PROTECTING BULK-PILED GREEN LUMBER FROM FUNGI BY DIP TREATMENT

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PROTECTING BULK-PILED GREEN LUMBER FROM FUNGI BY DIP TREATMENT

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Introduction

While fully seasoned lumber can be stored indefinitely under roof without decaying and losing strength, green lumber of most species cannot long be kept in sound condition during mild weather. Sapwood, which comprises a high proportion of second-growth timber, is highly vulnerable in the green condition to fungus attack. Questions have been raised from time to time, therefore, as to just how long unseasoned lumber can be bulk piled without seriously deteriorating, and to what extent damage may be postponed by surface treating the freshly cut stock with commonly used antistain chemicals.

The rapid deterioration of green, bulk-piled lumber was of more than ordinary interest during World War II, when emergency production conditions tended to bring about shipping of much green stock and greater intervals of time elapsed between sawing and drying at the sawmill. In that period, it was not uncommon to find, in lumber shipped from the South and the West Coast, decay that had progressed to a plainly visible stage. Decay was aggressively guarded against in aircraft lumber but nevertheless presented a constant threat to even this specially selected critical material.

Infections started during storage often continued to damage the lumber even in service. Rot was likely to occur if infected wood was not adequately seasoned and was installed in more or less closed-in locations where it could not dry. A number of instances of rot thus promoted by the use of already infected lumber were observed during the War in U. S. military buildings in various areas, and complaints about rot in buildings made of infected lumber imported from the United States were registered earlier in England.[2] It subsequently has been learned that slight decay infections in lumber also may greatly increase the opportunity for serious damage to wood that is exposed to the weather. Infection markedly increases the absorptiveness of the wood, so that dangerous amounts of rain water accumulate and are held in it.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] K. St. George Cartwright. Why These Complaints About Douglas-Fir? Timber Trades Journal 142(3179): 336, 346. 1937.

The acuteness of the problem in the later war years prompted field studies in the South and the Pacific Northwest to obtain quantitative information about the speed of deterioration of green sapwood lumber bulk piled in those regions. The information was sought for both untreated lumber and lumber that had been dipped or sprayed with an anti-fungal solution. Although surface treatment of green stock with any of the standard solutions was known to provide good protection against decay, sap stain, and mold in seasoning yards, little was known about what to expect from the treatment of green lumber to be bulk piled and thus prevented from drying. To make the information as meaningful as possible, records of the amounts of visible decay were related to the strength of the wood, generally its toughness. Toughness is a term applied to the capacity of the wood to withstand shock loading, as determined by a standard toughness test.

Besides the field work, a comprehensive investigation was conducted at the Laboratory on several species of southern and western lumber. This work was intended to disclose maximum rates of deterioration to be expected in bulk piles of untreated wood, and the magnitudes of loss in certain strength properties in addition to toughness.

The field studies and related decay observations were made by the Southern Forest Experiment Station and the Pacific Northwest Station.[3,4] Some of the work was done in connection with a broader project that was aimed primarily at the chemical protection of lumber in seasoning yards.

Establishment of Studies

Lumber Used and Treating Procedure

Lumber for the Southern Station's tests was entirely sapwood, chiefly of longleaf and slash pine (*Pinus palustris* and *P. elliotii var. elliotii*) and sweetgum (*Liquidambar styraciflua*) but included also a small amount of hickory (*Corya* sp.) and oak (*Quercus* sp.). The sapwood of pine and sweetgum is notably vulnerable to decay and sap stain. The study material consisted of pieces cut to 1 by 2 by 14 inches or 1 by 4 by 24 inches in size and sawed out of rough stock obtained from freshly-cut logs free of visible infection. Pieces to be treated were dipped on the day the lumber was sawed or the next day.

The Pacific Northwest Station's studies were conducted on Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and Sitka spruce (*Picea sitchensis*), obtained and prepared in essentially the same manner. The 1-inch material was, however, 4 or 6 inches wide by 12 inches long or 8 by 21 inches in size.

In all field studies, pieces selected to receive different dipping treatments and to be held in the test piles for different lengths of time were to a large extent cut from the same boards. Complete matching of boards was precluded, however, by the number of variables represented in each study.

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[3] Verrall, A. F. and Mook, Paul V. Research on Chemical Control of Fungi in Green Lumber, 1940-1951. U. S. Dept. Agr. Tech. Bull. No. 1046, 60 pp. 1951.

[4] Wright, Ernest. Sap Stain and Decay Control Tests. Timberman 53(6):140-142, 1952.

The Laboratory study was made on 1-inch boards of sweetgum, yellow-poplar, and Sitka spruce 6-1/2 by 23 to 25 inches in size. Both heartwood and sapwood were included in each board of all three species.

In the Laboratory investigation, the primary lumber, 2-1/4 inches thick and 46 to 50 inches long, was randomly selected for the different exposure groups. These were resawed and crosscut at the midpoint to furnish material for bulk piling that was fully board matched with respect to all other variables of the study.

Each board was immersed for 5 to 10 seconds in one of the anti-fungal solutions. Chemicals making up the solutions were the principal ones in commercial usage, although in a number of instances the proportions or combinations were experimental rather than standard. Most of the solutions were the same as, or much like, those extensively used today on lumber to be air seasoned. They are listed in table 1, which gives the concentrations used and those presently favored commercially.

Exposure Conditions

Lumber used in the field studies was piled in the open on slightly elevated wood platforms. Boards for each kind of chemical treatment and length of storage were solid stacked separately in one or two individual groups, and the groups were placed close together to form a pile. Groups representing all variables being compared were incorporated in a single pile. Generally, 10 to 20 pieces comprised a group.

To retard drying, each completed pile was banked around the edges, and some were overlaid on top, with such green lumber as remained, and the entire pile was loosely enclosed with roll roofing on top and roll roofing or boards on the sides. The intention throughout was to simulate conditions encountered in shipping green lumber or in bulk storage before kiln drying or stacking in the seasoning yard. In the Southern Station studies, summer test piles were shaded with an elevated canopy of pine boughs to prevent excessive heating.

For the supplementary study made at the Laboratory, the boards were bulk piled in a room maintained at a temperature of 80° F. and a relative humidity of 80 percent. In addition, they were covered with a heavy tarpaulin. Because one purpose of this study was to produce a maximum rate of decay, the boards were artificially inoculated. This was accomplished by spreading wheat previously infected with a decay fungus between the courses of boards. A mixture of grain infected with *Poria monticola* and *Polyporus versicolor* was used for the sweetgum and yellow-poplar boards, and grain infected with *P. monticola* alone was used for *Sitka* spruce.

Evaluation Procedures

Decay Observations

When a period of storage had ended, the group of boards to be examined was removed from the bulk pile and the remaining groups were promptly closed in again. Each piece was then inspected for decay. Records of decay in the Southern Station study were based on such indications of its presence as surface growth of the attacking fungus, characteristic discolorations of the wood, bleaching of stained areas, and to some extent softening of the wood. The percentage of surface area affected in one or more

of these ways was estimated. Lumber used in the Pacific Northwest studies was appraised similarly, except that greater stress was laid on softening, which was appraised by probing the board with a knife in an attempt to rate the decay in terms of area of lumber affected and the stage of wood deterioration.

Strength Observations

The toughness appraisals, which were made at the Laboratory on all wood evaluated for strength, were performed on small, clear specimens. In preparation, lumber sections from the field experiments were dried as soon as they were received at the Laboratory to equilibrium weight in a room maintained at a relative humidity of 65 percent and 80° F. Then the boards were sawed and surfaced into 5/8- by 5/8- by 12-inch specimens. Usually the initial surfacing of each rough board was done as lightly as possible on the face showing the most evidence of fungus infection. This face was marked for the tension side of the individual specimens in order to bring out the maximum effect of the infection. After reconditioning in the original conditioning room, which resulted in a moisture content of approximately 12 percent, the finished specimens were tested under third-point loading over a span of 9-3/4 inches.

The lumber used in the Laboratory study was appraised for static bending strength as well as toughness. Infected and uninfected (control) material to be appraised for each kind of strength was prepared in fully board-matched sets of four specimens. The bending properties determined were work to maximum load, modulus of rupture, and modulus of elasticity. Except for a difference in size, the test specimens were prepared essentially as described for those from the field material. The toughness pieces were 7/8 by 7/8 by 18-1/2 inches and the bending pieces 7/8 by 7/8 by 20-1/2 inches. Both types of strength were determined with third-point loading over a 16-1/2-inch span for toughness and 18-1/2-inch span for bending.

Development of Visible Decay

Several of the bulk piling studies in the South were conducted only for visible manifestations of decay. Results obtained in this way during winter and summer and for both hardwoods (mostly sweetgum) and pine are summarized in table 2.

For a month and a quarter, although sapstain and mold were present, there was little noticeable development of decay in any of the test material. With longer storage periods, it became progressively and rapidly conspicuous in the undipped stock. Decay involved on the average as much as 90 percent of the board area during 4 to 5 months in one group of summer exposures. Judged from the few comparisons that can be made between similar periods, it seems that the area of decay in the undipped summer-stored wood (May to October) tended to be about 2-1/2 to 3 times that in the winter stored (November to April).

All five solutions drastically limited occurrence of decay in all of the test groups. Most of the winter stock incurred little more than traces of decay in periods ranging up to 7 months, and generally only traces to small percentages of it were present in the summer-stored pine stock. Of the dipped lumber, the summer-stored hardwoods, held for a maximum of 2-1/2 months, were affected most by decay infection, showing evidence on 1 to 14 percent of their surface area. The decay varied according to the

dipping solution used, but the data are not comprehensive enough for conclusions on the representativeness of the differences. The point of chief significance is that treating provided a generally high degree of protection and evidence that any of the chemicals probably would be effective if applied in appropriate concentrations. The infection observed for a particular treatment tended to be distributed among a substantial proportion of the dipped samples.[3]

Results of three Southern Station studies that were evaluated for toughness changes as well as visible decay are given in table 3. The amounts of visible decay again indicate that infection occurred rapidly in untreated lumber but was held by dipping to slight amounts for several months. For example, even in 14 months of storage, visible decay on the surfaces of the dipped pine stock amounted to only about one-fourth (22 percent) as much as that on the undipped (85 percent).

Visible decay incurred in the Pacific Northwest tests on bulk-piled lumber is tabulated in table 4. The condition of the lumber held to the same general pattern as in the South. Decay was excessive in the undipped material but was kept to very low levels in the dipped.

Two features of the results warrant special attention; (1) decay developed much more slowly in the Douglas-fir, Sitka spruce, and western hemlock lumber than in the pine and sweetgum used in the Southern Station studies; and (2) the low incidence of decay in the dipped stock was maintained over periods as long as 15 months. For example, after 15 months of storage, the maximum surface area of visible decay on any piece in the three groups of dipped stock was 3 percent.

Strength Losses

Losses in toughness listed in table 3 for the lumber stored in the South were, as might be expected, correlated to some extent with the visible evidence of decay. The relation was not close, however, because surface development of an attacking fungus is not necessarily indicative of its progress inside a board. Nevertheless, it can be generalized that toughness was not significantly lowered where there was no more than a trace of visible decay. Toughness of the dipped stock was negligibly reduced in all the Southern Station studies through at least 4 months of nominal summer storage, whereas in the undipped stock it appeared to have dropped as much as 10 percent in the first month, and prevalently 5 percent or more per month thereafter.

In the Pacific Northwest studies (table 4), rates of toughness reduction were, as might be expected from the differences in visible decay, materially less than those incurred in the South. Moreover, the effectiveness of the dipping treatments in maintaining toughness persisted for a longer time. The maximum apparent loss of toughness in untreated wood over a 15-month period was 49 percent (hemlock); in dip-treated wood it was 19 percent (Douglas-fir). For the most effectively treated wood, however, the maximum loss of toughness during a 15-month period was only 4 or 5 percent; this result was obtained on all three woods, but with a different dipping solution in each case.

In order to obtain a clearer picture of toughness changes that might be expected generally, the data of tables 3 and 4 were plotted as shown in figure 1. In addition, maximum and minimum losses of toughness from period to period are given for individual dipped and undipped groups of lumber. The figure emphasizes the lesser decay hazard, already noted, for bulk-piled green Douglas-fir, Sitka spruce, and western hemlock

stored in the Pacific Northwest in comparison with that for southern pine and hardwoods stored in the South. It also indicates clearly for both regions the value of dipping for conserving the strength of green, bulk-piled lumber.

Strength losses in the undipped yellow-poplar, sweetgum, and Sitka spruce lumber that was artificially inoculated and stored in the Laboratory are presented in table 5. The toughness values for the yellow-poplar and sweetgum sapwood are roughly of the same general magnitude as those indicated in figure 1 for the untreated sweetgum stored about four times as long (2, 5, and 9 months) in the South.

A similar and even closer relationship of toughness is indicated for the untreated spruce sapwood between lumber in the Laboratory and the field. Thus the spruce lumber in the Laboratory seems to have been subjected to severe decay hazards with results in a given number of weeks broadly comparable to those occurring in a like number of months of warm outdoor storage in the Pacific Northwest. The spruce lost considerably less strength than the yellow-poplar and sweetgum, which suggests that the slower decay of the three softwoods in the Pacific Northwest tests was not altogether due to cooler climate.

In the 5- and 9-week periods of laboratory storage, the heartwood of yellow-poplar and sweetgum, but not that of spruce, retained substantially more of its toughness than the sapwood. This is in line with other evidence of the relative decay resistance of the heartwood and sapwood in these species.

Perhaps of greatest additional practical significance in the results of the laboratory study is the comparison afforded between the effects of decay on different strength properties and the evidence that the yellow-poplar, both sapwood and heartwood, is about as much in need of chemical protection as sweetgum when stored green in bulk piles. It is generally recognized that, of the conventional strength properties, toughness is most affected by decay, and this experience is substantiated by the data of table 5. The values for work to maximum load are similar to those for toughness, as they should be, since this measure of strength also is strongly indicative of toughness or shock resistance.

Modulus of rupture was reduced on the average less than 40 percent as much as toughness throughout the range of decay represented, and modulus of elasticity less than 20 percent as much. If these relations are projected for the purpose of broadly estimating the other strength properties from the toughness data given earlier (tables 3 and 4), one may conclude that modulus of rupture generally was not reduced more than 10 percent nor modulus of elasticity more than 5 percent where the toughness reduction did not exceed 25 percent.

General Conclusions

Tests here reported reveal that bulk-piled green lumber tends to lose strength because of fungus action shortly after it is cut, and the losses become progressively greater the longer the wood remains green. The seriousness of the losses is determined not only by the length of storage, but also by the kind of wood and the prevailing temperatures.

In the Pacific Northwest, green sapwood of Douglas-fir, Sitka spruce, and western hemlock bulk piled in early summer, seems to remain comparatively free of serious

damage to strength for possibly as long as 6 months. Nevertheless, a margin of safety provided by dipping or spraying in a suitable antifungal solution would be desirable for any stock that cannot assuredly be dried within a comparatively short time after it is sawed. Combined storage and shipping periods for green, Pacific Northwest lumber cannot always be accurately predicted. Moreover, infection by sapstain fungi and molds may become prevalent and discolor the wood in the first few months of storage; also it is known that such infection, although not particularly harmful to strength, make wood more absorbent and thus more subject to serious wetting and decay when exposed to the weather.[5]

Conventional treatment with commercial products available for lumber dipping or spraying apparently is capable of holding toughness losses below the 10 percent level in the above-mentioned woods for periods of a year or so if storage temperatures are comparable to those in the Pacific Northwest.

In the South, untreated pine and sweetgum sapwood lumber bulk piled during the warmer seasons may lose as much as 10 percent of its toughness within a month's time, and losses thereafter, in terms of original toughness, may commonly amount to 5 percent or more per month. Losses during winter-time storage may be no more than half as rapid--or even slower--but this cannot be accurately predicted. The decay hazard depends, moreover, to a considerable extent on proximity to the Gulf; the hazard is higher for lumber stored nearby than at places further inland.

The results here reported indicate that appropriate dipping of southern pine and sweetgum in one of the conventional solutions will protect green bulk-piled stock from serious toughness losses for periods up to possibly 6 months, but that losses may occur rather rapidly once they have started.

In considering this good showing of the treated pine and sweetgum lumber, however, it should be emphasized that the dipped wood was fresh and the treating was done promptly after sawing and with carefully prepared solutions. When operating under general sawmill conditions, therefore, it would be wise to limit bulking of treated southern woods to periods much shorter than 6 months--as a general rule, in fact, to perhaps no more than 1 month if the stock is to be subsequently air seasoned. If the stock is to be kiln dried, this period might be at least doubled.

The length of time over which bulk-piled lumber can be safely protected by surface treating will depend in part on the strength of the treating solution. In the event that a particular solution does not provide the desired degree of fungus control, its effectiveness can be increased by making it stronger. Even though they were generally effective in the present tests, solution strengths normally employed to protect lumber during air seasoning should be regarded as the minimum acceptable for lumber to be bulk piled for any length of time.

Surface treatment of the stock with an appropriate fungus-inhibiting solution does not fulfill the entire requirement for good temporary protection of bulk-piled lumber. It is known from earlier experiments that if lumber comes from logs that have become infected, poor results may be expected even though the dipping is done properly. Also, the treating must be done shortly after the lumber is sawed, otherwise fungi may become established in the lumber before treatment. When such infection occurs, either

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[5] Verrall, A. F. Preventing Moisture Problems in Wood Siding in the South. Forest Products Jour. 10(3):148-151. 1960.

in the logs or lumber, decay can progress inside a board despite the presence later of a preservative chemical on its surfaces. In warm weather in the South, 24 hours seems to be the maximum permissible length of time that treating can be safely delayed after cutting of the lumber. Forty-eight hours or longer can be tolerated during cooler weather, when fungi develops less rapidly.

An important consideration in these bulk-piling studies is that they were directed primarily at decay and its effect on strength of the wood. Bulk-piled lumber, whether untreated or treated, also is subject to sapstain and mold infection. As already noted in connection with the western woods, such infected stock, although not appreciably weakened, will be blemished and its absorptivity will be greatly increased. Increasing the absorptiveness of wood can lead to several difficulties, one of which is that such wood exposed to weather in use is more likely to soak up enough rain to support decay. Sapstain and mold usually develop in objectionable amounts before consequential decay becomes apparent in either treated or untreated bulked lumber. Therefore, piling periods that appear safe for decay and strength-loss prevention in the present studies could easily be excessive if avoidance of stains and molds also is important.

Table 1.--Dipping solutions used in the tests and present-day commercial counterparts

Solution	Chemicals used	Amounts used per 50 gallons of water	
		In the tests	In commercial usage
		Lb.	Lb.
A	Ethyl mercuric phosphate (6.25 percent pure)	1	1
B	Sodium pentachlorophenate (commercial grade)	3.5 or 4	3.5
C	Ethyl mercuric phosphate (6.25 percent) plus sodium pentachlorophenate	0.5 + 2	0.5 + 1
D	Sodium pentachlorophenate plus borax	2 + 3 (or 6) or 1 + 4	1.75 + 3.25 or 1.25 + 3.75
E	Mixture of solution C plus borax	0.25 + 1 + 3 or 0.25 + 2 + 6	(1)
F	Sodium tetrachlorophenate	3.5	3.5
G	Borax	12	(1)
H	Ethyl mercuric chloride plus sodium tetrachlorophenate plus borax	0.25 + 1 (or 2) + 6	(1)

[1] Not used commercially.

Table 2.--Effectiveness of various dipping solutions in controlling visible decay in the sapwood of green southern pine and hardwood lumber bulk-piled 1-1/4 to 8 months in southern Mississippi

Dipping solution	Average lumber area with visible decay[1]								
	Summer exposure[2]					Winter exposure[2]			
	Hardwoods		Pine			Hardwoods		Pine	
	1-1/4 months	2-1/2 months	2 months	4 to 5 months	7 to 8 months	1-1/4 to 2 months	2-1/2 months	7 months	2 months	4 months
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
A	0	5	[3]T	7	3	0	0	4	0	1
B	0	14	T	2	2	0	T	1	0	0
C	0	1	0	0	0	.....	.....	.....	0	0
D	0	3	0	1	T	0	0	T	.....	.....
E	T	7	0	0	0	.....	.....	.....	.....	.....
None	1	37	51	90	71	1	11	69	.....	34

[1]Rated in the rough.

[2]Approximately 50 percent or more of the time covered by a summer exposure was in the period May through October. A winter exposure was largely in the period November through April. The summer exposures represented here included two on sweetgum and five on pine. The pine exposures included one each in the 2- and 4- to 5-month periods, and three in the 7- to 8-month period. Winter exposures consisted of two on sweetgum; one each on hickory and oak; and, on pine, three in the 2-month and one in the 4-month period.

[3]T = Trace.

Table 3.--Decay and toughness data for dipped and undipped sapwood lumber bulk-piled green from the saw for various lengths of time in southern Mississippi

Length of storage	Average lumber area with visible decay[3]		Relative wood toughness (Initial value = 100)	
	Dipped	Not dipped	Dipped	Not dipped
Months	Percent	Percent	Percent	Percent
PINE TEST--STARTED IN SEPTEMBER--DIPPING SOLUTIONS A, B, D (RESULTS AVERAGED)				
1	0	9	101	90
2	0	56	116	83
4	[2]T	92	108	66
7-1/2	1	97	84	41
11	8	89	64	26
14	22	85	70	34
PINE TEST--STARTED IN JULY--DIPPING SOLUTION E				
8	[2]T	30	[3]100	[3]61
SWEETGUM TEST--STARTED IN FEBRUARY--DIPPING SOLUTIONS A, B, D, F (RESULTS AVERAGED)				
6	[2]T	95	[3]100	[3]77

[1]Rated in the rough.

[2]T = Trace.

[3]Not determined from comparisons with unstored, control lumber, but assumed from evidence, given by comparison in other tests, that the toughness of lumber with only a trace of decay generally had been but little affected.

Table 4.--Decay and toughness data for dipped and undipped sapwood lumber bulk-piled green from the saw for various lengths of time in the Pacific Northwest

Dipping solution	Length of storage period (tests started in June)	Average index of visible decay (maximum = 100)[1]		Relative wood toughness[2] (initial value = 100)	
		Dipped	Not dipped	Dipped	Not dipped
	Months	Percent	Percent	Percent	Percent
		DOUGLAS-FIR			
G	15	.....	44	96	59
H	15	3	.....	81	.....
		SITKA SPRUCE			
G	15	0	25	88	65
H	15	2	.....	95	.....
		WESTERN HEMLOCK			
D	3	1	1	99	99
D	11	0	5	101	92
D	15	0	22	96	51

[1]From examinations in the rough. By the method of indexing, both the area of infected wood and the stage of wood deterioration were taken into account. The maximum possible index was 100, and wood so rated would be unusable.

[2]The initial toughness was estimated from the average values for stored test wood that had incurred no visible fungus infection.

Table 5.--Changes in various strength properties of undipped green lumber, artificially infected and bulk-piled at 80° F. in the laboratory for up to 9 weeks

Lumber species	Relative wood strength[1] (initial value = 100)					
	Sapwood			Heartwood		
	2 weeks	5 weeks	9 weeks	2 weeks	5 weeks	9 weeks
	TOUGHNESS					
Yellow-poplar	98	80	46	98	94	83
Sweetgum	93	74	42	95	85	70
Sitka spruce	100	98	93	100	98	95
	WORK TO MAXIMUM LOAD					
Yellow-poplar	100	76	44	100	87	73
Sweetgum	90	68	37	90	85	79
Sitka spruce	100	100	100	100	98	93
	MODULUS OF RUPTURE					
Yellow-poplar	100	93	83	97	95	93
Sweetgum	96	87	77	97	97	97
Sitka spruce	100	99	97	100	100	100
	MODULUS OF ELASTICITY					
Yellow-poplar	100	96	90	96	96	96
Sweetgum	98	96	90	96	96	96
Sitka spruce	100	100	100	100	100	100

[1]Derived from smoothed strength-time curves of the actual data.

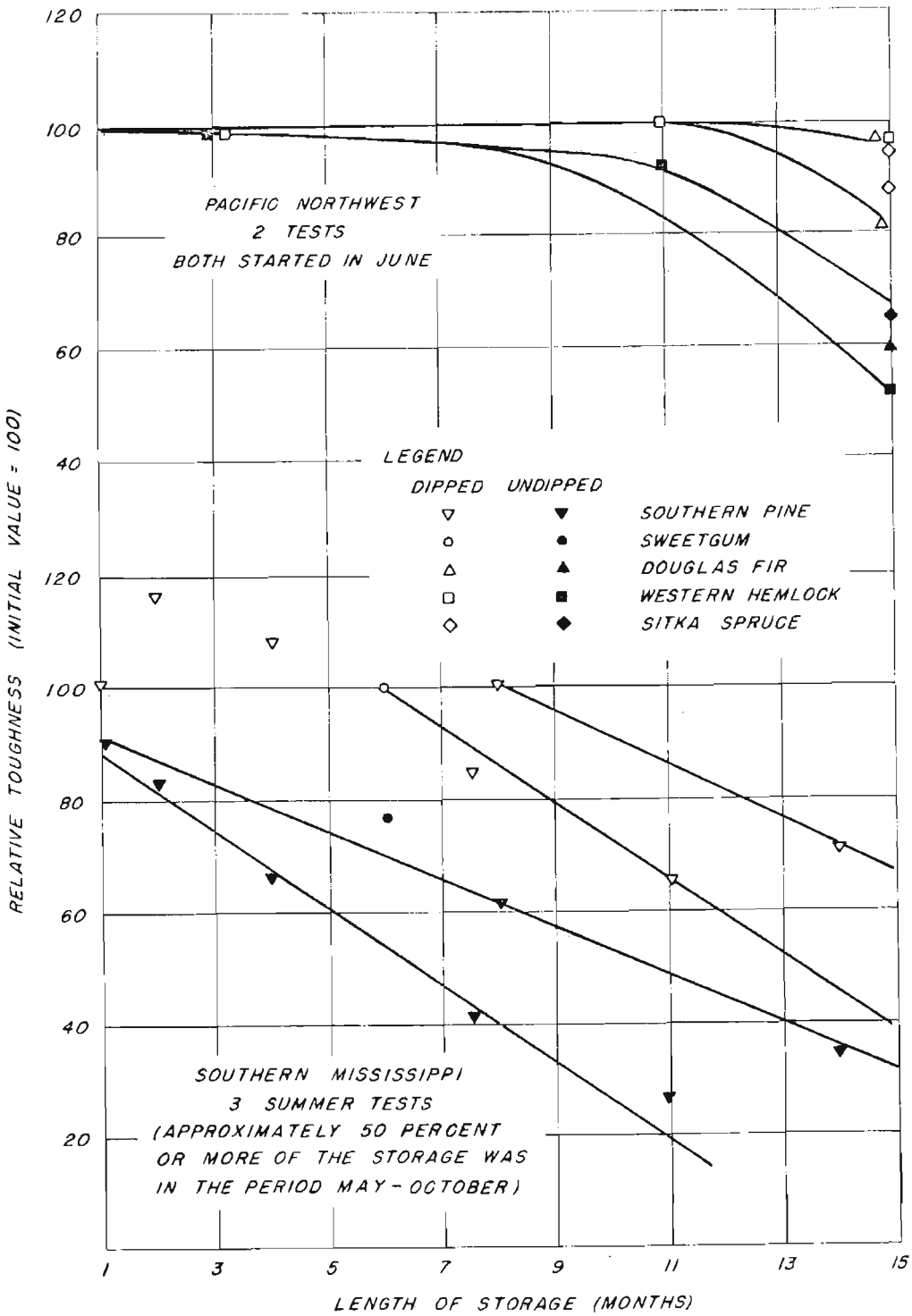

Figure 1.--Graphic summary of toughness observed in dipped and undipped green, bulk-piled lumber after various lengths of storage in the Pacific Northwest and the South. The paired curves denote the indicated minimum (upper curve) and maximum (lower curve) rates of toughness reduction.