Keep lumber at least 15 cm off the ground by setting it on spare timbers. Keep weeds and brush down to allow the air flow to get to the bottoms of the pile.
- Excessive sunshine is a problem for air drying. the hot sun will cause cupping, twisting, warping and checking, particularly on the top layer of boards. A sheet of Aspenite can be used to keep off the rain and sun. For valuable hardwood species, the use of a drying shed with open sides is recommended. Valuable hardwood species, such as oak, ash and hickory have a high initial moisture content; the lumber dries slowly and tends to warp and end check easily if dried too quickly.
- End coating the green lumber with a commercial sealer, paraffin, beeswax, or paint will prevent too rapid drying, which causes end checking. Sealing the ends of the lumber is particularly important for dense hardwoods which are prone to end checking. Latex paint does not work as well as oil-based paint.
- Keep dried lumber (@ 6-8% MC) indoors in a heated location until you are ready to make the final product. If not, it will revert to the air dry moisture content (20%). A moisture meter can be used to measure moisture content from 0 to 30%. They cost $200 or more, and are available from sawmill and forestry equipment suppliers.



Lumber properly stacked for air drying.



Top view of tier of boards, illustrating the system of alternating short lengths for box piling. Unsupported ends of boards placed on the inside will dry with less defect than if allowed to extend over the end of the pile.



Small quantities of lumber can be boxed inside a wooden frame using double wedges tapped in to maintain tension as the wood shrinks. If possible, keep the boards in the order that they came off the logs.

KILN DRYING

Kiln drying is the accelerated removal of water from lumber under controlled conditions, usually to a target moisture content of 6-8% for lumber manufactured into items such as furniture, flooring and millwork. It can then be used for interior uses because no more shrinkage is likely to occur. Softwood dimension lumber, used in construction, is usually kiln dried to 15%.

The *advantages of kiln drying* are: With kiln drying, the pitch in the wood is hardened, so it is less likely to bleed later. Insects, fungi and stain are killed. Future dimensional changes for interior use of the lumber will be minimal. Kiln-dried lumber holds nails, paint and glue better. Also, stiffness and strength of the lumber is increased.

The *disadvantages of kiln drying* are that nails are harder to drive in and the wood splits more easily from nails. Also the wood may be darkened, surface checked and less attractive.

For sawmillers, an excellent source of information on air drying and kiln drying of lumber is the *Dry Kiln Operator's Manual**. There are also other articles and books available on these topics.

In some areas, kiln drying in conventional steam-type dry kilns is available to bandsaw mill owners. The cost

* Anon. 1988. *Dry Kiln Operator's Manual*. Hardwood Research Council. Memphis, Tenn. U.S.A. 250 p.

will vary from $100-$300/Mfbm. A minimum quantity of 3-5 Mfbm is usually required. Kiln operators usually insist that the wood be air dry (20% moisture content) before it is kiln dried and that the entire batch be dried the same amount. This does not permit mixing 1" and 2" lumber in the same batch. Inevitably, there will be problems with this approach. It is not ideal for the portable bandsaw mill owner. Another approach is, to purchase a dry kiln.

The portable mill owner interested in purchasing a dry kiln should base that decision on the likelihood of selling direct to small local markets, such as small shops, hobbyists, home renovators, etc. If selling kiln-dried lumber to a lumber yard, lumber broker or large furniture company, the price that the mill owner will receive per board foot will be much lower. Usually, retail lumber yards charge their customers twice the price that they pay for kiln-dried hardwood and white pine lumber. By selling kiln-dried lumber direct to the customer, the bandmill owner can double his profit.

The portable mill owner with a dry kiln can develop local markets for kiln-dried lumber by placing a classified advertisement in local newspapers. The mill owner should have a storage building, preferably beside his home where he can store and display the lumber. Salesmanship and a good knowledge of local wood markets are the key to selling small quantities of kiln-dried lumber at a profit.

For the hobbyist, small-shop market, hardwood lumber is usually sold in the rough-sawn (unplaned) form. Table 2 provides information on the thickness of unplaned (rough) lumber and planed hardwood lumber. It should be graded and be at 6-8% moisture content.

The following inventory distribution was suggested by a hobbyist, small-shop lumber supplier:

5/8	4/4	6/4	8/4	12/4	16/4
10%	40%	15%	15%	10%	10%

In addition to the local hobbyist, small-shop market, the sawmill owner can advertise in woodworking magazines (e.g., Canadian Wood Working). Usually it is best to develop a specialty niche. An example of this is providing a good selection of lumber sizes for one or two species, such as black walnut or white oak. This will permit shipping small quantities of lumber to a distant customer.

Table 2. Standard thickness for rough and planed (S2S) hardwood lumber

Nominal rough thickness (in.)	S2S* thickness (in.)
3/8	3/16
1/2	5/16
5/8	7/16
3/4	9/16
1 (4/4)	3/4
1-1/4 (5/4)	1-1/16
1-1/2 (6/4)	1-5/16
1-3/4 (7/4)	1-1/2
2 (8/4)	1-3/4
2-1/2 (10/4)	2-1/4
3 (12/4)	2-3/4
3-1/2 (14/4)	3-1/4
4 (16/4)	3-3/4

* S2S refers to lumber that is surfaced on two sides.

If you are interested in an in-depth look at wood in relation to woodworking projects, we recommend the book *"Understanding Wood - A Craftsman's Guide to Wood Technology"**.

Types of Dry Kilns

There are four basic types of dry kilns:

- conventional steam kilns
- dehumidifications kilns
- solar kilns
- vacuum kilns.

* Hoadley, R.B. 1980. Understanding Wood: A Craftman's Guide to Wood Technology. The Taunton Press Inc. Newton. Connecticut, U.S.A. 251 p.

END COATING

END COATING ARE NOT USUALLY REQUIRED WHEN LUMBER IS PLACED IN THE KILN DIRECTLY AFTER BEING SAWN. HOWEVER WHEN LUMBER IS AIR DRIED PRIOR TO KILN DRYING, END COATING IS OFTEN HELPFUL IN PREVENTING END CHECKS.

U. C. COATINGS IS THE MAJOR SUPPLIER OF END COATINGS. CONTACT THEM FOR FURTHER INFORMATION:

U. C. COATINGS
P. O. BOX 1066
BUFFALO, NY 14215

TEL: 716/833-9366
FAX: 716/833-0120

United States
Department of
Agriculture

Forest
Service

Forest
Products
Laboratory

Drying of Wood

List of Publications

February 1989

The publications in this list present results of Forest Products Laboratory research. These publications were written to facilitate application of new and existing technologies. Most publications are available through at least one of the following sources:

1. **Forest Products Laboratory (FPL).** Quantities are limited because of policies aimed at reducing the Federal Government's printing and distribution costs.
2. **Government Sales Outlets.** Major outlets are:
   (a) Superintendent of Documents, U.S. Government Printing Office (GPO)
   (b) National Technical Information Service (NTIS)
3. **Third-Party Services.** Examples of active commercial and/or nonprofit vendors are:
   (a) University of Wisconsin Library (U. WIS.)
   (b) Forest Products Research Society (FPRS)
   (c) Institute of Paper Chemistry (IPC)
   (d) Original Article Text Service (OATS)
   (e) Institute for Scientific Information (ISI)
   (f) University Microfilms, Incorporated (UMI)
4. **Libraries.** Research publications are available through many public and university libraries. U.S. Government publications are also available through many Government Depository Libraries.

Order Information

The primary source for each publication is indicated in parentheses with the entry for that publication. *Complete order details are given on the last page of this list.*

When publications are not available through one of the sources above, order information is provided with the entry for that publication.

89-008

(formerly 84-032)

Contents

Physical Properties of Wood Related to Drying

Permeability, Diffusion, and Drying Rate

The effect of wetwood on lumber drying times and rates: An exploratory evaluation with longitudinal gas permeability. Ward, J.C. Wood Fiber Sci. 18(2):288–307. 1986.
(FPL)

Drying rate of northern red oak lumber as an analytical function of temperature, relative humidity, and thickness. Tschernitz, J.L., and Simpson, W.T. Wood Sci. 11(4):202–208. 1979.
(U. WIS., FPRS, IPC, OATS, UMI)

Effect of steaming on the drying rate of several species of wood. Simpson, W.T. Wood Sci. 7(3):247–255. 1975.
(U. WIS., FPRS, IPC, OATS, UMI)

Shrinkage and Swelling

Dimensional changes in kiln-dried softwood lumber after surfacing and during storage. Comstock, G.L. U.S. Forest Serv. Res. Note FPL-0144. 1966.
(NTIS)

Shrinkage of coast-type Douglas-fir and old-growth redwood boards. Comstock, G.L. U.S. Forest Serv. Res. Pap. FPL 30. 1965.
(NTIS)

Moisture Content

Preliminary evaluation of electronic measurements for presorting Hem-Fir dimension lumber. Ward, J.C., James, W.L., and Kozlik, C.J. In: Proc., Western Dry Kiln Clubs Joint Meeting, Corvallis, OR, p. 97–98, May 8–10, 1985.
(FPL)

In-kiln moisture monitoring systems. James, W.L., and Boone, R.S. In: Robertson, D., coord. Computer Automation for Sawmill Profit: Proc. 7333, October 4–6, 1982. Norfolk, VA. Forest Prod. Res. Soc., Madison, WI, p. 91–94. 1984.
(FPRS, FPL)

Moisture levels and gradients in commercial softwood dimension lumber shortly after kiln-drying. James, W.L., Choong, E.T., Arganbright, D.G., Doucet, D.K., Gorvad, M.R., Galligan, W.L., and Simpson, W.T. Forest Prod. J. 34(11/12):59–64. 1984.
(FPRS, FPL)

Influence of wetwood on pulsed-current resistances in lumber before and during kiln-drying. Ward, J.C. Wood Fiber Sci. 16(4):598–617. 1984.
(FPL)

Maximum safe initial moisture content for press-drying oak lumber without honeycomb. Simpson, W. Forest Prod. J. 34(5):47–50. 1984.
(FPRS, FPL)

List of manufacturers and dealers handling apparatus for determining moisture content of wood and suppliers of electric moisture meters. Forest Prod. Lab. Rep. 84-036. 1984.
(FPL)

Using speed of sound in wood to monitor drying in a kiln. James, W.L., Boone, R.S., and Galligan, W.L. Forest Prod. J. 32(9):27–34. 1982.
(FPL)

Capacitive in-kiln wood moisture content monitors: Principles of operation and use. James, W.L., and Boone, R.S. Wood Sci. 14(4):146–164. 1982.
(U. WIS., FPRS, IPC, OATS, UMI)

Some general characteristics of capacitive in-kiln moisture monitors. James, W.L., and Boone. R.S. Forest Prod. J. 32(4):57. 1982.
(FPRS)

Equilibrium moisture content of wood at high temperatures. Simpson, W.T., and Rosen, H.N. Wood and Fiber 13(3):150–158. 1981.
(U. WIS., FPRS, IPC, OATS, UMI)

Sorption theories applied to wood. Simpson, W.T. Wood and Fiber 12(3):183–195. 1980.
(U. WIS., FPRS, IPC, OATS, UMI)

Electric moisture meters for wood. James, W.L. USDA Forest Serv. Gen. Tech. Rep. FPL–6. Rev. 1988.
(NTIS, FPL)

Effects of wood preservatives on electrical moisture meter readings. James, W.L. U.S. Forest Serv. Res. Note FPL–0106. Rev. 1980.
(NTIS, FPL)

Stresses

Press-drying plantation-grown loblolly pine 2 by 4's to reduce warp. Simpson, W.T., Danielson, J.D., and Boone, R.S. Forest Prod. J. 38(11/12):41–48. 1988.
(FPL)

High-temperature drying and equalizing: Effects on stress relief in yellow-poplar lumber. Maeglin, R.R., Liu, J.Y., and Boone, R.S. Wood Fiber Sci. 17(2):240–253. 1985.
(FPL)

Effect of high-temperature drying on bending strength of yellow-poplar 2 x 4's. Gerhards, C.C. Forest Prod. J. 33(2):61–66. 1983.
(FPRS)

Could S-D-R be the answer to the aspen oversupply problem? Maeglin, R.R. Northern Logger and Timber Process., p. 24–25. July 1979.
(FPL)

A "pinned" sticker to reduce crook in kiln-drying lumber. Wengert, E.M., and Baltes, R.C. Forest Prod. J. 24(8):23–24. 1974.
(FPRS)

Honeycomb and ring failure in bacterially infected red oak lumber after kiln drying. Ward, J.C., Hann, R.A., Baltes, R.C., and Bulgrin, E.H. USDA Forest Serv. Res. Pap. FPL 165. 1972.
(NTIS)

Transverse strain during drying of 2-inch ponderosa pine. McMillen, J.M. USDA Forest Serv. Res. Pap. FPL 83. 1968.
(NTIS)

Other Problems Related to Drying

Bacterial infection of oak—an update. Ward, J.C., and Schink, B. In: Applying the Latest Research to Hardwood Problems: Proc. 15th Annual Hardwood Symposium of the Hardwood Research Council, May 10–12, 1987, Memphis, TN. Hardwood Research Council, Memphis, TN, p. 87–91. 1987.
(FPL) (Entire proceedings available from Hardwood Research Council, P.O. Box 34518, Memphis, TN 38184-0518, $10.00)

Comparison of four methods for drying bacterially infected and normal thick red oak. Ward, J.C., and Simpson, W.T. Forest Prod. J. 37(11/12):15–22. 1987.
(FPRS, FPL)

Drying North American oak lumber—the bacterial problem. Ward, J.C., and Hart, C.A. In: Mitchell, P.H., comp. Proc. North American Wood Drying Symp., November 27–28, 1984, Mississippi State, MS. Mississippi State Forest Prod. Util. Lab., p. 90–96. 1985.
(FPL)

Bacterial oak: Drying problems. Ward, J.C., and Groom, D.A. Forest Prod. J. 33(10):57–65. 1983.
(FPRS)

Predrying before press-drying to reduce drying defects in hardwoods. Simpson, W.T. Forest Prod. J. 32(11/12):77–80. 1982.
(FPRS)

Importance of relative humidity and temperature control in conditioning wood products. Simpson, W.T. Wood and Fiber 14(2):94–103. 1982.
(U. WIS., FPRS, IPC, OATS, UMI)

The effect of air velocity on reaching dry kiln saturation temperatures of oak. Bois, P.J., and Tschernitz, J.L. USDA Forest Serv. Forest Prod. Util. Tech. Rep. 11. 1981.
(NTIS)

Evaluating humidity at dry bulb temperatures above the normal boiling point of water—a research note. Rosen, H.N., and Simpson, W.T. Wood and Fiber 13(2):97–101. 1981.
(U. WIS., FPRS, IPC, OATS, UMI)

Characteristics for presorting white fir lumber with wetwood. Ward, J.C., and Shedd, D. Proc. Western Dry Kiln Clubs Annual Meeting, Oregon State University, Corvallis, OR, 1981.
(FPL)

Drying procedures for bacterially infected northern red oak lumber. McMillen, J.M., Ward, J.C., and Chern, J. USDA Forest Serv. Res. Pap. FPL 345. 1979.
(NTIS)

California black oak drying problems and the bacterial factor. Ward, J.C., and Shedd, D. USDA Forest Serv. Res. Pap. FPL 344. 1979.
(NTIS)

Does thickness variation in sawing affect kiln drying? Simpson, W.T., and Tschernitz, J.L. South. Lumberman, p. 15-17, July 1, 1978.
(FPRS)

Kiln drying lumber from American elm trees killed by Dutch elm disease. Boone, R.S., and Ward, J.C. Forest Prod. J. 27(5):48-50. 1977.
(FPRS)

Control of reddish-brown coloration in drying maple sapwood. McMillen, J.M. USDA Forest Serv. Res. Note FPL-0231. 1976.
(NTIS)

Physical characteristics of seasoning discolorations in sugar maple sapwood. McMillen, J.M. USDA Forest Serv. Res. Pap. FPL 248. 1975.
(NTIS)

Gray-brown chemical stain in southern hardwoods. Bois, P.J. USDA Forest Serv. Forest Prod. Util. Tech. Rep. 1. 1970.
(FPL)

Prevention of pinkish-brown discoloration in drying maple sapwood. McMillen, J.M. USDA Forest Serv. Res. Note FPL-0193. 1968.
(NTIS)

Methods of Drying Lumber

Air Drying

A calendar for air-drying lumber in the upper Midwest. Rietz, R.C. USDA Forest Serv. Res. Note FPL-0224. 1972.
(NTIS)

Air drying of lumber: A guide to industry practices. Rietz, R.C., and Page, H. U.S. Dep. Agric. Handb. No. 402. 110 p. 1971.
(GPO, Stock No. 001-000-04332-3, $4.75)

Kiln Drying

Partial list of lumber dry kiln manufacturers in the United States. Forest Prod. Lab. Rep. 89-004. 1989.
(FPL)

Partial list of manufacturers and distributors of dehumidification lumber drying units available in North America. Forest Prod. Lab. Rep. 89-003. 1989.
(FPL)

Dry kiln schedules for commercial woods—temperate and tropical. Boone, R.S., Kozlik, C.J., Bois, P.J., and Wengert, E.M. USDA Forest Serv. Gen. Tech. Rep. FPL-GTR-57. 158 p. 1988.
(FPL)

Kiln-drying time of split oak firewood. Simpson, W.T., Boone, R.S., and Chern, J. USDA Forest Serv. Res. Note FPL-RN-0254. 5 p. 1987.
(FPL)

Dielectric properties of lumber loads in a dry kiln. James, W.L. USDA Forest Serv. Res. Pap. FPL 436. 1983.
(FPRS)

Using speed of sound in wood to monitor drying in a kiln. James, W.L., Boone, R.S., and Galligan, W.L. Forest Prod. J. 32(9):27-34. 1982.
(FPRS)

Warp reduction in kiln-drying hardwood dimension. Simpson, W.T. Forest Prod. J. 32(5):29-32. 1982.
(FPRS)

Properties and kiln-drying characteristics of young-growth western hemlock dimension lumber. Kozlik, C.J., and Ward, J.C. Forest Prod. J. 31(6):45-53. 1981.
(FPRS)

Kiln-drying hardwood dimension parts. Simpson, W.T., and Schroeder, J.G. USDA Forest Serv. Res. Pap. FPL 388. 1980.
(NTIS)

Steaming northern red oak to reduce kiln drying time. Simpson, W.T. Forest Prod. J. 26(10):35-36. 1976.
(FPRS)

Kiln drying sinker heartwood from young-growth western hemlock: Preliminary evaluation. Ward, J.C., and Kozlik, C.J. Proc. Western Dry Kiln Clubs 26th Annual Meeting, May 1-2, 1975, Oregon State University, Corvallis, OR.
(FPL)

How to reduce energy consumption in kiln-drying 4/4 hardwoods at high temperatures. Wengert, E.M. USDA Forest Serv. Res. Note FPL-0228. 1974.
(NTIS)

Schedules for foreign woods. McMillen, J.M., and Bois, P.J. USDA Forest Serv. Forest Prod. Util. Tech. Rep. 2. 1972.
(FPL)

Accelerated oak drying by presurfacing, accelerated schedules, and kiln automation. Wengert, E.M., and Baltes, R.C. USDA Forest Serv. Res. Note FPL-0214. 1971.
(NTIS)

Properties of imported tropical woods. (Kiln schedules included.) Kukachka, B.F. USDA Forest Serv. Res. Pap. FPL 125. 1970.
(NTIS)

Seasoning and handling of ramin. McMillen, J.M. U.S. Forest Serv. Res. Note FPL-0172. 1967.
(NTIS)

Solar Drying

Investment opportunity: the FPL low-cost solar dry kiln. Harpole, G.B. USDA Forest Serv. Gen. Tech. Rep. FPL-GTR-58. 5 p. 1988.
(FPL)

Performance of a solar/wood energy kiln in tropical latitudes. Simpson, W.T., and Tschernitz, J.L. Forest Prod. J. 39(1):23-30. 1988.
(FPL, FPRS)

Solar energy for wood drying using direct or indirect collection with supplemental heating: A computer analysis. Tschernitz, J.L. USDA Forest Serv. Res. Pap. FPL-RP-477. 1986.
(FPL)

FPL design for lumber dry kiln using solar/wood energy in tropical latitudes. Tschernitz, J.L., and Simpson, W.T. USDA Forest Serv. Gen. Tech. Rep. FPL-44. 17 p. 1985.
(FPL)

Solar dry kiln for tropical latitudes. Simpson, W.T., and Tschernitz, J.L. Forest Prod. J. 34(5):25-34. 1984.
(FPRS, FPL)

Constructing and operating a small solar-heated lumber dryer. Bois, P.J. USDA Forest Serv. Forest Prod. Util. Tech. Rep. 7. Jan. 1977.
(FPL)

Improvements in solar dry kiln design. Wengert, E.M. USDA Forest Serv. Res. Note FPL-0212. 1971.
(FPL)

Special Drying Methods

Press-drying plantation-grown loblolly pine 2 by 4's to reduce warp. Simpson, W.T., Danielson, J.D., and Boone, R.S. Forest Prod. J. 38(11/12):41-48. 1988.
(FPL, FPRS)

Comparison of four methods for drying bacterially infected and normal thick red oak. Ward, J.C., and Simpson, W.T. Forest Prod. J. 37(11/12):15–22. 1987.
(FPRS, FPL)

Alternative methods for sawing and drying structural lumber from second-growth loblolly pine *(Pinus taeda)*. Maeglin, R.R., and Simpson, W.T. In: Proc. 6th Reunion Sobre Investigacion y Desarrollo en Productos Forestales, November 25–27, 1987, Concepcion, Chile. Universidad Del Biobio, Concepcion, Chile. 12 p. 1987.
(FPL)

Laser incising to increase drying rate of wood. Simpson, W.T. Wood Fiber Sci. 19(1):9–25. 1987.
(FPL)

Vacuum drying northern red oak. Simpson, W.T. Forest Prod. J. 37(1):35–38. 1987.
(FPRS, FPL)

High-temperature kiln-drying of 1-inch red alder lumber. Kozlik, C.J., and Boone, R.S. Forest Prod. J. 37(6):21–24. 1987.
(FPRS, FPL)

High-temperature kiln-drying red maple lumber—some options. Boone, R.S. Forest Prod. J. 36(9):19–25. 1986.
(FPL, FPRS)

Producing studs from paper birch by Saw-Dry-Rip. Erickson, R.W., Petersen, H.D., Larson, T.D., and Maeglin, R.R. USDA Forest Serv. Res. Pap. FPL-RP-480. 8 p. 1986.
(FPL)

An evaluation of the Saw, Dry and Rip process to convert red alder into studs. Layton, T.F., Smith, W.R., and Maeglin, R.R. Wood Sci. Technol. 20(2):185–200. 1986.
(Available from W. Ramsay Smith, College of Forest Resources, AR 10, University of Washington, Seattle, WA 98195. No charge.)

Increased STUD grade yield of plantation Southern Pine by Saw-Dry-Rip. Maeglin, R.R., and Boone, R.S. USDA Forest Serv. Res. Pap. FPL-RP-479. 8 p. 1986.
(FPL)

The use of Saw-Dry-Rip to produce southern red oak, sweetgum, and blackgum squares. Maeglin, R.R., Simpson, W.T., and Schroeder, J.G. In: Business as Usual—A Sure Loser! Proc., 14th Annual Hardwood Symposium of the Hardwood Research Council, May 18–21, 1986, Cashiers, NC. Hardwood Research Council, Memphis, TN, p. 148–161. 1986.
(FPL)

Comparison of drying methods for paper birch SDR flitches and studs. Larson, T.D., Erickson, R.W., and Boone, R.S. USDA Forest Serv. Res. Pap. FPL 465. 1986.
(FPL)

A technique for simulating lumber drying using small clear specimens. Boone, R.S., Winandy, J.E., and Bendtsen, B.A. Forest Prod. J. 35(11/12):49–51. 1985.
(FPRS, FPL)

Use of acoustic emissions to control drying rate of red oak. Honeycutt, R.M., Skaar, C., and Simpson, W.T. Forest Prod. J. 35(1):48–50. 1985.
(FPRS, FPL)

Evaluation of mixed hardwood studs manufactured by the Saw-Dry-Rip (SDR) process. Maeglin, R.R., and Boone, R.S. USDA Forest Serv. Res. Note FPL-0249. 10 p. 1985.
(FPRS, FPL)

Process for rapid conversion of red oak logs to dry lumber. Simpson, W.T. Forest Prod. J. 35(1):51–56. 1985.
(FPRS, FPL)

Press drying quartersawn hard maple lumber. Simpson, W.T. Forest Prod. J. 35(4):31–32. 1985.
(FPRS, FPL)

Empirical equations for estimating drying times of thick rotary-cut veneer in press and jet dryers. Tschernitz, J.L. USDA Forest Serv. Res. Pap. FPL 453. 16 p. 1985.
(FPL)

Mechanism of crook development in lumber during drying. Simpson, W.T., and Gerhardt, T.D. Wood Fiber Sci. 16(4):523–536. 1984.
(FPL)

Maintaining lumber quality in press drying by manipulating sawing patterns. Simpson, W.T. Wood Fiber Sci. 16(3):411–426. 1984.
(FPL)

Obtaining uniform final moisture content in the high temperature drying of paper birch flitches. Erickson, R.W., Petersen, H.D., and Larson, T.D. Forest Prod. J. 34(2):27–32. 1984.
(FPRS)

High-temperature kiln-drying of 4/4 lumber from 12 hardwood species. Boone, R.S. Forest Prod. J. 34(3):10–18. 1984.
(FPRS, FPL)

Manufacture of quality yellow-poplar studs using the Saw-Dry-Rip (SDR) concept. Maeglin, R.R., and Boone, R.S. Forest Prod. J. 33(3):10–18. 1983.
(FPRS)

Methods of reducing warp when drying. Simpson, W.T. Asian Timber 2(5):80–81. Sept./Oct. 1983.
(FPL)

A checklist for drying small amounts of lumber. Bois, P.J., Wengert, E.M., and Boone, R.S. USDA Forest Serv. Forest Prod. Util. Tech. Rep. 6, revised. 1982.
(FPL)

Manufacturing quality structural lumber from hardwoods using the saw-dry-rip process. Maeglin, R.R., and Boone, R.S. Ninth Annual Hardwood Symp., Hardwood Research Council. 1981.
(FPL)

Radio-frequency dielectric drying of short lengths of northern red oak. Simpson, W.T. USDA Forest Serv. Res. Pap. FPL 377. 1980.
(NTIS)

High temperature drying of 7/4 yellow-poplar flitches for S-D-R studs. Boone, R.S., and Maeglin, R.R. USDA Forest Serv. Res. Pap. FPL 365. 1980.
(NTIS)

Effect of high-temperature drying on tensile strength of Douglas-fir 2 by 4's. Gerhards, C.C. Forest Prod. J. 29(3):39–46. 1979.
(FPRS)

An introduction to high-temperature drying: Past research efforts and definitions of terms and procedures. Boone, R.S. From: Proc. Symp. on High-Temperature Drying of Hardwoods, New Albany, IN, March 22, 1979, p. 1–9.
(FPL)

High-temperature drying of hardwoods A progress report on current research at FPL. Boone, R.S. From: Proc. Symp. on High-Temperature Drying of Hardwoods, New Albany, IN, March 22, 1979, p. 25–40.
(FPL)

Salvaging flooded lumber. USDA Forest Serv. Forest Prod. Util. Tech. Rep. 5. April 1973.
(FPL)

Veneer cutting and drying properties: Western larch. U.S. Forest Serv. Res. Note FPL-0163. 1967.
(NTIS)

Veneer cutting and drying properties: Tanoak. U.S. Forest Serv. Res. Note FPL-0164. 1967.
(NTIS)

Veneer cutting and drying properties: Water oak. U.S. Forest Serv. Res. Note FPL-0105. 1965.
(NTIS)

Veneer cutting and drying properties: Cottonwood. U.S. Forest Serv. Res. Note FPL-044. 1964.
(NTIS)

Moisture Content and Temperature Control During Fabrication and Use

Storage of lumber. Rietz, R. U.S. Dep. Agric. Handb. No. 531. 1978.
(FPL, GPO)

Maintaining moisture content conditions during lumber storage. Bois, P.J. USDA Forest Serv. Forest Prod. Util. Tech. Rep. 3. 1972.
(FPL)

Moisture content of laminated timbers. Hann, R.A., Oviatt, A.E., Markstrom, D.M., and Duff, J.E. USDA Forest Serv. Res. Pap. FPL 149. 1970.
(NTIS)

General and Related Publications

List of manufacturers and dealers for log and lumber end coatings that reduce checking and splitting. Forest Prod. Lab. Rep. 89-002. 1989.
(FPL)

The effects of CCA preservative treatment and redrying on the bending properties of 2 x 6 southern pine lumber. Winandy, J.E., and Boone, R.S. Wood and Fiber Sci. 20(3):350–364. 1988.
(FPL, UMI, OATS)

High-temperature drying of Southern Pine 2 by 4's: Effects on strength and load duration in bending. Gerhards, C.C. Wood Sci. Technol. 20:349–360. 1986.
(FPL)

Interaction of CCA preservative treatment and redrying: Effect on the mechanical properties of southern pine. Winandy, J.E., and Boone, R.S. Forest Prod. J. 35(10):62–68. 1985.
(FPL, FPRS)

Drying wood: A review. Simpson, W.T. In: Drying Technology—An International Journal (originally a two-part article). 1983–84.
(FPL)

Effects of delay between treatment and drying on toughness of CCA-treated southern pine. Winandy, J.E., and Boone, R.S. Forest Prod. J. 33(6):53–58. 1983.
(FPL, FPRS)

Economics of manufacturing straight structural lumber from hardwoods. Harpole, G.B., Maeglin, R.R., and Boone, R.S. In: Stumbo, D.A., ed. Utilization of Low-Grade Southern Hardwoods—Feasibility Studies of 36 Enterprises, Forest Prod. Res. Soc., p. 156–162. 1981.
(FPRS)

A new look at aspen studs. Maeglin, R.R. The Timber Producer 11:36. 1979.
(FPL)

Overseas measures to improve initial seasoning and handling. McMillen, J.M. Import/Export Wood Purchasing News 4(4). June/July 1978.
(FPL)

Veneer species that grow in the United States. Lutz, J.F. USDA Forest Serv. Res. Pap. FPL 167. 1973.
(NTIS)

How PEG helps the hobbyist who works with wood. Mitchell, H.L. Unnumbered report.
(NTIS; Order No. ADA 753-840)

Addresses of the Sources (updated 1/93)

FPL
Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53705–2398
(608)231–9248 or 9237
FAX (608)231–9592
No charge for single copies of publications.

GPO
Superintendent of Documents
Government Printing Office
710 North Capitol Street
Washington, DC 20402
(202)783–3238
Prices vary.

NTIS
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703)487–4650 or (800)553–6847
(703)487–4700 (Rush Orders)
Prices vary.

U. WIS.
Information Services Division
Kurt F. Wendt Library
College of Engineering
University of Wisconsin–Madison
215 North Randall Avenue
Madison, WI 53706
(608)262–5913
(608)262–5917
25 cents per page, plus $4 service charge.
WI residents add 5 percent sales tax.
Non-WI residents add 10 percent surcharge.

FPRS
Mary Gordon, Data Base Manager
Forest Products Research Society
2801 Marshall Court
Madison, WI 53705
(608)231–1361
50 cents per page ($5 minimum); add 10 percent for shipping and handling. *Note: When ordering from FPRS, please indicate the "E" number, when listed for the publication.*

IPST (formerly IPC)
Information Services
Institute of Paper Science & Technology
(formerly Institute of Paper Chemistry)
500 10th Street NW
Atlanta, GA 30318
(404)853–9500
FAX (404)853–9510
$4 per article of 1 to 15 pages; $1 per extra 10 pages (or portion thereof) for U.S. federal and state agencies, U.S. academic institutions, and Institute members.
$8 per article of 1 to 15 pages; $1 per 10 pages extra (or portion thereof) for others.

OATS
Original Article Text Service
Institute for Scientific Information
3501 Market Street
University Science Center
Philadelphia, PA 19104
(215)386–0100
Prices vary.

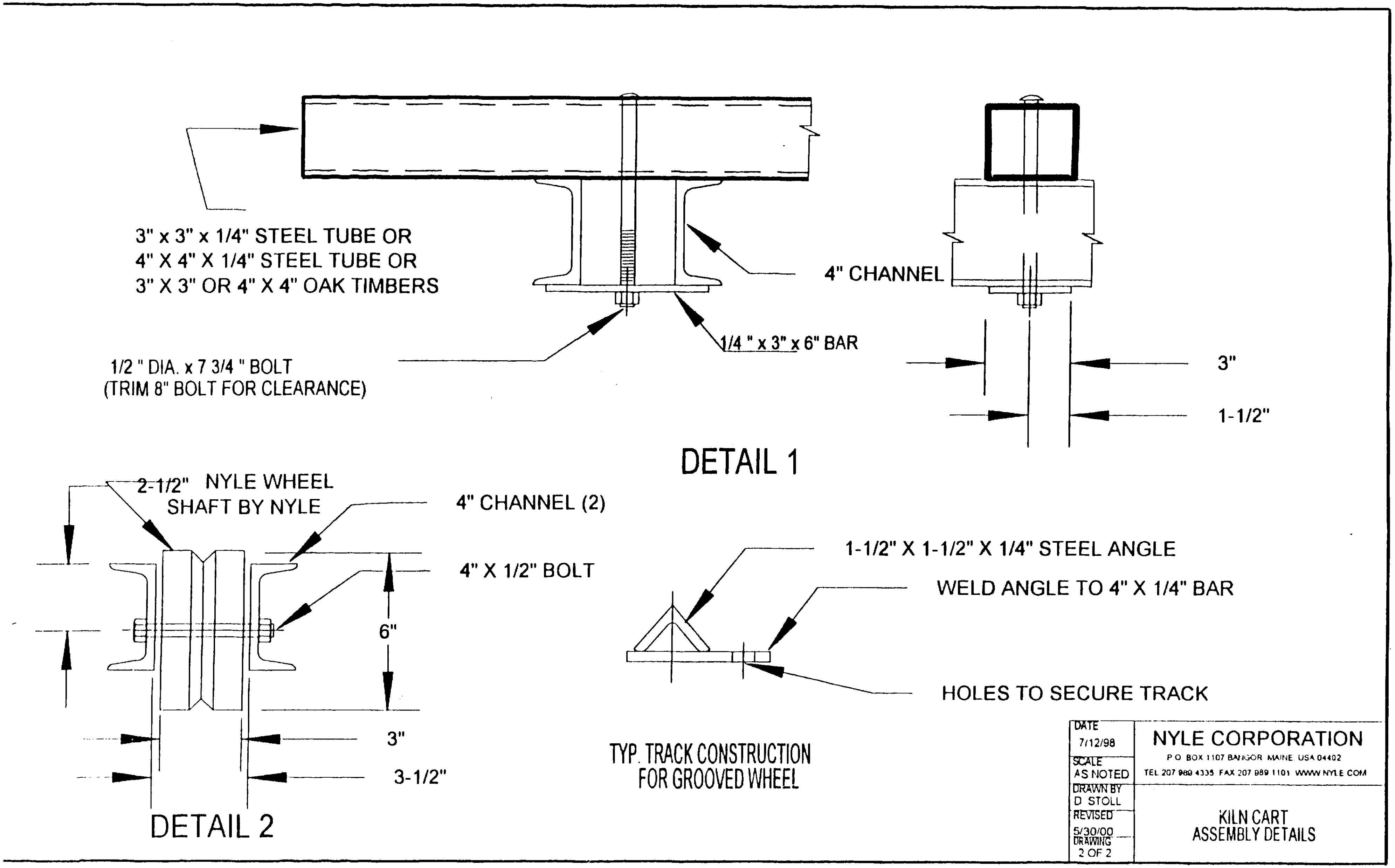
PURDUE EXT
Cooperative Extension Service
Purdue University
West Lafayette, IN 47907
(317)494–8491

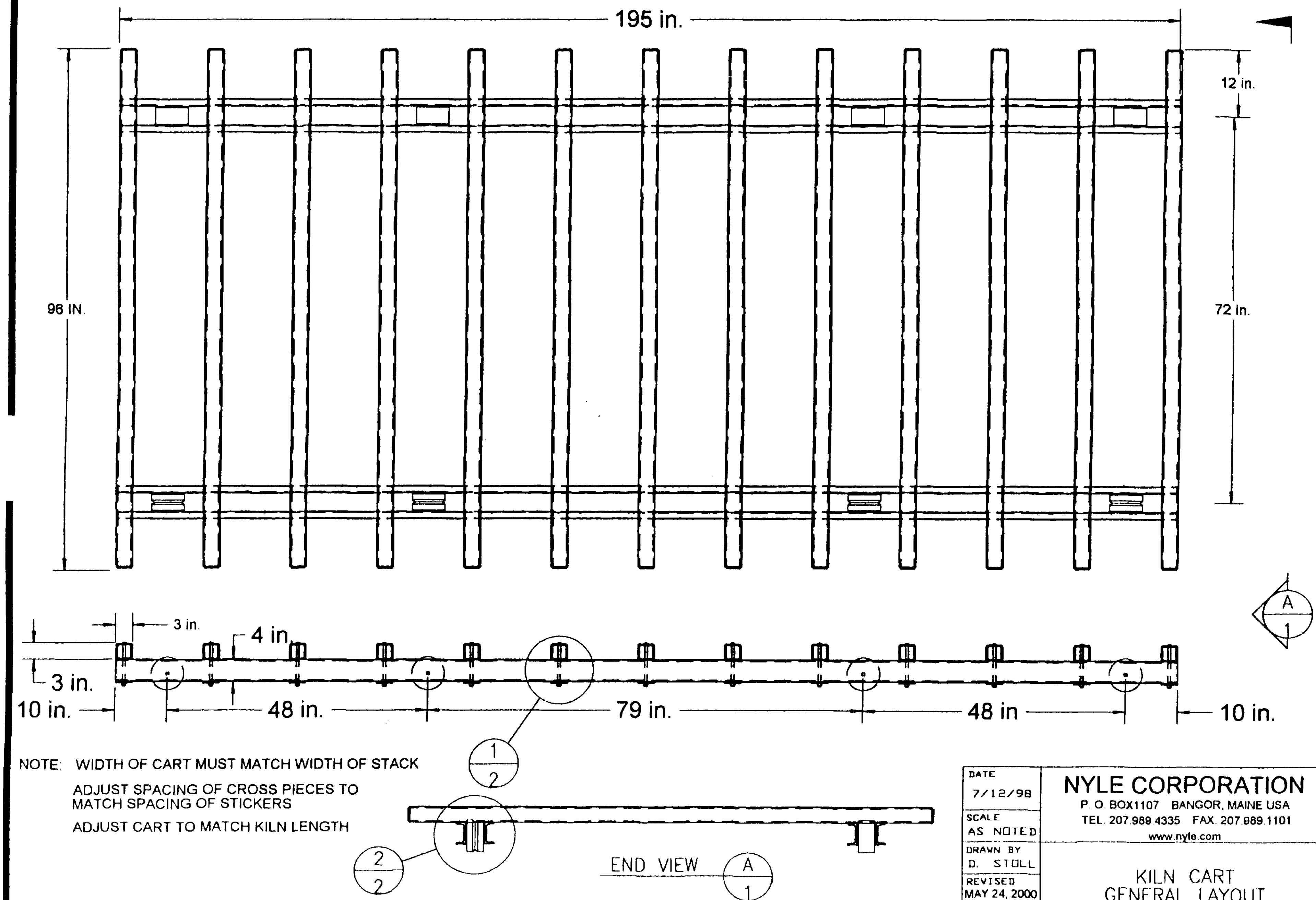
UMI
University Microfilms International
300 North Zeeb Road
Ann Arbor, MI 48106
800–732–0616 (except from MI, AK, and HI).
MI, AK, and HI, call (313)761–4700 collect.
$15 per article prepaid or by major credit card.
Deposit account may be established for reduced rates.

Please note: Prices subject to change without notice. Contact the publications sources for current prices.

Many of these publications are also available through public and university libraries, and through Government Depository Libraries. Check with your local librarian for further details.

Printed on recycled paper


3" x 3" x 1/4" STEEL TUBE OR
4" X 4" X 1/4" STEEL TUBE OR
3" X 3" OR 4" X 4" OAK TIMBERS
4" CHANNEL
1/4 " x 3" x 6" BAR
1/2 " DIA. x 7 3/4 " BOLT
(TRIM 8" BOLT FOR CLEARANCE)
3"
1-1/2"
DETAIL 1
2-1/2" NYLE WHEEL
SHAFT BY NYLE
4" CHANNEL (2)
4" X 1/2" BOLT
6"
3"
3-1/2"
DETAIL 2
1-1/2" X 1-1/2" X 1/4" STEEL ANGLE
WELD ANGLE TO 4" X 1/4" BAR
HOLES TO SECURE TRACK
TYP. TRACK CONSTRUCTION
FOR GROOVED WHEEL
DATE
7/12/98
SCALE
AS NOTED
DRAWN BY
D STOLL
REVISED
5/30/00
DRAWING
2 OF 2
NYLE CORPORATION
P O BOX 1107 BANGOR MAINE USA 04402
TEL 207 989 4335 FAX 207 989 1101 WWW.NYLE.COM
KILN CART
ASSEMBLY DETAILS



NOTE: WIDTH OF CART MUST MATCH WIDTH OF STACK

ADJUST SPACING OF CROSS PIECES TO MATCH SPACING OF STICKERS

ADJUST CART TO MATCH KILN LENGTH

DATE 7/12/98	NYLE CORPORATION P. O. BOX1107 BANGOR, MAINE USA TEL. 207.989.4335 FAX. 207.989.1101 www.nyle.com
SCALE AS NOTED	
DRAWN BY D. STOLL	KILN CART GENERAL LAYOUT
REVISED MAY 24, 2000	
DRAWING 1 OF 2	

General Maintenance for L200

L200 are designed for continuous duty, with little maintenance. However, when a problem does arise prompt repair will ensure long life for the machine.

The blower system is direct drive and the motor has sealed high temperature ball bearings. This unit does not need regular maintenance.

The air filter should be washed when dirty and replaced when necessary. If the filter becomes clogged, the air supply will be drastically reduced, causing the heater to overheat and the refrigeration system to overload.

The refrigeration system is a sealed system with its own oil supply. Again, regular maintenance is not required. However, if the system is not removing the normal amount of water at the appropriate conditions, the refrigeration system should be looked at by a reputable refrigeration mechanic. (The charging procedures are elsewhere in this section.) When the system experiences reduced water output, this is generally associated with a leak in the refrigeration system. If the leak is found and repaired before the system is empty, there is little chance that the system will be contaminated with moisture. If the system is ignored for a long period of time, moisture can enter the system and combine with the refrigerant to form acid. The system will then corrode from the inside-out if not corrected properly.

The circulating fan system is also direct drive with a ball bearing motor. The motor does require lubrication at six (6) month intervals. See the lubrication section.

AIR INLET FILTERS

The air filters are provided to keep the air inside the unit as clean as possible. Dirt build-up on the coils will lead to poor heat transfer with loss of capacity. In extreme cases, the coil will completely clog. The supplied filter is washable and should be replaced **when worn.**

REFRIGERANT CHARGING PROCEDURE L50, L200

The refrigeration system is a closed loop system with its own lubricating oil supply. Nyle uses only the best trade practices when assembling these systems, such as silver soldering in an inert environment, etc. The system should give years of trouble free service. However, if the system is not removing the right amount of water, or if a problem should arise from rough shipping or a refrigeration leak, the system should only be worked on by a qualified refrigeration mechanic. He should be warned that the conditions are different than he is used to seeing.

These systems operate over a very wide temperature and humidity range. The pressures will be relatively high when compared to air conditioners and heat pumps. For these reasons, you CANNOT CHARGE BY THE SIGHT GLASS, the sight class glass will eventually clear at certain conditions but it is unlikely that those conditions will exist when servicing.

If the kiln is loaded with lumber, it will be very dangerous to run the kiln at the extreme limits, as the lumber will degrade severly. Because of this danger, and the time factor involved of heating the kiln, NYLE insists that these machines have a weighed in charge. The amounts are as follows:

L200 55 ozs. R-416a (FR-12)

LUBRICATION INSTRUCTIONS
FOR BALL BEARING MOTORS

LUBRICATION

This is a ball bearing motor. No lubrication need be added before start up. The bearings have been lubricated at the factory.

RELUBRICATION INTERVALS

The following intervals are suggested as a guide:

Hours Of Service Per Year	H.P. Range	Suggested Relube Interval
5,000	1/8 to 7 ½ 10 to 40 50 to 150	5 Years 3 Years 1 Year
Continuous Normal Applications	1/8 to7 ½ 10 to 40 50 to 150	1 Year 1 Year 9 Months
Seasonal Service Motor Is Idle For 6 Months Or More	All	1 Year (Beginning Of Season)
Continuous High Ambients Dirty Or Moist Locations, High Vibrations, Or Where Shaft End Is Hot (Pumps-Fans)	1/8 to 40 50 to 150	6 Months 3 Months

'JBRICATION

Use high quality ball bearing grease. Use consistency of grease suitable for class of insulation stamped on nameplate as follows:

INSULATION CLASS	CONSISTENCY	TYPE	TYPICAL GREASE	FRAME TYPE
A & B	#2	LITHIUM BASE	SHELL ALVANIA	215T & SMALLER
A & B	MEDIUM	POLYUREA	SHELL DOLIUM R	254 & LARGER
F & H	MEDIUM	POLYUREA	SHELL DOLIUM R	ALL

PROCEDURE

If motor is equipped with Alemite fitting, clean tip of fitting and apply grease gun. Use 1 to 2 full strokes on motors in NEMA 215 frame and smaller. Use 2 to 3 strokes on NEMA 254 thru NEMA 365 frame. Use 3 to 4 strokes on NEMA 404 frames and larger. On motors having drain plugs, remove grease drain plug and operate motor for 20 minutes before replacing drain plug.

On motors equipped with slotted head grease screw, remove screw and apply grease tube to hold. Insert 2 to 3 inch length of grease string into each hole on motors in NEMA 215 frame and smaller. Insert 3 to 5 inch length on larger motors. On motors having grease drain plugs, remove plug and operate motor for 20 minutes before replacing drain plug.

CAUTION

Keep grease clean. Lubricate motors at standstill. Remove and replace drain plugs at standstill. Do not mix petroleum grease and silicone grease in motor bearings.

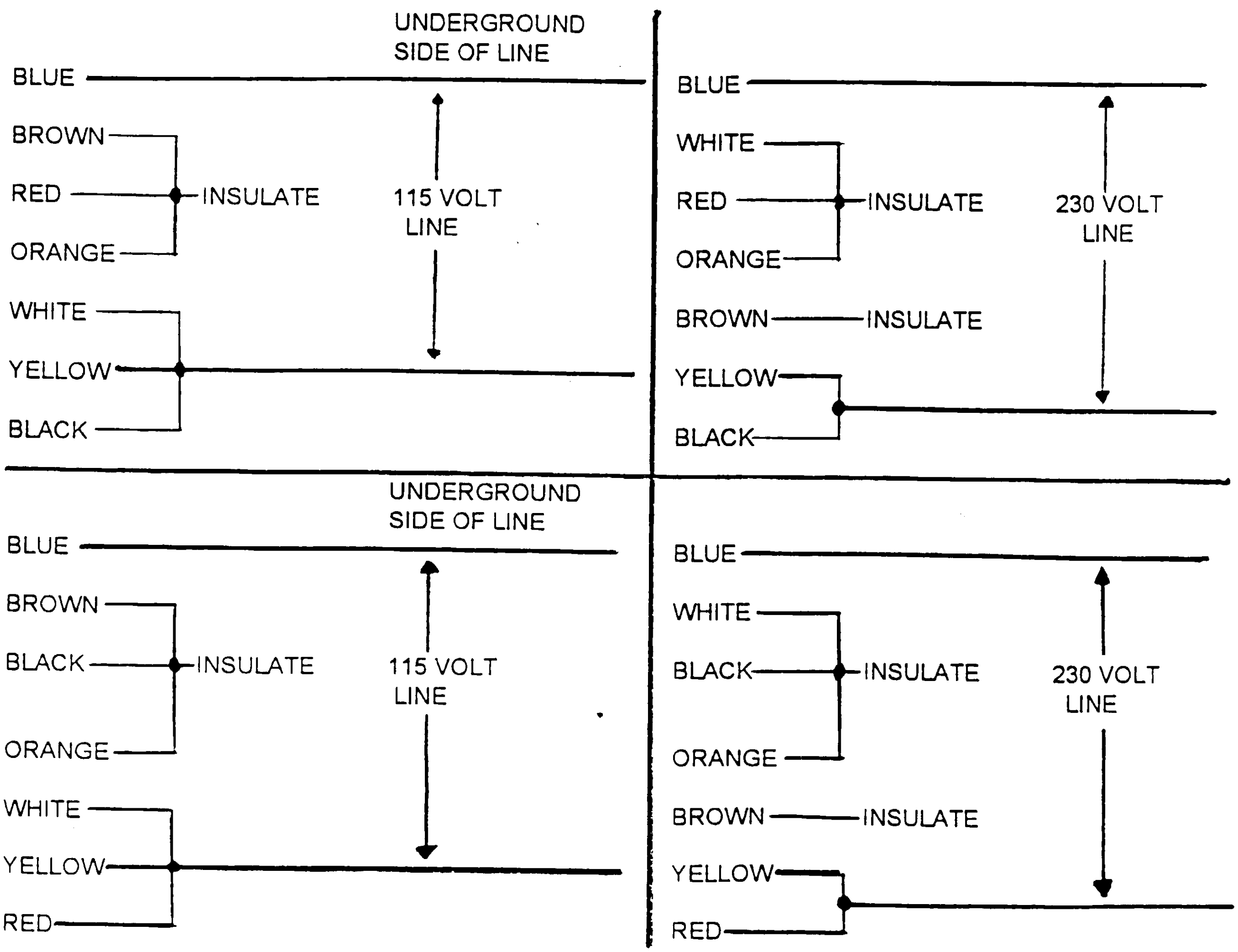
The fan motors must be installed so that the air flow is away from the dehumidifier. Be sure that the fan motors and housings are properly installed and be sure the motors are turning in the proper direction. If the motor is a model 5K191C, the diagram below can be used to rewire the motors to turn in the opposite direction. In the event, the motor supplied with your equipment had a different model number, check the nameplate wiring diagram for wiring instructions.

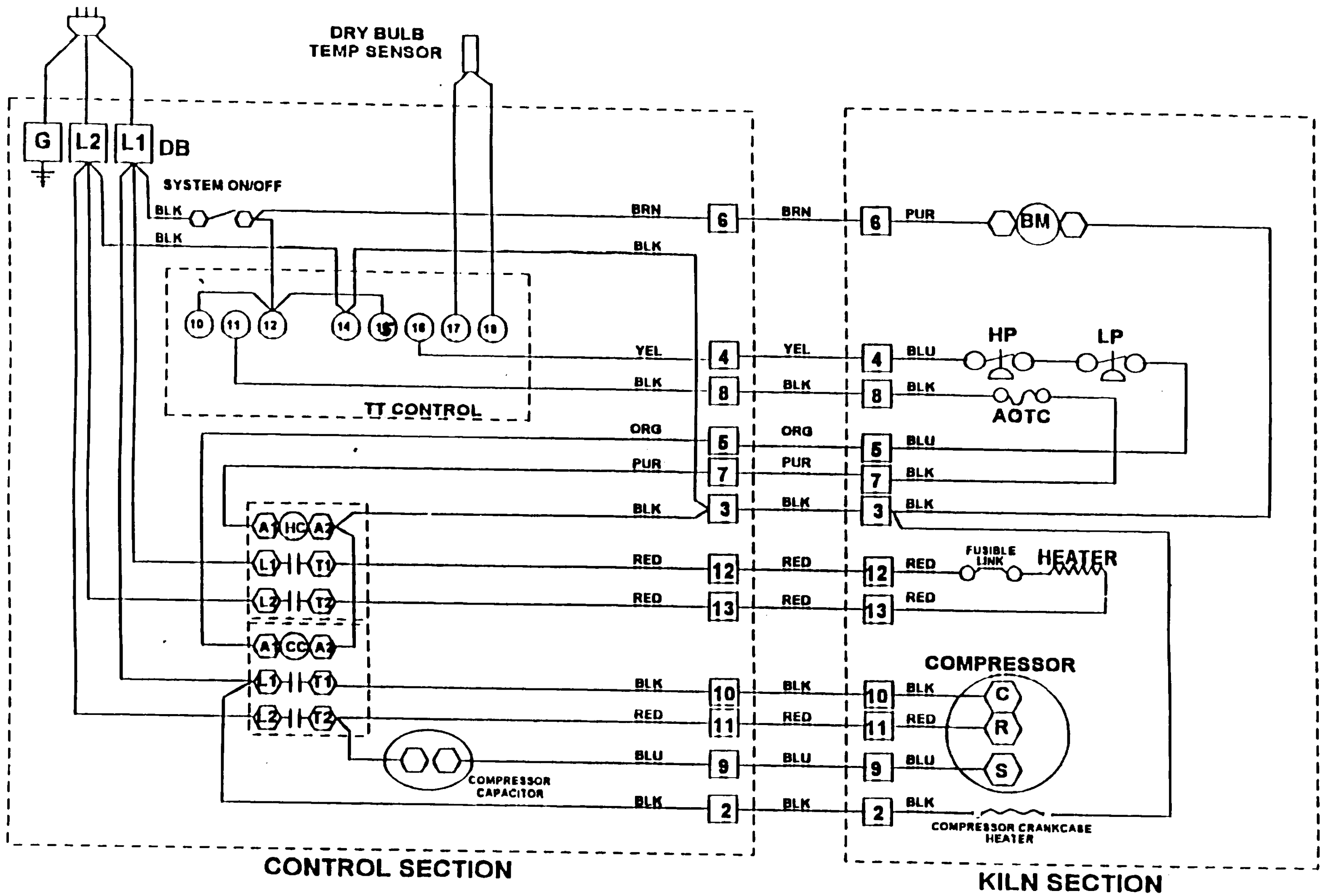
READ THIS FIRST!!

- Read enclosed "Motor Installation and Maintenance" Pamphlet. Read entire nameplate carefully.
- Heed all Warnings.
- This motor not suitable for use in hazardous or explosive locations.
- Always be sure that motor is connected for proper voltage and rotation Before energizing.
- Insulate any unused leads.

Motor Connection Diagrams

CW ROTATION FACING SHAFT AS SHOWN





NYLE MODEL L200 WIRING

PRODUCTION AFTER 4/22/97

Honeywell UDC 1000 Temperature Control Settings

Programming Instructions

These are provided should the control ever need to be re-programmed, they are shipped programmed already.

"raise key" = ▲ ▼ "lower key" =

To enter the CONFIGURATION MODE

1. Within 30 seconds of powering UDC, press and hold SET UP key and the raise key at the same time until "inPt" appears on the display.
2. Press SET UP key and the lower key at the same time. "dEFn" will appear on the display.
3. Press either the lower or raise key to change the value showing on the display to '1110'. The '1110' will blink for a short time until the MAN/AUTO key is pressed. Pressing the MAN/AUTO key saves the value to memory.
4. Press SET UP key and the lower key at the same time. "inPt" will show on the display.
5. Press the lower or raise key to change the value showing on the display to "2296" (or 2295 for °C.). Press the MAN/AUTO key.
6. Press SET UP key. "CtrL" will appear on the display.
7. Press the lower or raise key to change the setting showing on the display to 'rEv'. Press the MAN/AUTO key.
8. Press SET UP key. "ALA1" will appear on the display.
9. Press the lower or raise key to change the setting showing on the display to 'none'. Press the MAN/AUTO key.
10. Press SET UP key. "ALA2" will appear on the display.
11. Press the lower or raise key to change the setting showing on the display to 'P_Lo'. Press the MAN/AUTO key.
12. Press SET UP key. "Inhi" will appear on the display.
13. Press the lower or raise key to change the setting showing on the display to 'none'. Press the MAN/AUTO key.
14. Press SET UP key. "USE2" will appear on the display.
15. Press the lower or raise key to change the setting showing on the display to 'A2_r'. Press the MAN/AUTO key.
16. Press SET UP key and the raise key.
17. Allow for UDC to stop the display from flashing. When flashing stops, the UDC will be on the operator mode.

To enter the SET UP MODE

18. Press SET UP key and the raise key at the same time. "Uloc" will appear on the screen.
19. Press on the raise key to change the value on the display to '10'. Press the SET UP key. "Filt" will appear on the display. The SET indicator light will also be on to indicate the UDC is in the set up mode.
20. Keep pressing SET UP key until "Ptb1" appears on the display.
21. Press the lower key to change the value showing on the display to '0.0'.
22. Press SET UP key. "diF1" will appear on the display.
23. Press the raise key to change the value showing on the display to '2.0'.
24. Keep pressing SET UP key until "L_A2" appears on the display.
25. Press the raise key to change the value showing on the display to '80.0'.
26. Keep pressing SET UP key until "sPSt" appears on the display.
27. Press the raise key to change the value showing on the display to '2'.
28. Keep pressing SET UP key until the operator mode values appears on the display.
29. Press SET UP key and the raise key at the same time to exit the set up mode. The SET indicator light will no longer be on.

Honeywell UDC 1000 Humidity Control Settings

Programming Instructions

These are provided should the control ever need to be re-programmed, they are shipped programmed already.

▲= "raise key" = "lowerkey" ▲

To enter the CONFIGURATION MODE

1. Within 30 seconds of powering UDC, press and hold **SET UP** key and the raise key at the same time until "inPt" appears on the display.
2. Press **SET UP** key and the lower key at the same time. "dEFn" will appear on the display.
3. Press either the lower or raise key to change the value showing on the display to '3110'. The '3110' will blink for a short time until the **MAN/AUTO** key is pressed. Pressing the **MAN/AUTO** key saves the value to memory.
4. Press **SET UP** key and the lower key at the same time. "inPt" will show on the display.
5. Press the lower or raise key to change the value showing on the display to '3414'. Press the **MAN/AUTO** key.
6. Press **SET UP** key. "CtrL" will appear on the display.
7. Press the lower or raise key to change the setting showing on the display to 'dir'. Press the **MAN/AUTO** key.
8. Press **SET UP** key. "ALA1" will appear on the display.
9. Press the lower or raise key to change the setting showing on the display to 'none'. Press the **MAN/AUTO** key.
10. Press **SET UP** key. "ALA2" will appear on the display.
11. Press the lower or raise key to change the setting showing on the display to 'none'. Press the **MAN/AUTO** key.
12. Press **SET UP** key. "Inhi" will appear on the display.
13. Press the lower or raise key to change the setting showing on the display to 'none'. Press the **MAN/AUTO** key.
14. Press **SET UP** key. "USE2" will appear on the display.
15. Press the lower or raise key to change the setting showing on the display to 'A2_d'. Press the **MAN/AUTO** key.
16. Press **SET UP** key and the raise key.
17. Allow for UDC to stop the display from flashing. When flashing stops, the UDC will be on the operator mode.

Then enter the SET UP MODE

18. Press **SET UP** key and the raise key at the same time. "Uloc" will appear on the screen.
19. Press on the raise key to change the value on the display to '10'. Press the **SET UP** key. "Filt" will appear on the display. The SET indicator light will also be on to indicate the UDC is in the set up mode.
20. Keep pressing **SET UP** key until "Ptb1" appears on the display.
21. Press the lower key to change the value showing on the display to '0.0'.
22. Press **SET UP** key. "diF1" will appear on the display.
23. Press the raise key to change the value showing on the display to '2.0'.
24. Keep pressing **SET UP** key until "rhi" appears on the display.
25. Press the raise key to change the value showing on the display to '95.0'.
26. Keep pressing **SET UP** key until "rLo" appears on the display.
27. Press the raise key to change the value showing on the display to '3.0'.
28. Keep pressing **SET UP** key until "sPSt" appears on the display.
29. Press the raise key to change the value showing on the display to '2'.
30. Keep pressing **SET UP** key until the operator mode values appears on the display.
31. Press **SET UP** key and the raise key at the same time to exit the set up mode. The SET indicator light will no longer be on.

UDC 1000 Parameter Sheet

Temperature Controller Settings

Mode	Parameter	Factory Setting	Value or Selection
CONFIGURATION	dEFn	2110	1110
	inPt	7220	2296 (°F) 2295 (°C)
	Ctrl	varies	rEv
	ALA1	varies	nonE
	ALA2	varies	P_Lo
	Inhi	varies	nonE
	USE2	varies	A2_r
	Loc	10	
SET UP	Filt	2.0	2.0
	OFFS	0	0
	Out1	read only	
	Pb1	10.0	0.0
	diF1	0.5	2.0
	SPhi	213.6 (105°C.)	213.6 (105.0°C.)
	SPLo	32.0 (0.0°C.)	32.0 (0.0°C.)
	L_A2	32.0 (0.0°C.)	80.0 (27°C.)
	LAEn	0	0
	APt	0	0
	PoEn	0	0
	rPEn	0	0
	SPSt	1	2
	Loc	10	

If °C. is selected, make sure you use °C settings below

Humidity Controller Settings

Mode	Parameter	Factory Setting	Value or Selection
CONFIGURATION	dEFn	2110	3110
	inPt	7220	3414
	Ctrl	varies	dir
	ALA1	varies	nonE
	ALA2	varies	none
	Inhi	varies	nonE
	USE2	varies	A2_d
	Loc	10	
SET UP	Filt	2.0	2.0
	OFFS	0	0
	Out1	read only	
	Pb1	10.0	0.0
	diF1	0.5	2.0
	SPhi	100.0	95.0
	SPLo	0.0	3.0
	LAEn	0	0
	rPnt	1	1
	rhi	100.0	95.0
	rLo	0.0	3.0
	APt	0	0
	PoEn	0	0
	rPEn	0	0
	SPSt	1	2
	Loc	10	