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Part II [of problem]

"SOME EVIDENCES OF THE PRESENCE OF TENSION WOOD IN THREE NATIVE HARDWOODS"

by

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(second semester)

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Forestry in the University of Michigan.

Ann Arbor, Michigan June, 1939

ACKNOWLEDGMENTS

The candidate wishes to extend his thanks to Professor William Kynoch without whom this study would have been impossible, to Dr. N. A. Norton for assistance in the laboratory, and to other helpful members of the faculty and student body at the School of Forestry and Conservation in the University of Michigan.

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INTRODUCTION

Within the past few years, investigations into the cellular structure of wood have become increasingly important in the wood-using industries. Research along this line, although of highly technical nature, is not beyond the scope of the trained experimenter, and the results may prove to be of significant value.

For some time, there have appeared, in literature pertaining to wood anatomy, articles on an anomalous structural feature to which many names have been attributed such as compression wood, red-wood or rotholz, and pressure wood. This peculiarity occurs commonly on the underside of eccentric stems and branches of practically all coniferous species. The nature and distribution of this abnormal wood have been studied intensively, but the actual significance of this phenomenon remains to be determined. In forest management of coniferous stands, it should be an important issue to reduce the formation of compression wood by various silvicultural methods. There is also a possibility that compression wood may introduce intricate problems into the southern pine country, which is being developed for pulp production.

As a consequence of such an abnormality in conifers, investigators have been asking themselves what the chances are for a similar occurrence in hardwood species. The English Forest Products Laboratory has excelled in this direction and has produced results which promise to be of importance in many wood-using industries. In England, they have worked with their native species, beech, *Fagus sylvatica L.*,and ash, *Fraxinus excelsior L.*, and in each species, they have associated an abnormal occurrence of thick gelatinous fiber walls, present mostly in the springwood, with greater specific gravity and lower strength in compression parallel to the grain. This anomalous feature in hardwoods occurs on the upper or tension side of eccentric stems, and is referred to as "tension wood."

The writer has selected for his problem three indigenous hardwood species; namely, quaking aspen, *Populus tremuloides*; red maple, *Acer rubrum*; and shagbark hickory, *Carya ovata*. The attempt was to discover evidences of tension wood in these species.

It is with the hope of instigating interest to students of wood technology along this line, and with the intention of suggesting to them a reasonable manner of approach, that this paper is presented.

DISCUSSION

a. <u>Eccentricity in Growth</u>.--Ever since the time of Malpighi, it has been known that eccentricity of radial growth in the woody stem exists frequently in trees, but there continues to be, even at the present time, a conflict of opinion as to its cause. Priestley and Tong (15) have concluded, after considerable investigation, that "On the whole, horizontal and weeping branches show eccentricity in wood formation, while upright stems are symmetrical." They found that Dicotyledons have more wood on the upper side of the branches and Conifers more on the lower side. They attributed to the cause of this phenomenon the activating forces of gravity. Gravity acts upon the cambium in such a way as to cause it to produce more wood elements on the upper or tension side, and less on the lower or compression side. In addition, in the Dicotyledons, there is an acceleration of lignification on the lower side and a retardation of lignification on the upper side. In the Gymnosperm there is more wood on the lower side, and the thicker walls and lignification are on the lower side.

Further investigation along the line of eccentricity in tree growth will tend to clarify its cause and significance, and will be extremely useful.

b. <u>Gelatinous-appearing Cell Walls</u>. The first mention of gelatinous thickenings of lignified cell walls was made in 1860 by T. Hartig (14), and this was confirmed by von Mohl. But except as the result of the destructive action of certain fungi, no reference, with a few exceptions, has been made in literature to the presence of gelatinous thickenings in wood fibers.

About 40 years later, M. C. Potter studied this phenomenon, and concluded that the abnormal thickenings were a normal condition in perfectly healthy and vigorously growing stems.

Only recently have investigators associated the so-called gelatinous walls with the physical properties of wood. The Forest Products Laboratory in Princes Risborough, England, has surpassed any body of investigators in this direction. S. H. Clarke and B. J. Rendle have been particularly active and together constitute the authority on the subject.

The mechanical properties of wood are functions of the amount of wood substance present. This general belief leads to the assumption that specific gravity is the best single feature to use as an index of mechanical strength. The writer, in his conclusions, will challenge this claim. Clarke (4), also associating higher specific gravity with greater strength, added that the relation between these two factors is masked by the behaviour of other variates. In a later article, however, Clarke (7) began to detect the importance of these so-called "other variates." He realized the significance of the physico-chemical nature of the cell wall, and concluded that the nature of the fiber wall is probably of more importance than specific gravity in its effect upon mechanical strength.

With this discovery, there came increasingly interesting research on the occurrence and importance of "tension wood" in hardwoods. B. J. Rendle (17) found that a characteristic of tension wood is the occurrence of gelatinous fibers on one side of the stem, the tension side. Other names used for tension wood have been Bois de Tension, Zugholz, and Weissholz.

Attempts have been made to correlate the presence of gelatinous fibers with circumstances conducive to the formation of tension wood but not with success. Observations, however, as the writer himself has found, lean to a direct connection between the two.

In converted timber or manufactured articles, these fibers have proved their presence. They have indicated their association with some technical defect or abnormality. Wood containing these fibers has shown striking effects in its machining. When it is rip-sawn, planed, recessed, or worked in lathe or spindle moulder, it shows rough woolly finish on the longitudinal surfaces. This might be due to the rubbery nature of the fibers which are pressed down or torn by the cutter instead of being cut cleanly. In an automatic lathe, turnings from tension wood come off in long, unbroken ribbons, whereas those on the compression side are short, brittle chips (17).

Clarke (6) has found that tension wood shrinks much more tangentially and longitudinally than does normal wood. Little evidence has been compiled as yet in the seasoning qualities of tension wood.

Clarke (2) discovered the correlation between these fibers and strength, and has concluded the following: Tension wood has abnormally low crushing strength in proportion to specific gravity;

tension wood is weaker in compression parallel to grain than normal wood; tension wood is appreciably stronger than normal wood of the same specific gravity in tension; and finally, that in toughness, there is no appreciable effect.

With that brief discussion of what has been found out about tension wood, the writer will present the procedure which he has followed in his search for tension wood in three native species.

FIELD PROCEDURE

Three species were selected for testing; namely, aspen, Populus tremuloides; red maple, Acer rubrum; and shagbark hickory, Carya ovata. Two trees of each species were marked to be cut. The writer concluded from literature that trees growing on steep slopes or trees with crooked stems are most likely to demonstrate the presence of tension wood. For this reason, the maples and hickories selected were situated on a 50 per cent slope and the two aspens had decided crooks in their stems. (see figures 1-6)

Care was taken in marking to mark either the upper or tension side of the tree or the lower or compression side, or possibly both. By removing some of the bark with an ax, and marking the exposed wood with a soft pencil or black lumber crayon, a reliable mark was made.

The trees were photographed after marking. The diameter at breast height was measured to the nearest tenth of an inch and recorded. The trees at this point were ready for felling. One foot stumps were left.

After the tree was on the ground, its height was determined by a chain. The tree was then marked and bucked into 8 foot logs, each log containing a mark similar to the butt log, showing either the tension or compression side. Three one-inch discs located at the large end of the butt log, at the large end of the second log, and at the small end of the third log were sawn from each tree, all carefully marked as to tension side. (see figure a.) The records and illustrations of each tree follow:

Figure no. 1

Record

Tree No.-- 1

Species.--Populus tremuloides

Locality cut.-- Saginaw Forest

County.-- Washtenaw

Township.--Scio

Date cut.--February 28, 1939

Slope.-- none

Aspect.-- none

Undergrowth.--sparse

Height.-- 34 feet

Seedling or Sprout.-- Seedling

Crown.-- 70% of height of tree

D.B.H.-- 4.5 inches

Age.-- 23 years

Stem.-- with crook

Date sawed.-- Feb. 28, 1939

FIGURE a.

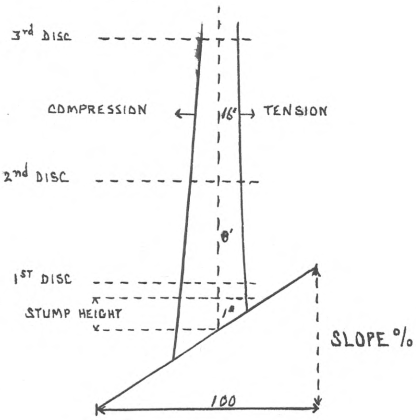


Figure no. 2.

Record

Tree No.-- 2	Species.--Populus tremuloides
Locality cut.-- Saginaw Forest	County.-- Washtenaw
Slope.-- none	Aspect.-- none
Township.-- Scio	Date cut.-- February 28, 1939
Undergrowth.-- Slight	Height.-- 35.5 feet
Seedling or Sprout.-- Seedling	Crown. -- 60% of height of tree
D.B.H.-- 5.3 inches	Age.-- 18 years
Stem.-- with crook	Date sawed.-- February 28, 1939

Figure no. 3.

<u>Record</u>

Tree No.-- 3	Species.-- Acer rubrum
Locality cut.-- Saginaw Forest	County.-- Washtenaw
Township.-- Scio	Date cut.-- February 28, 1939
Slope.-- 52%	Aspect.-- north
Undergrowth.-- moderate	Height.-- 40 feet
Seedling of Sprout.-- seedling	Crown.-- 40% of height of tree
D.B.H.-- 6.7 inches	Age.-- 38 years
Stem.-- vertical	Date sawed.-- Feb. 28, 1939

Figure no. 4.

Record

Tree No.--- 4

Species.--- Acer rubrum

Locality cut.--- Saginaw Forest

County.-- Washtenaw

Township.--- Scio

Date cut.--- February 28,1939

Slope.---50 %

Aspect.--- north

Undergrowth.--- moderate

Height.--- 37 feet

Seedling or Sprout.-- seedling

Crown.-- 30% of height of tree

D.B.H.--- 5.0 inches

Age.--- 28 years

Stem.--- vertical

Date sawed.--- February 28.

Figure no. 5.

Record

Tree No.-- 5

Locality cut.-- Saginaw

Township.-- Scio

Slope.-- 48%

Undergrowth.-- moderate

Seedling or Sprout.-- seedling

D.B.H.-- 4.8 inches

Stem.-- vertical

Species.-- Carya ovata

County.-- Washtenaw

Date cut.-- February 28, 1939

Aspect.-- north

Height.-- 41 feet

Crown.-- 40% of height of tree

Age.-- 45 years

Date sawed.-- February 28, 1939

Figure no. 6.

Record

Tree No.-- 6

Species.-- Carya ovata

Locality cut.-- Saginaw Forest

County.-- Washtenaw

Township.-- Scio

Date cut.-- Feb. 28, 1939

Slope.-- 48%

Aspect.-- north

Undergrowth,-- moderate

Height.-- 40 feet

Seedling or Sprout.-- seedling

Crown.-- 50% of height of tree

D.B.H.-- 5.2 inches

Age.-- 45 years

Stem.-- vertical

Date sawed.-- Feb. 28, 1939

LABORATORY TECHNIC

a. Mechanical Tests.--All mechanical tests were made with wood in a green condition. It was found best to make the mechanical tests as soon as possible after the logs are brought in from the woods. Upon arrival, the discs were sawn through to the pith, in order to minimize cracking and checking, and were laid aside to dry.

A piece six inches long was sawn from the large end of the butt log of each tree for specific gravity determinations. Two squares $1\frac{1}{2}$ x $1\frac{1}{2}$ inches were drawn on the cross-sections of these pieces in such a way that one was located in the compression wood and the other in the tension wood. Precaution was taken to mark these squares directly opposite one another so that they included the same growth rings. The test pieces were marked carefully as to tree number and compression or tension side.

A planer saw was used to saw out the test pieces in order to make them as true in dimension as possible. After sawing, these blocks were left to dry for two weeks in a basement room, where the humidity was relatively high; then they were placed in a drier room for two weeks, and finally, they were placed in an oven. Gradual drying will minimize checking and splitting which might alter the specific gravity tests.

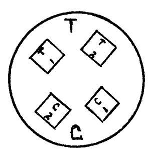
The test pieces were kept in the oven at 212 degrees Fahrenheit until they showed constant weight. This took about 24 hours in all the cases. Upon removal from the oven, they were left to cool for a minute or two, then weighed to a hundredth of a gram, and the weights recorded as oven-dry. The pieces were ready to be dipped into melted paraffin. An attempt was made to secure as thin a coating of paraffin as possible and yet one which completely covered each block. When the wax cooled and hardened, the blocks were immersed in water, and the weight of water displacement was recorded. The formula used for specific gravity was

$$\text{Spec. grav.} = \frac{W_1}{W_2}$$

where W_1 = oven dry weight and W_2 = weight of water displacement

or specific gravity based upon oven dry weight. A heavy coating of wax or a scanty coating leaving openings for possible water absorption might reduce the degree of accuracy desired.

The remaining logs were marked and cut into four-inch pieces with indications as to tension or compression sides. On the cross-section of each small piece, four one-inch squares were drawn, as illustrated below, two being located in the tension side, and two in the compression side.



These test pieces should be as alike as is possible; that is, they should contain the same growth rings, and those on the compression side should be directly opposite those on the tension side. Each square is designated as to tree number, log number, piece number, and location in tension or compression wood.

The pieces were now ready for sawing. Care was exercised in attempting to make the test pieces 1 x 1 x 4 inches, to the nearest hundredth. A planer saw was used in order to give relatively smooth blocks. After sawing, the blocks were all placed in a large box containing wet sawdust in order to keep them green.

The blocks were ready for testing. The mechanical test which demonstrates the greatest difference between the wood from the tension and compression sides of a tree is the compression parallel to grain test. The machine employed for these tests was a RIEHLÉ STATIC testing machine equipped with two round platens, a stationary one on the bottom located on the stationary head of the machine, and a self-adjustable one on the top, set into the movable head. The platens are marked with concentric circles to facilitate placing the test piece in the dead center of each one. This machine works on the basis of the application of a steady load, by a steady movement of the head per minute. The head speed employed in this test was .024 inches per minute. This was obtained by using gears 1 and 3, with fast gear, and the rheostat set at 520.

In preparing the blocks for the actual test, it was found best to wrap up the blocks, to be tested on the following day, in wet cloth so that only about one-sixteenth of an inch was exposed on either end of each test piece, and to let them stand overnight. This precaution eliminated end shearing, thus making the strength results more accurate.

crushing

In order to confirm the green condition of the test pieces during the mechanical tests, a moisture content determination was carried out. This was done by weighing one block of each species upon removal from the sawdust. These blocks were then placed in an oven at 212 degrees Fahrenheit until they reached a constant weight. They were then removed, cooled, and weighed. By dividing the green weight by the oven-dry weight, the moisture content based upon phd be based on oven-dry wt.

green weight was calculated.

Formula: $MC = \frac{W_1}{W_2}$

Moisture content = MC

Weight when green = W_1

Weight when oven-dry = W_2

?

b. Microscopic Examination.--It was found to be desirable to minimize the time during which the test blocks were to be in sawdust. As soon after the mechanical tests as was found possible, small one-half inch cubes were sawn from selected test blocks. The selections were limited to those which contained no defect, and showed good failure. The cubes were sawn near to the location of failure.

The cubes were ready for treatment in preparation for microscopic sectioning. They were first placed in boiling water for a few minutes, then removed and dropped into cold water. This intermittent cooling and heating made the blocks water logged; that is, it drove all the air out of the cell cavities, and completely filled the cell walls and cavities with water. When all the cubes sank to the bottom of the cold water beaker, a wax bottle was prepared to hold the hydrofluoric acid, in which they were to soak for about 10 days. The neck of the wax bottle was cut cleanly with a knife, and enough hydrofluoric acid was poured into the wax bottle to cover completely all the test cubes. Great care was taken to act quickly and with caution because of the danger from the fumes of this acid. When the cubes were in the bottle, the head was placed back in its original position, and by manipulation with a Bunsen burner, the neck was sealed carefully and securely.

The bottle was then placed in a cupboard in the corner of a room sufficiently distant from any fine instruments which the fumes from the acid might ruin. The original bottle in which the acid was obtained was also wax, and was treated in the same manner.

The cubes were left to soak in acid for 10 days. After this period, they were removed, the bottle sealed again, and the cubes boiled once more for a few minutes. They were then put into a solution of glycerine and 95 per cent alcohol (mixing an equal quantity of each). In this solution, they remained soft for three months, throughout the duration of the microscopic work.

The cubes were then ready to be sectioned. A good microtone, made by H. W. Spence, Toronto, was employed in this work. The sections varied from 16 μ to 30 μ (microns) in thickness. The 20 μ sections were best for comparative purposes.

When it was necessary to leave these sections for a few days, they were kept in good condition in the same solution of glycerine and alcohol.

Three different stains were used; namely, phloro-glucin and concentrated HCl; iodine green and safranin (1 per cent aqueous solutions of each); and methyl violet. The best results were obtained with the methyl violet. The sections were removed from the glycerine-alcohol solution and placed into the stain. The time of immersion in the stain was varied from two to five minutes. After sufficient staining, each section followed the following procedure: first, into distilled water to wash off excess stain; then into 35 per cent alcohol, for about 30 seconds; then into 50 per cent alcohol for 30 seconds; then into 70 per cent alcohol for about 30 seconds; then into 85 per cent alcohol for same time;

then into 95 per cent alcohol for the same time; then into absolute alcohol for the same time; and finally, into xylene. The sections were then ready for mounting. A drop of balsam was added to the section on the slide glass, and the cover glass carefully placed over the section so as to avoid the formation of bubbles. The balsam used in this work was the kind obtained in small tubes, and it was found to be advantageous to add a drop or two of xylene onto the balsam to make it less viscous.

The slides were left to stand under cover for a few days to eliminate the possibility of dirt accumulating on the cover glass or balsam; after that they were placed in the oven at about 95° Fahrenheit, making certain not to exceed 100° Fahrenheit.

Identification

Aspen, normal wood.

General characteristics.--Numerous small pores, invisible without a lens, diffused throughout the growth ring, larger in the early spring wood. Growth ring becomes more dense in late wood. Growth rings distinct. Outermost rows of fibers tangentially flattened. Rays not broad, indistinct even under lens. Texture very fine.

Minute anatomy.--Parenchyma terminal, vessels in spring wood 76μ to 140μ in diameter; in summer wood 27μ to 130μ . Fibers 16μ to 36μ in diameter in spring wood, 6μ to 30μ in summer wood. Rays unstoried, uniseriate and homogeneous.

Aspen, tension wood.

General characteristics.--Same as aspen, normal wood.

Minute anatomy.--Tertiary wall torn off or separated in cell cavity. Spring wood vessels 60μ to 150μ in diameter. Parenchyma terminal. Fibers angular, very irregularly shaped, 5μ to 25μ in diameter; 2μ to 15μ in summer wood. Rays uniseriate and homogeneous.

Maple, normal wood.

General characteristics.--Pale color, light, soft wood, and fairly strong. Pores smaller than rays in breadth. Growth rings not very distinct. Pores evenly distributed throughout growth ring, not crowded, occurring solitary or in radial groups of 2 to 3. Outermost rows of fibers tangentially flattened. Rays fairly broad.

Minute anatomy.--Vessels 20μ to 100μ . Parenchyma sparse, mostly terminal. Fibers 2μ to 25μ in diameter, thin-to medium-walled. Rays unstoried, 1 to 5 seriate, homogeneous.

Maple, tension wood.

General characteristics.--Same as maple, normal wood.

Minute anatomy.--Vessels 18μ to 110μ . Parenchyma sparse. Fibers medium-to thick-walled. Fibers 2μ to 18μ in diameter, mostly circular in form. Rays same as normal.

Hickory, normal wood.

General characteristics.-- Wood very hard, heavy and strong. Fibers thick-walled, wood elements not in tier-like arrangement. Perenchyma lines distinct. Cells small. Tyloses heavy, thick white sapwood. Pores isolated in summer wood, but more numerous although not abundant in spring wood, and very large. Rays uniform but not conspicuous. Parenchyma in fine tangential lines.

Minute anatomy.--Vessels 25 μ in diameter in summer wood to 320μ in diameter in spring wood. Parenchyma metatracheal and terminal. Fibers 2 μ to 20 μ in diameter and thin to medium walls. Rays 1 to 5 seriate, homogeneous to heterogeneous.

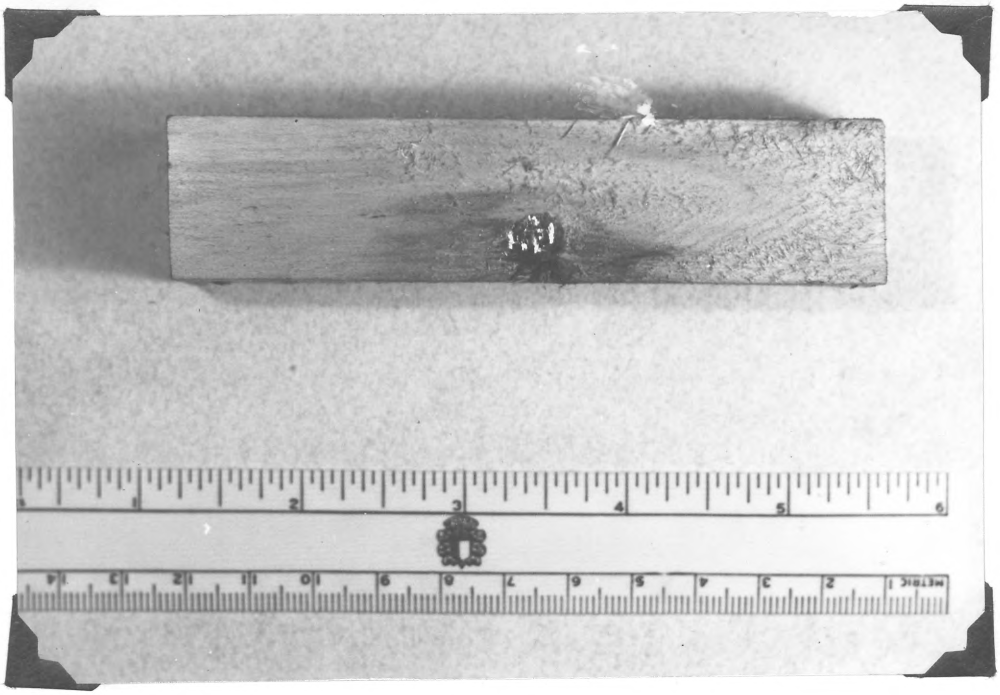
Hickory, tension wood.

General characteristics.--Same as hickory, normal wood.

Minute anatomy.--Vessels same as in normal. Fibers 2 μ to 10 μ in diameter, mostly thick-walled. Rays and parenchyma same as in normal wood.

A portion of tree No. 1 (see figures 1 and 8) showed some interesting discoloration, due, probably, to the chemical disintegration of the wood cells. The area of discoloration was located near the base of the first 8-foot log cut from the tree, or at a height of two feet from the ground. A test block which was cut from the portion of this log just below this area of discoloration, revealed a lead bullet (see figure 7) which had penetrated the tree some time ago, and had been completely enveloped due to the subsequent growth of the tree. It seemed likely that the entrance of this bullet brought about the disintegration and discoloration present in the wood.

Figure no. 7.



Figure

Showing where bullet has entered tree
and introduced discoloration.

RESULTS

Five of the six trees which were cut for the experiment showed eccentric growth. (See figures 8 to 12 .) There was marked eccentricity in both aspen trees, each of which gave evidences of possessing tension wood and so-called gelatinous fibers.

After a few days in the yard, the green aspen logs began to dry out on the ends and displayed a peculiar silky luster. Rendle (17) has stated that this proves probably without further examination the presence of gelatinous fibers and tension wood. The hickory and maple logs displayed no such phenomenon.

In the case of every tree used in the experiment, the test pieces from the tension side were weaker in compression parallel to grain than those from the compression side. The aspens showed the greatest discrepancy in this respect. (see tables 1 to 6.)

In every case, test pieces from the tension side gave higher specific gravity than those from the corresponding compression side. In the aspen trees, this difference was appreciable. In the other trees, it was slight. (see table 7.)

From the time the test pieces were sawn through to the time they were tested, they were kept green in wet sawdust. By wrapping the blocks to be tested on the following day in wet cloth with just a small fraction of an inch exposed on the ends, it was found that no end shearing took place.

Of the three stains which were tried, methyl violet gave the best results. This stain may be used in lieu of gentian violet (10). Sections from the tension side of each aspen showed a colorless region inside the cell cavities bound on the inside by a stained tertiary wall. It was more difficult to detect any difference between the tension and compression sections from the hickory and maple trees, but it was the impression of the writer that the cell walls of the tension side were slightly thicker than those from the compression side.

Figure

Showing eccentricity in growth in tree no.1.
Arrow points towards upper or
tension side.

Figure no. 9.

Figure

Showing eccentricity in growth in tree no.2.
Arrow points to uphill or tension side.

Figure no. 10.

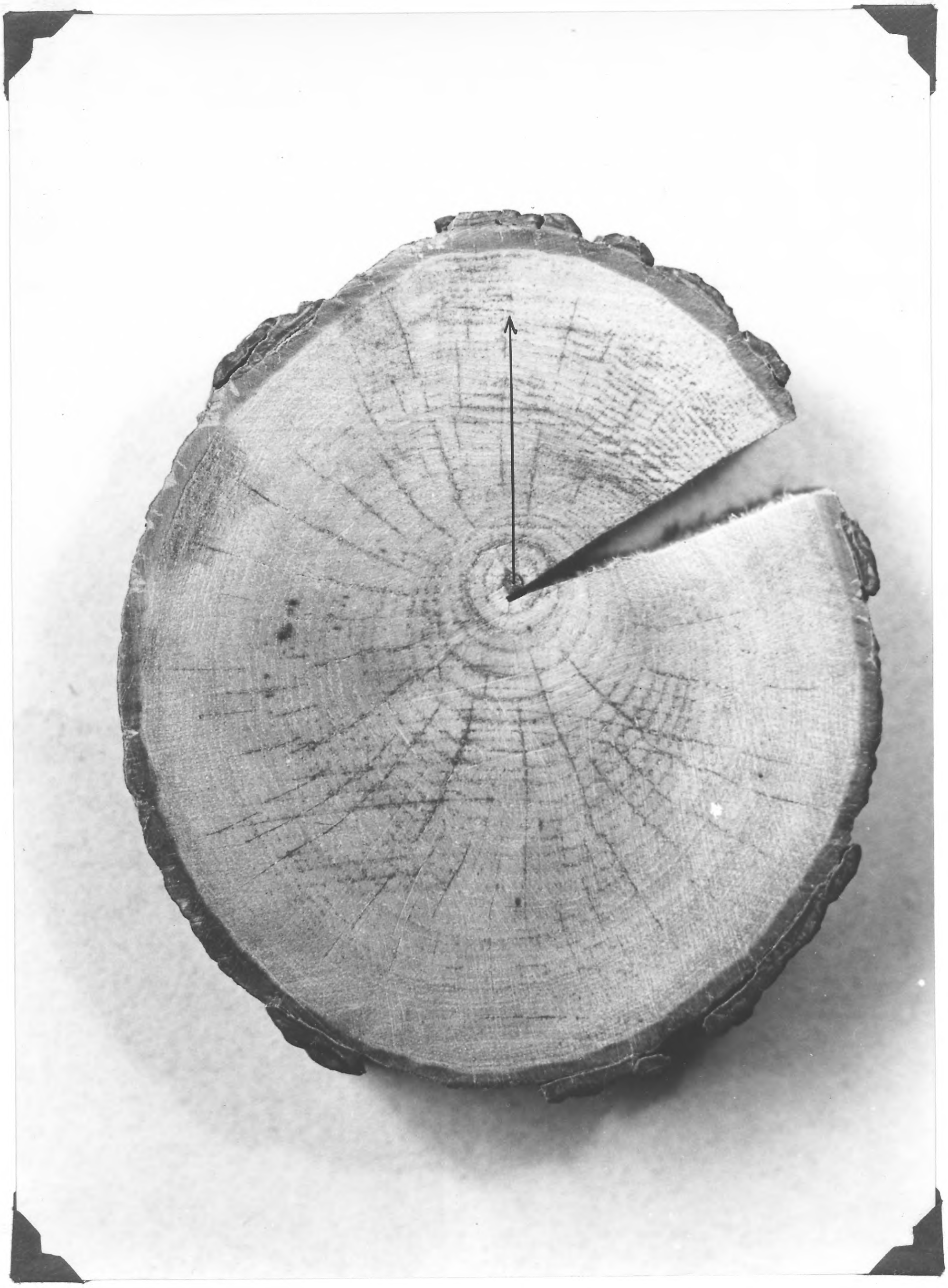
Figure

Showing eccentricity in growth in tree no.4.
Arrow points toward uphill or
tension side.

Figure no. 11.

Figure

Showing eccentricity in growth in tree no.5.
Arrow points toward uphill
or tension side.



Figure

Showing eccentricity in growth in tree no.6.
Arrow points toward uphill or
tension side.

Table 1.

Table Showing Strength in Compression
Parallel to Grain.

Block No.	Tension (Load per sq. in., Pds. per sq. in.)	Compression (Load per sq. in., Pds. per sq. in.)
1	2111	2280
1	2130	2270
1	2100	2227
1	2000	2257
1	2110	2200
1	2150	2250
1	2160	2370
1	2160	2230
1	2110	2400
1	2140	2330
1	2200	2330
1	2145	2270
1	2165	2275
1	2135	2340
1	2140	2295
1	2160	2285
1	2100	2300
1	2160	2310
1	2115	2290
1	2190	2315
Total---	42,711	45,824
Average-	2,136	2,291

(Moisture Content over 100%)

Table 2.

Table Showing Strength in Compression Parallel to Grain.

Block No.	Load Tension *side*	Compression *side*
	Pds. per sq. in.	
2	2400	2887
2	2285	2578
2	2450	2788
2	2450	2745
2	2446	2738
2	2286	2550
2	2480	2770
2	2460	2930
2	2410	2850
2	2445	2730
2	2550	2750
2	2475	2700
2	2435	2750
2	2590	2745
2	2325	2738
2	2325	2815
2	2235	2805
2	2549	2750
2	2446	2855
2	2355	2795
2	2435	2730
2	2470	2790
2	2495	2855
2	2475	2795
2	2395	2815
2	2505	2760
2	2420	2775
2	2355	2825
2	2415	2765
2	2395	2700
Total--	72,757	82,979
Average	2,427	2,765

(Moisture Content over 100%)

species?

Table 3.

Table Showing Strength in Compression Parallel to Grain.

Block No.	Load Tension *side* Pds. per sq. in.	Load Compression *side* Pds. per sq. in.
3	3194	3530
3	3252	3415
3	3200	3580
3	3360	3450
3	3370	3400
3	3370	3470
3	3395	3465
3	3350	3520
3	3340	3575
3	3365	3645
3	3405	
3	3375	
3	3305	
Total--	43,281	35,050
Average	3,330	3,505

species?

Table 4.

Table Showing Strength in Compression Parallel to Grain.

Block No.	Load Tension *side* Pds. per sq. in.	Load Compression *side* Pds. per sq. in.
4	3480	3530
4	3220	3575
4	3420	3500
4	3450	3540
4	3425	3385
4	3405	3410
4	3450	3465
4	3505	3530
4	3470	3540
4	3420	3490
4	3490	
Total--	37,725	34,965
Average	3,430	3,496

(Moisture Content over 100% in both tables)

species?

Table 5.

Table Showing Strength in Compression
Parallel to Grain.

Block No.	Load Tension Pds. per sq. in.	Load Compression Pds. per sq. in.
5	3390	3640
5	3480	3570
5	3460	3510
5	3505	3595
5	3395	3490
5	3495	3470
5	3410	3570
5	3420	3490
5	3510	3570
Total--	31,065	31,905
Average	3,451	3,545

(Moisture Content over 100% in both tables)

species ?

Table 6.

Table Showing Strength in Compression
Parallel to Grain.

Block No.	Load Tension Pds. per sq. in.	Load Compression Pds. per sq. in.
6	4295	4305
6	4180	4420
6	4255	4415
6	4270	4390
6	4295	4400
6	4325	4360
6	4305	4430
6	4315	4340
6	4240	4350
6	4305	4430
6		4380
Total--	42,785	48,220
Average	4,278	4,383

species ?

Table 7.

Table Showing Specific Gravity of Test Pieces.

			Grams-unit of weight.		
Block No.	Tension	Compression	Wt. of Displacement	Oven Dry Wt.	Specific Grav. based on oven dry wt.
1	"		188.5	97.08	.515
1		"	182.7	76.7	.42
2	"		190.7	100.7	.528
2		"	198.9	87.3	.438
3	"		190.4	114.6	.60
3		"	187.9	110.5	.58
4	"		196.3	120.3	.613
4		"	201.6	118.9	.589
5	"		177.5	145.4	.82
5		"	171.9	140.0	.815
6	"		157.0	171.7	.91
6		"	156.3	181.6	.86

species?

CONCLUSIONS

1. With due regard for the small number of trees tested, the mere fact that two out of six trees showed signs of tension wood is probable evidence of its frequent occurrence in hardwoods.

2. Tension wood is more apt to be present in hardwood trees with crooked stems than in those which have vertical stems and which grow on steep slopes.

3. Compression parallel to grain is less easily affected by various factors than other strength functions (12). In every case, the tension side proved to be higher in specific gravity and weaker in compression parallel to grain. Although no appreciable difference in structure could be detected in the hickory and maple trees, it might be concluded that the difference is involved in the chemical make-up of the cell walls.

4. The two aspen trees have displayed definite evidences of tension wood.

5. It is not always true that higher specific gravity in wood signifies greater strength.

6. Much is left to be done on the physico-chemical make-up of the cell wall of wood before more definite conclusions are arrived at.

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