KILN DRYING OF WHITE BIRCH TURNING SQUARES

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KILN DRYING OF WHITE BIRCH TURNING SQUARES

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Introduction

Kiln-drying schedules for most species of hardwoods and softwoods have been developed at the Forest Products Laboratory. These schedules, as given in the "Kiln Drying Handbook," Bul. No. 1136, and in Forest Products Laboratory Technical Note No. 175, have served extensively as a standard for kiln operation and as a basis for modified schedules. Recent work at the Laboratory has been directed toward developing improved schedules. Among the significant findings of this work is that the drying time shown in the original schedules may be reduced safely for some items and species through the use of lower relative humidities and higher temperatures.

The original schedules were developed for drying random-width lumber, and no specific schedules have been available for kiln drying squares. As part of the Laboratory's current work in improving schedules, the drying characteristics of the Northeastern hardwoods commonly used in the turning industry are being studied. In order to have a wide selection of representative material available for this study, the required kiln equipment was moved from the Laboratory into the Northeastern hardwood region. With the assistance of the Forest Utilization Service of the Northeastern Forest Experiment Station, Philadelphia, the cooperation of the Stowell-MacGregor Corporation at Dixfield, Maine, was obtained. The many services furnished by the cooperator made possible the experimental work here reported.

Material

All-sapwood white birch (Betula papyrifera) turning squares were dried in the study of the Northeastern hardwoods. The squares were sawed from bolts that were newly cut from the woods, and were then kiln dried directly after their manufacture. This procedure assured fresh, green material of maximum moisture content. Only a sufficient number of squares were sawed as they were required for each kiln run.

The material dried included squares that were 1, 1-1/2, and 2-1/2 inches in size. Most of the experimental work was with the 1-inch and the 1-1/2-inch squares. One run of 2-1/2-inch squares gave valuable information on drying defects and drying time, but insufficient data for recommending a kiln schedule.

The bolts from which the test material was sawed were 50 inches long. They had a minimum diameter of 6 inches and an average diameter of 9 inches. The grade of logs varied somewhat throughout the experiment. There was no matching of material in the different kiln runs other than for the selection of freshly cut bolts and for similar handling of the material.

Each kiln run contained approximately 300 board feet of material, or the equivalent of 900 to 1,000 1-inch squares 4 feet long. There were proportionately fewer squares of the larger sizes.

Equipment

The experimental kiln runs were made in a kiln designed and built at the Forest Products Laboratory for this type of work. It is a steam-heated, internal-fan, cross-circulation kiln with automatic control of temperatures and of relative humidity. The humidity can be controlled either by a pneumatically operated recorder-controller or by a wood-element hygrostat. The latter instrument is not manufactured commercially, but is relatively easy to make. Its design and operation are described in Forest Products Laboratory Report No. R1602. The moisture evaporated from the wood is utilized in this kiln for humidity control through the manipulation of vents. A steam spray is provided to supply additional moisture to the kiln when required. This procedure of utilizing the moisture from the lumber being dried for maintaining the desired humidity, reduces the amount of steam required for operating the kiln. As will be pointed out later, the problem in drying white birch green from the saw, was not one of maintaining a high relative humidity, but rather one of providing sufficient venting to lower the relative humidity to the desired level.

Preliminary Work

The results of exploratory work in the Laboratory kilns indicated that severe drying conditions can be used successfully. Squares up to 1 inch in size and with 70 percent moisture content were dried to 10 percent moisture content in a few hours with temperatures up to 210° F. and relative humidities of less than 10 percent. The only drying defects then apparent were end checks and a discoloration from the original white to a slight buff. The end checks were of an objectionable depth that indicated the need for milder drying conditions or for protective end coatings in commercial drying.

Test Procedure

The test material was placed in the experimental kiln to form a pile 4 feet long, 3 feet wide, and 5 feet high. Squares up to 1-1/4 inch in size were self-stuck, using three stickers per course. The larger sizes were stuck with green 1-inch squares of similar material, also using three stickers per course. The spaces at the ends and above the pile were baffled to force a brisk rate of air circulation through the test load.

In drying the first kiln run of 1-inch white birch, a schedule (table 1) was used similar to the general hardwood schedule No. 1 given in Forest Products Laboratory Technical Note No. 175. The initial relative humidity in this first run was lower than that in the general schedule No. 1, and because of the rapid rate of drying of this material, the several steps listed in schedule No. 1 could not be followed closely.

Squares located on the entering-air side of the pile, where the relative humidity was lower than on the leaving-air side, were found to be whiter than those in the rest of the load. The schedules for the next three kiln runs were modified accordingly in order to obtain the greater whiteness in the dried squares throughout the load.

Six experimental kiln runs were made on 1-inch squares at initial temperatures ranging from 120° to 160° F. and at initial relative humidities ranging from 76 to 50 percent for different runs. A full charge of 1-inch squares was then dried in a commercial kiln to check the results obtained in the smaller experimental unit.

Three experimental kiln runs were also made on 1-1/2 inch white birch squares at initial temperatures ranging from 120° to 160° F. and at initial relative humidities ranging from 35 to 75 percent for the different runs.

Drying Time

One-inch white birch squares were dried in the experimental unit in less than 2 days. One run was dried in only 38 hours, and the average drying time for six kiln runs was 48 hours.

Squares 1-1/4 inch in size were dried in less than 3 days. One run was dried in only 58 hours, and the average drying time for three kiln runs was 68 hours.

The commercial kiln used for the check run was a modern double-track internal fan, cross-circulation kiln with automatic control of temperature and humidity and automatic reversing of the fans. The drying time of more than six days for 1-inch squares was much longer than in the experimental kiln. These results indicate that the fast drying in the experimental kiln cannot always be duplicated in a larger commercial kiln, due to the lack of venting capacity and less uniform drying conditions through the wide loads.

Drying Defects

The defects usually encountered in kiln drying long lumber and large sizes of dimension stock may be classified as surface checks and end checks, honeycombing, collapse, warping, case-hardening, and stain or discoloration. Fortunately, all these types of drying defects are not serious in drying white birch turning squares.

Surface checks.--Surface checking usually occurs in the wide, flat-sawed surfaces of heartwood boards, especially such refractory species as oak or beech. The smaller surfaces of turning squares are less subject to surface checking, and such checking in white birch turning squares was found to be of no consequence.

End checks.--End checking, however, developed in all the white birch squares, including small squares dried by the mildest kiln schedules. The depth of penetration of the checks was least in the small-sized squares dried by the mildest schedule and greatest in the large-sized squares dried by the most severe schedule. The greater size of the larger squares was more accountable for producing deeper penetration of end checks than the kiln schedule used, as shown in table 2.

The occurrence of end checks is a serious problem in drying the larger-sized squares, and speed of drying these larger sizes will be limited by the tendency to end check. Either very mild schedules must be used, or the end surfaces must be protected by a coating that will retard end drying, and thus prevent end checking.

In these experimental kiln runs no end coatings were used. The desirability of using an end coating on the larger-sized squares, and of thus permitting the use of faster drying schedules, must be weighed against the cost of applying the protective end coating. The use of end coatings on certain items, such as shoe-last blocks, gunstock blanks, and bowling-pin blanks is an established practice. The use of end coatings should be considered on squares larger than 1-1/2 inches.

Honeycombing.--Honeycomb checks usually develop from end checks or surface checks that extend to the wood from the surface. Honeycombing can largely be prevented by eliminating end and surface checking. Honeycomb checks did not develop in the sapwood squares, even when dried by the most severe schedules, but did develop in the heartwood portion of the larger squares.

Collapse.--Collapse is abnormal shrinkage due to an irregular drawing together of the cell walls as the free water leaves the cell cavities. Collapse occurred only in the heartwood portion of the squares, particularly when they were dried at high temperatures. The drying characteristics of sapwood and heartwood are widely different, and in kiln drying a charge of sapwood material by a schedule suitable for the sapwood, any small amount of heartwood present in the charge may check, honeycomb, and collapse badly.

Warping.--Warping of the squares during kiln drying was due mainly to irregularity of the grain. Straight-grained, clear material dried flat, while material that was cross-grained, particularly near knots, showed considerable warp. No comparison was made between the amount of warp in the kiln-dried and that in similar air-seasoned material. Properly kiln-dried squares could be expected to remain as straight and flat as similar air-seasoned material. Good piling practices, such as firm, level pile bottoms, vertical alignment of stickers over the pile bottoms and the use of at least three and preferably four stickers per course of 50-inch stock, will also reduce the amount of warp.

Case-hardening.--Drying stresses develop as wood dries. Lumber that contains drying stresses is called "case-hardened." The term therefore refers to a condition of stress rather than a variation of hardness of the fibers throughout the thickness of the piece. In a case-hardened square or board, the fibers in the zone of wood near the surface are in compression, while the fibers in the central zone of wood are in tension. The detection and relief of case-hardening stresses is discussed in Forest Products Laboratory Technical Note No. 213.

Tests on air-seasoned stock showed that all material being used was case-hardened. Kiln-dried material will also develop drying stresses, but these stresses can be relieved by proper conditioning treatment of the material before it is removed from the kiln. The squares dried in the experimental kiln runs were given a final equalizing and conditioning treatment to remove the case-hardening stresses.

Stresses developed during drying and that have not been relieved, may cause objectionable cupping and warping of "long lumber" during its subsequent machining operations. Spools and similar turned items that are manufactured from short lengths are not affected by case-hardening stresses. Long dowels that are turned from squares that are badly case-hardened may bow. The effect of case-hardened lumber upon the finished item, therefore, depends to a great extent upon its final use requirements.

Stain or discoloration.--Certain use requirements demand bright, white wood, while others are exceedingly tolerant of color, and even of certain stages of decay. In drying white birch spool stock, color was considered important, and the schedules used were modified in order to develop one by which squares could be dried and still retain their natural white color.

The established practice in the past has been to cut white birch only during the dormant season and to pile the squares in a yard for air-seasoning. The cutting season usually extends from early October through March. This "winter-cut" wood produces bright, white squares when properly piled for air-seasoning. Low winter temperatures prevent the formation of stain and mold during drying.

Squares sawed from trees cut during the growing season and air-seasoned during the warm summer months are likely to stain. Several methods of piling for air-seasoning have been tried in an effort to reduce the degree of stain, but no method of piling for summer air-seasoning has produced wood so white as the winter-sawed wood.

Besides the danger of stain and mold due to fungi growth during the summer, there may be some difference in the nature of the soluble extractives in the sap in the summer-cut wood that causes a browning during kiln drying. The browning appears to be similar to the chemical stain common in the drying of other woods, notably white pine. The degree of stain is only slight in the white birch compared to that found in some other woods.

Two additional kiln runs of 1-inch white birch squares were made, in which material sawed from winter-cut bolts was used in the hope of kiln drying the winter-cut material at higher temperatures without causing the brown or buff discoloration. Unfortunately, the squares dried by the high-temperature schedule did show a brown or buff discoloration; and therefore, in the last kiln run a constant temperature of 130° F. was maintained. This temperature resulted in bright squares, but not so white as those dried at 120° F. It must, therefore, be concluded that in order to retain the bright, white color of white birch during kiln drying, low temperatures and humidities should be used. The method of kiln drying appears to be more effective in maintaining the white color of wood than the season of the year in which it is cut.

Machining Qualities of the Kiln-dried Squares

The machining qualities of the kiln-dried squares and of the air-seasoned squares were studied to determine what effect, if any, the kiln drying had on the occurrence of defective turnings in machining. Squares that were dried by the first four kiln runs were manufactured into spools. The waste at different stages of the operation was compared with that from a control lot of best-quality, winter-cut, air-seasoned squares. The results indicated that the kiln-dried squares machined equally as well as the control group of air-seasoned squares.

Temperature and Relative-humidity Limitations

Figure 1 shows a comparison of the drying time for two kiln runs of 1-inch white birch squares dried in the small experimental kiln, to the drying time for one kiln run of similar material dried in a large commercial kiln. In kiln run No. 4, the relative humidity was increased after only 28 hours to prevent excessive drying during the following 12-hour period. The drying was retarded more than necessary, and the final moisture content was greater than the desired 15 percent. Usually, such an equalizing period is begun when the drier samples begin to dry below the desired final moisture content. The initial set temperature and humidity in the commercial kiln were 120° F. for the dry bulb and 100° F. for the wet bulb, producing a relative humidity of 49 percent. The vents were fully open and the steam spray was closed, but the moisture coming from the squares being dried was sufficient to maintain a relative humidity ranging from almost 70 percent at the start down to 50 percent at the end of the run. The drying rate was slower in the commercial kiln because of the higher humidities and also because of the wider loads, which caused less uniform temperatures. In the experimental kiln, the drying rate was more rapid because lower humidities could be maintained and the narrower loads made possible more uniform temperatures.

Conclusions

The important factor in obtaining rapid drying of white birch material is a uniform, brisk air circulation, and sufficient venting capacity to reduce the relative humidity during the early stages of drying when large quantities of water are evaporating from the wood. The required venting should be obtained through vent openings properly designed and provided for this purpose. A kiln building that is not "tight" and that allows leakage of air through cracks around the doors and other openings, will not be satisfactory because the leakage of air is certain to disrupt the uniformity of temperature and of air circulation throughout the kiln. Cold air that is taken into the kiln through proper openings is conditioned to the proper temperature and relative humidity before it enters the load of lumber. Better temperature distribution throughout the kiln is thus maintained.

White birch turning squares dry readily and are not subject to critical temperatures during kiln drying as are many other species of woods, such as oak, sweetgum, and black walnut. There is a broad choice of temperatures that will be satisfactory for drying. Such choice should not be interpreted to mean that wide variations of drying conditions throughout the kiln are permissible, for the desired temperature should be maintained as uniformly as possible to obtain uniformity of drying.

Suggested Schedule

The schedule given in table 3 is suggested for drying white birch sapwood squares 1-1/2 inches or less in size in kilns having accurate control of temperature and relative humidity and having a brisk rate of air circulation. At the temperatures indicated, there will probably be some discoloration of the white sapwood to a slight buff color. For the manufacture of certain items, such as spools, the maximum whiteness of the birch is desired; therefore, when kiln drying squares for such items, the temperatures should be much lower than those shown in the recommended schedule. A temperature of 120° F. was found to produce bright, white squares that compared favorably with the best winter-cut, air-seasoned squares. The same relative humidities as shown in the recommended schedule (fig. 2) should be satisfactory. Higher temperatures, even during final conditioning treatment, produced a slight brown or buff color.

The drying time of 2-1/2 days, including a conditioning treatment, is for 1-inch squares, and it can be expected to be attained only if the desired temperatures and relative humidities and a brisk rate of air circulation are maintained uniformly throughout the kiln.

These ideal conditions are often less easily maintained in a commercial kiln than in the small experimental kiln, and the drying time may be much longer. The drying time for 1-1/2 inch squares will also be proportionately longer.

Table 1.--General hardwood schedule No. 1

Moisture content	Dry bulb	Wet bulb	Relative humidity
Percent	°F.	°F.	Percent
Green to 40	140	132	80
40 to 30	145	135	75
30 to 25	150	137	70
25 to 20	155	136	60
20 to 15	160	135	50
15 to 10	165	127	35
10 to final	170	116	20

Table 2.--Maximum depth of end checks (all sapwood)

Thickness of squares	Type of kiln schedule	Occurrence of end checks by depth classes								
		0 to 1/2 inch	1/2 to 1 inch	1 to 1 1/2 inch	1-1/2 to 2 inches	2 to 3 inches	3 to 4 inches	4 to 5 inches	5 to 6 inches	6 to 7 inches
Inches		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Mild	54	31	15						
1	Severe	50	27	21	2					
1-1/4	Mild	25	50	25						
1-1/4	Severe	5-1/2	11	45	33	5-1/2				
2-1/2	Severe					5-1/2	22	39	28	5-1/2

Table 3.--Suggested schedule for white birch squares up to 1-1/2 inches in size, based on moisture content

Moisture content	Dry bulb	Wet bulb	Relative humidity
Percent	° F.	° F.	Percent
Green to 45	140	125	64
45 to 30	140	120	54
30 to final	180	135	30
Conditioning 6 to 8 hours	180	170	79

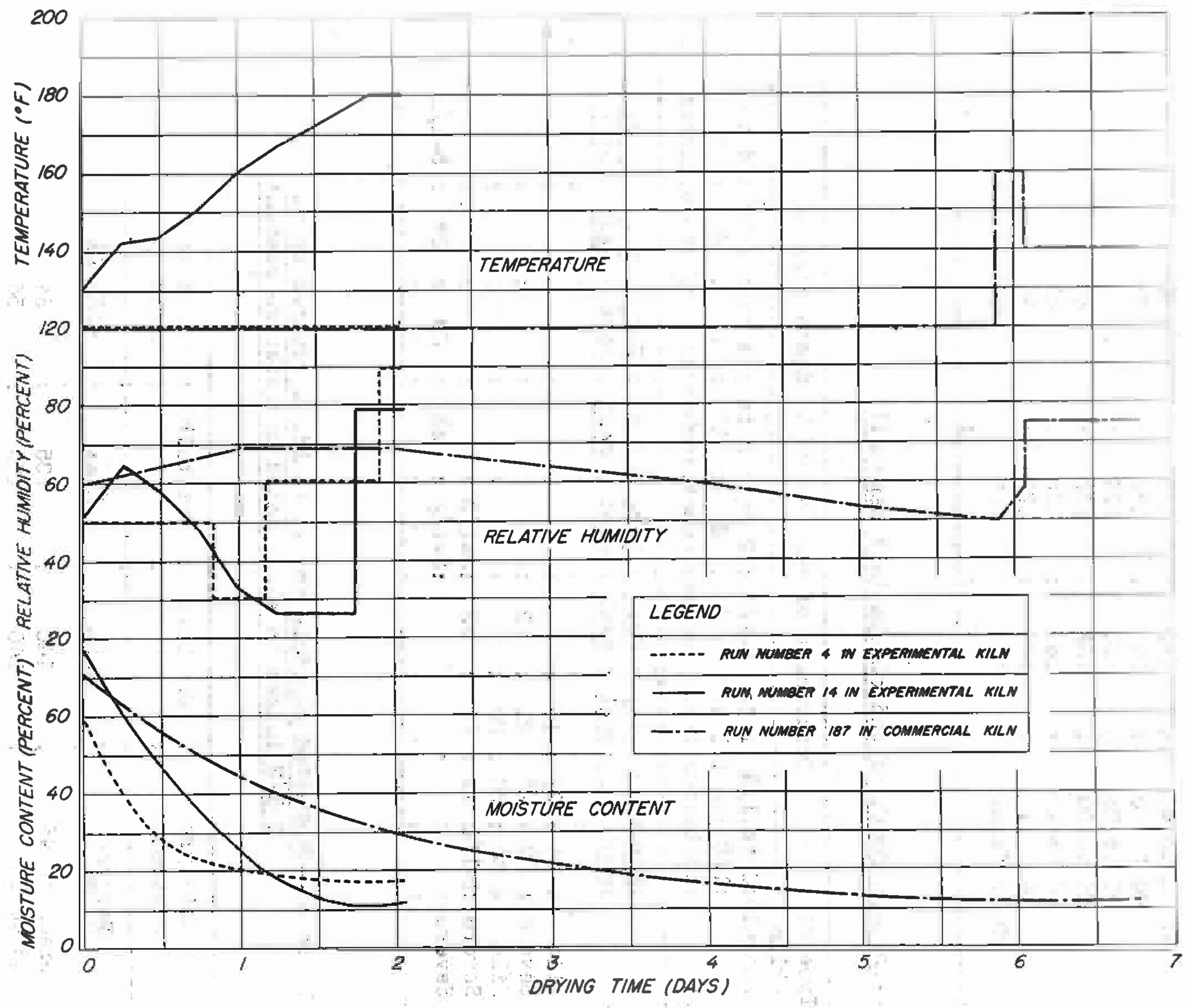

Figure 1.--Comparison of the drying time for two kiln runs of white birch sapwood 1-inch squares in a small experimental kiln to drying time for one kiln run of similar material in large commercial kiln.

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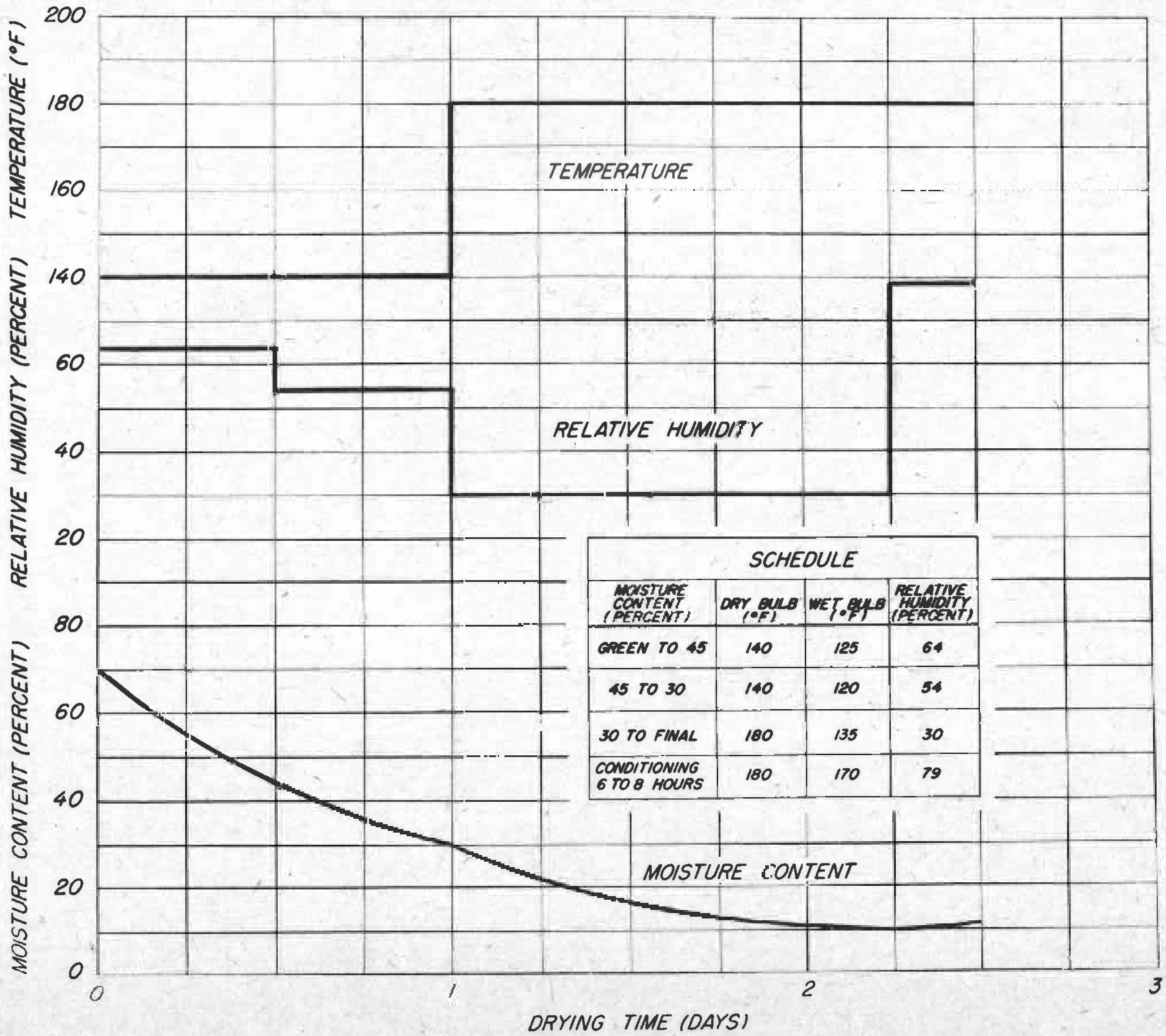

SCHEDULE

MOISTURE CONTENT (PERCENT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (PERCENT)
GREEN TO 45	140	125	64
45 TO 30	140	120	54
30 TO FINAL	180	135	30
CONDITIONING 6 TO 8 HOURS	180	170	79

Figure 2.--Suggested kiln schedule for white birch sapwood turning squares up to 1-1/2 inches in size, based on moisture content.

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