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...Mechanical and physical properties of..."Yellow jack" and "Black jack" jack pine.

Forestry

University of Michigan

School of Forestry and Conservation

A Study of the Mechanical and Physical Properties of the Wood of "Yellow Jack" and "Black Jack" Jack Pine (*Pinus banksiana* Lam.)

A Report

Submitted in Partial Fulfilment

of the Requirements for the Degree of

Master of Forestry

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May 31, 1941

ACKNOWLEDGMENT

To Professor William Kynoch, Professor of Wood Technology, I should like to express my sincere appreciation for all assistance given me during my year as a graduate student in the School of Forestry and Conservation.

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INTRODUCTION

It has long been the opinion of woodsmen, farmers, and some trained foresters living and working in the northern section of lower Michigan, and in the Upper Peninsula, that there is a wide variation in the appearance and in the quality of Jack Pine (*Pinus banksiana* Lam.) Because of the very evident difference in the appearance of the bark of some trees as compared to others, the natives of the area have come to use the terms "yellow jack" and "black jack" to differentiate between what they believe to be two distinct types of jack pine. In fact, many of the farmers, and so-called "old timers", are so firm in their belief that "yellow jack" is a very different tree from "black jack" that they will, without much provocation, inform the young forester, who usually insists that jack pine is jack pine regardless of the color of the bark, that there are many differences between the two trees. Some contend that the wood of "yellow jack" is much heavier than the corresponding wood of "black jack" and that it is also more durable, holds nails better and is generally a stronger, better wood.

Still others are of the opinion that "yellow jack" is, as they say, a "cross" between jack pine and Norway pine (Pinus resinosa Ait.)

A review of a considerable amount of the available literature in the field of forestry failed to reveal anything which would lead one to believe that the Dendrologist or Wood Anatomist makes any distinction between the wood of jack pine growing in Michigan and that which occurs in any other area within the range of the species. For this reason it was thought that a scientific comparison of representative samples of wood taken from trees of each type ("yellow jack" and "black jack") growing in the same area, under comparable conditions, would provide an excellent problem for study, and possibly reveal any existing differences in the wood.

OBJECTIVES

The solution of a problem is quite often made less difficult if one is able to define clearly one's objectives prior to the initiation of activity.

When this investigation was being considered it was decided that a very logical approach to a problem of this type would be to outline clearly just how the two woods to be compared were to be tested, and then to perform each operation in sequence until the necessary data for analysis was obtained. Since it was for the purpose of determining if there exists an appreciable difference in the mechanical, and some of the physical properties of these two woods, that this experiment was undertaken, it was agreed that the following tests should be performed in the approved manner, on a specified number of clear test specimens, at 12% moisture content*, obtained from each of the two types of wood:

1. Static Bending
2. Compression Parallel to Grain
3. Hardness
4. Specific Gravity Determination

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*Moisture content based on the oven dry weight. See page 56 for method of computing.

PROCEDURE

Selection and Procurement of Material

If one is to obtain data of reasonable accuracy one should perform a sufficient number of tests to be assured that most of the possible variation within the material being tested will be reflected in the resultant data. Also, because it is necessary when testing wood that all tests be made on clear specimen, free from defect that might in any way affect the strength of the wood, one must use extreme care in the selection of representative material, and procure much more of it than would be necessary for the required number of test blanks if defects were ignored. Therefore, since jack pine is well known as a tree species which prunes itself very slowly when growing as it usually occurs scattered over the barren sand plains, and as a result contains many knots and other defects, it was necessary to cut and transport to the laboratory a considerable amount of material. A total of twelve bolts were obtained for this experiment. Each bolt was four feet in length. Each tree was cut at an elevation of one foot from the ground. Only the butt twelve foot log was used in each case and the average diameter on the stump was 8.75 inches.

In order that the experiment might be broad enough to afford an opportunity to secure data on material from more than one area, it was decided that an attempt should be made to secure both types of material from two widely separated localities and also from two different types of site. Accordingly, trees were cut in the area north of West Branch, Ogemaw County, Michigan, and also at a point north of Curran, Alcona County, Michigan. The latter area is just south of the southern Boundary of Alpena County.

Site Conditions Near West Branch

The trees cut from the area north of West Branch in Ogemaw County occupied a dominant position in the stand. In this area there is a small tract of about fifty acres which is covered with an almost pure stand of jack pine. The extremities of the stand contain a mixture of poplar or aspen in association with various kinds of scrub oak so common in this vicinity. The entire area is relatively flat and free from any noticeable change in elevation.

This popularly designated jack pine plains section of Ogemaw county lies in the northwestern part of the county and is mainly an area of level, dry sand plains, but there are some places where there is a more fertile type of soil than the predominant Grayling sand. In these areas of transition from the sterile sand to the more productive Roselawn and Newton types of soil jack pine apparently grows at its best. It was from such an area of reasonably good soil that one shipment of test material was taken.

Site Conditions Near Curran

The section of country north of Curran in Alcona County where the second shipment of test material was cut is an area of many hills and plateau-like ridges penetrated by several valley plains many of which are swampy. The sterile sandy ridges support an abundant growth of jack pine while the more fertile areas still show the remnants of what were once fairly good stands of Norway and white pine.

Although there is considerable variation in the soil types of this region the area from which the test material was taken is largely Roselawn sandy loam in the better sections and sterile Grayling sand of very low fertility along the ridge tops. The trees cut were growing on the top of one of these ridges.

Preparation of Material

Care of Green Wood at the Laboratory

When material collected in the field is received at the laboratory it is not at all times convenient to have it cut immediately into the desired sizes for seasoning prior to the final machining. Consequently, it becomes necessary to devise a means of preventing the escape of moisture from the ends of the bolts, and thus retard the associated checking of the ends of the logs until it is convenient to have the sawing operation done. One way to accomplish this is to coat the ends with paraffin as was done when the material collected arrived at the laboratory.

Sawing Prior to Air Seasoning

Following the acquisition of the material to be tested provision must be made for the "cutting-out" of the required blanks from which the test specimen are later obtained. This cannot be done without considerable thought because it necessitates the preparation of a sawing diagram for each bolt so that a maximum quantity of stock of the desired dimension may be obtained from each stick. It is especially true that one must give this matter considerable thought if ones'available supply of material is at all limited. For this experiment it was decided that such a diagram would be applied to the small end of each bolt making adequate provision for shrinkage during seasoning and for saw kerf. At all times it was necessary to bear in mind that the objective was to acquire an equal number of test blanks of each dimension desired (blanks were laid out as $1\frac{1}{2}$" squares and as $2\frac{1}{2}$" squares) from comparable bolts of each kind of wood, so that the test specimens prepared later would be secured from relatively comparable positions, and would thus result in a more accurate comparison of the strength values of the respective woods. (See sawing diagram illustrating method used on page 37).

After the above mentioned diagrams are made it is essential for desirable results that a definite procedure in sawing be adopted; that is, each bolt must be slabbed in a manner that will result in the formation of a plane which will be parallel to the pith of the bolt. This is necessary precaution because all test blanks must be straight-grained as well as free from all common defects such as knots, etc. This was the procedure followed in the preparation of the test blanks of jack pine used in this experiment.

Seasoning:

Air Seasoning

When the rough-cut, green test stock has been sawed from the bolts collected in the field it is necessary that this material be piled carefully so that the preliminary air seasoning, or evaporation of some of the moisture contained in the wood, may progress uniformly and with as little damage to the blanks as possible. The moisture content of the wood at this stage is usually high and varies considerably. The moisture content of the material used in this experiment varied from 36% to 141% green from the saw. (See method used to compute moisture content on page 56.) During this period of air seasoning which usually covers several weeks it is advisable to change the position of the various blanks in the pile at intervals thus promoting more uniform drying out of all blanks.

Seasoning in the Kiln Room

If one were to leave wood out-of-doors during the winter months in the Ann Arbor area it would gradually assume the moisture content of the environment, but such a value would be too high for testing if such tests are to be made at a low moisture content. Therefore, it was decided that when the spread of the moisture content of the test blanks was reduced to a reasonable degree, indicating that the moisture content of the entire group was approaching the equilibrium for the environment, the material would be moved into the kiln room where an accelerated continuation of the drying process would be assured. This was done on January 2, 1941. The spread in moisture content was at this time between 30% and 54% based on the oven dry weight of test samples taken. Most of the samples indicated that a vast majority of the wood had come to a moisture content of about 39% at this time. The blanks were allowed to remain in the kiln room until they had assumed an average moisture content of about 14%. This data was obtained on January 28, 1941 at which time all of the material was moved into a previously prepared constant temperature and humidity room.

Seasoning, and Control of Moisture Content in the Constant Temperature and Humidity Room

After having carefully and successfully dried the material down to 14% moisture content it was necessary that it be brought down still more, or to about 12%, and that it be kept at this value for a period of sufficient duration to assure that this condition would be uniform throughout all test pieces. This was accomplished by controlling the temperature and the humidity within the room where the sticks were stored through the use of low pressure live steam which was permitted to enter the room at a constant rate by way of an improvised jet and a throttle valve. A recording instrument, Hygro-thermograph, was maintained in the room to assure an absolute check on the variation of temperature and humidity at all times. In this way it was possible to keep the wood at a constant moisture content.

Machining of Test Blanks

When the blanks placed in the constant temperature and humidity room had come to the desired moisture content, and sufficient time had elapsed so that one could be sure that all parts of the blanks were at about the same degree of moisture content, it was necessary that they be dressed down to the sizes specified for the test specimens. For this experiment it was necessary to have those blanks which were sawed to $1\frac{1}{2}$" dressed to 1". The $2\frac{1}{2}$" stock was surfaced to 2", and all machining was done to an accuracy of 1/100". Thus the material was prepared in cross-section to the required dimension for the specimens to be tested.

Preparation of Test Specimens

When a decision was made as to the exact tests to be performed in comparing the strength properties of the two woods a decision was also made relative to the exact dimension of each type of specimen to be used. For the static bending test it was agreed that data obtained from 40 clear 1" x 1" x 10" test specimens taken from each type of wood, making a total of 80 such tests, would be adequate for reliable results. Compression-parallel-to-grain tests were to be made on an equal number of clear specimens (40 of each type) surfaced to 1" x 1" x 4". For the hardness tests it was thought that a total of 40 tests (20 from each type of wood) made on specimens of 2" x 2" x 6" should result in satisfactory information. Specific gravity determinations were to be made on a total of 20 clear specimens of each kind of wood of the same dimension as the hardness test specimens - 2" x 2" x 6". When the specimens were being prepared an extra effort was made to obtain as near to an equal number of test specimens of each type from comparable bolts of "yellow jack" and "black jack" as it was possible to obtain considering the various types of defect encountered. Each specimen was given a number as it was cut from the machined blank according to its position in the blank; thus each specimen tested from each kind of pine actually came from relatively the same position within comparable bolts. For this reason it is believed that the resultant data obtained is quite comparable. In the preparation of the various test specimens the laboratory bench saw was used, and as in the case of the machining operation an accuracy of 1/100" was maintained. A steel hook scale graduated to be read to a hundredth of an inch was used for measuring, and to check the accuracy of each measurement a 10-X hand lens was employed.

Testing

Equipment Used in Performing Tests

All of the mechanical tests completed were made on one of three static testing machines of the screw powered type available for used at the laboratory. This machine (see illustration on page 61) is a three-screw unit of 60,000 pounds capacity driven by an electric motor and is complete with all of the necessary attachments to enable the technician to perform the standard tests commonly made on this type of testing machine. When in good working order it is accurate to within five pounds of the true value of the load applied.

Mechanical Tests*

Static Bending

In the static bending test, resistance to slowly

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*Descriptions of tests from U.S.D.A. Technical Bulletin No. 479, Strength and Related Properties of Woods Grown in the United States.

applied loads is measured. The specimen is 2" x 2" in cross section and 30" long and is supported on roller bearings which rest on knife edges placed 28 inches apart. Load is applied at the center of the length through a hard maple block, 3 3/16" wide, having a compound curvature. The curvature has a radius of 3" over the center 2 1/8" of arc, and is joined by an arc of 2" radius on each side. The standard placement is with the annual rings of the specimen horizontal. A constant rate of deflection (0.1" per minute) is maintained until the beam fails. Load and deflection are read at suitable intervals. Data on a number of properties are obtained from static-bending tests, the most important of which are stress at proportional limit, modulus of rupture and modulus of elasticity.

The above description and objectives of the static-bending test apply equally well to tests conducted on small, clear test specimens of dimensions other than those given above. However, one would not be able to make direct comparisons between data obtained from standard specimens and data secured from tests made on other than the standard specimens. In the case of the tests conducted in this experiment the test specimen was, as stated above, 1" x 1" x 10". However, the standard head speed (0.1" per minute) was used and the strength properties mentioned above were computed for each specimen and these values were subsequently converted to a 12% moisture content basis. A smaller maple block was used to apply the load. (See illustration of set-up on page 62).

To arrive at the various strength functions referred to it is necessary to prepare a graph of each test made and then by interpolation, and the use of certain standard formulae, it is possible to compute the value of the strength function for the moisture content at which the wood is when tested. Thus, if one wishes to obtain values for any other moisture content than that at which the test was made, as was the case in this instance, it becomes necessary to run a moisture determination on each specimen tested and then knowing this value it is possible to adjust the strength values to the values which would be obtained if the test material were at the moisture content for which information is desired. The graph referred to above is made by plotting load increment values along the ordinate (100 pound increments used in this experiment)and the deflection values along the abscissa. An Ames dial graduated to read in thousandths of an inch was used to record deflection. The first few points plotted are more-or-less in a straight line because the load is proportional to the deflection. (See graph on page 48). However, as the load increases it is apparent that this direct relationship between load and deflection is disturbed. The point at which this relationship ceases to be constant is the proportional limit. The corresponding stress in the top and bottom fibers of the member at this time is the stress at proportional limit. We are able to compute the value of this stress in pounds per square inch by inserting the correct values in the formula given below. This value was determined for each member tested and the results were in all cases adjusted to the absolute value at 12% moisture content.

$$S_{pl} = \frac{3 \times P' \times L}{2 \times b \times d^2}$$

P' the load at proportional limit in pounds. This value is read from the graph.

L the span of the member in inches. A span of nine inches was used in all tests.

b the breadth of the member in inches. This value was 1 inch in all cases because the specimens were machined to an accuracy of 1/100 of an inch in all cases.

d the depth of the member in inches. Also 1 inch in all tests made.

The method of adjusting values obtained to the corresponding 12% value is shown on page 57 . The table of values given on page 38 which makes possible such an adjustment is taken from U.S.D.A. Technical Bulletin, No. 479, and has been worked out by the Madison Laboratory.

The values for modulus of rupture were computed by the same formula as stress at proportional limit, using the maximum load instead of the load at proportional limit. These values were also adjusted to corresponding 12% moisture content values in the same manner as were the values for stress at proportional limit.

$$R = \frac{3 \times P \times L}{2 \times b \times d^2}$$

P load at failure (maximum load) in pounds.

L the span of the member in inches.

b the breadth of the member in inches.

d the depth of the member in inches.

The value of the modulus of elasticity is determined by the slope of the straight line portion of the load-deflection graph (see graph on page 48), the steeper the line the higher being the modulus. By inserting in the formula below values obtained from the test specimen and from the graph of load over deflection the value of the modulus of elasticity in thousands of pounds per square inch may be obtained. This value was obtained for each of the 80 specimens tested and the corresponding 12% moisture content value was also computed. (See tabulated results on page 39-42).

$$E = \frac{P' \times L^3}{4 \times b \times d^3 \times y}$$

P' load at proportional limit-pounds.

L the span of the member in inches.

b the breadth of the member in inches.

d the depth of the member in inches.

y the deflection in inches at the proportional limit.

Compression Parallel to Grain

In the compression-parallel-to-grain- test, when performed in the manner outlined by the American Society for Testing Materials*, a 2" x 2" x 8" block is compressed in the direction of its length at a constant rate (0.024 inches per minute). The load is applied through a spherical bearing block, preferably of the self-aligning type, to insure uniform distribution of

*1933. Standard Methods of Testing Small Clear Specimens of Timber. A.S.T.M. Designation D143-27. American Society Testing Materials A.S.T.M. Standards, (pp 408 - 444).

the stress. (See illustration of the set-up on page 63.) The load and the deflection in a six-inch central gage length are read simultaneously until the proportional limit is passed. The test is discontinued when failure occurs.

In this experiment instead of using the standard dimension specimen it was agreed, as previously stated, that a test specimen having dimensions of 1" x 1" x 4" would be used and only the load values at failure would be recorded for comparative purposes. (See test set-up on page 64). From this data the maximum crushing strength was computed by inserting the proper values in the formula given below. All values obtained were adjusted to the corresponding 12% moisture content values.

$$S_c = \frac{P}{A}$$

S_c the maximum crushing strength (pounds per square inch).

P the load at failure in pounds.

A the cross-sectional area of the test specimen.

Hardness

Hardness is measured by the load required to embed a 0.444 inch steel ball to one-half its diameter in the wood being tested. (The diameter of the ball is such that its projected area is one square centimeter). The rate of penetration of the ball is 0.25 inches per minute. A penetration was made on each end, and two on each radial and tangential surface. A special tool makes it possible to determine when the proper penetration of the ball has been reached. The load required to embed the ball is recorded as the hardness value of the wood. The average of the radial and tangential average values is recorded as the side hardness. End hardness is the average value obtained for the two end penetrations. (See illustration of set-up for tests on page 65).

Other Tests Completed

Specific Gravity

In addition to conducting the three types of standard strength determination tests given above it was found possible to examine each type of wood in other respects. One such additional test made was the determination of the specific gravity based on the oven dry volume of representative samples selected from both "yellow jack" and "black jack". Twenty test specimens of each wood having dimensions of 2" x 2" x 6" were placed in the electric drying ovens at a constant temperature of slightly less than 212 degrees F. and kept in this atmosphere until repeated weighing of the samples failed to reveal any loss of weight. The three dimensions of each specimen were then measured to the closest hundredth of an inch and the oven dry weight of each specimen was recorded. The volume of each piece in cubic inches was computed and then changed to the equivalent value in cubic centimeters. Since all weights were recorded to the closest hundredth gram it was possible to obtain the specific gravity value for each specimen by dividing the weight when dry in grams by the computed cubic content of the piece in cubic centimeters. This latter value being the equivalent expression of the weight of a volume of water equal to the volume of the test specimen. (For a sample computation see page 59 ; the results are tabulated on page 43).

Nail Holding Capacity

Because of the fact that some farmers contend that "yellow jack" has a greater nail holding capacity than "black jack" it was decided that a test would be made to determine if supporting data could be obtained to substantiate such a claim. The tests undertaken were made only on the material cut in the West Branch area with but one size of nail - the common 8d wire nail. All nails were driven into the tangential surface of the test specimens to a uniform depth at right angles to the surface of the wood. The information obtained is recorded in tabular form on page 44. The maximum number of pounds of effort required to overcome the force holding the nail in place was in each case recorded for comparative study. In every case this maximum value was found to be the load registered at the moment when the nail first gave way and extraction began. (See illustration on page 66 for set-up).

Extractives

Since it is contended by some field men that "yellow jack" appears to be more resistant to decay than "black jack", it was decided that a test would be made to determine if this contention could be shown to be a fact. To accomplish the desired result a cold water extraction test was made, in the following manner, on 100 grams of sawdust prepared from each type of pine. The sawdust was in each case soaked in 1000 cubic centimeters of distilled water for a period of one week (seven days). Following this preliminary soaking, the sawdust was washed with an additional 500 cubic centimeters of distilled water and the filtrate was collected.

This filtrate was in each case boiled for a period sufficiently long to reduce the liquid to 100 cubic centimeters. The concentrated solution was then added to an agar preparation in the amounts necessary to result in a 20% concentration. Cultures were then prepared (six plates for each pine together with controls) for the fungi listed below:

1. Porea incrassata
2. Lenzites trabea

At intervals of seven days and fourteen days the growth of each fungus was observed and recorded. The relative activity of each fungus growing in the medium containing each extractive was then studied.

Microscopic Examination of Cell Structure

When two or more woods, or other substances are being compared from the point of view of strength, appearance or quality it is not uncommon to examine under the microscope representative samples of each material. This is done in order that minute differences in structure, or other features which escape detection upon gross examination, or which do not reveal themselves in strength tests, may be isolated for study. Therefore, it was decided that an examination of slides prepared from each type of wood would be undertaken. The material for study was prepared in the following manner. Small cubes ($\frac{1}{2}$" x $\frac{1}{2}$" x $\frac{1}{2}$") were cut from representative samples of each type of pine and then these cubes were water-logged by alternately boiling them and plunging them into a beaker of cold water. Following this each cube was immersed in a quantity of hydrofluoric acid for a period of one week. They were then removed from the acid, which acts upon the wood substance rendering it less resistant to cutting action if a sharp tool such as a razor is used, and placed in a bath of cool, clear water which was constantly being changed, until all of the acid was removed. All of the material was then covered with a storage solution of 50% - 50% alcohol and 50% glycerine. The cubes remained in this solution for a period of five days and they were then removed for sectioning. The thin sections were cut with the aid of a microtome. The sections were mounted on slides and after a period of drying they were ready for use.

RESULTS OBTAINED

Gross Features -Bark and Wood

One of the outstanding distinguishing features of "yellow jack" pine mentioned by most field men (farmers and woodsmen) when they attempt to differentiate between "yellow jack" and "black jack" is the color of the bark. One is told that "yellow jack" bark appears to the eye more like the bark of Norway pine; that is, it has very definite yellow plates which stand out, while the bark of "black jack" is more like the bark of old white pine. (For bark illustrations see page 67).

A close examination of discs cut from each bolt of the material for study failed to reveal any appreciable difference in the rate of growth of the two types of wood; however, there was a marked difference in the percentage of summerwood and its apparent density. The "yellow jack" appeared to have more summerwood per ring of growth, and it was also quite evident to the eye upon examination of the two woods in sunlight that wood of "yellow jack" appeared to be cream colored while the wood of the "black jack" seems to have a pronounced reddish cast. (Comparable discs of the two woods are shown on page 68).

Mechanical Tests

Static Bending

The data obtained from the static bending tests conducted are presented graphically on pages 49,50,51 and in tabular form on pages 39,40,41-2 All Strength values are adjusted to a 12% moisture content basis. From an examination of the data it is clearly evident that the so-called "yellow jack" pine is consistently stronger in those strength properties determinable from this test. It is also quite evident that when "yellow jack" is grown on a reasonably good site for jack pine, such as was the case near West Branch, it is a wood of considerably greater strength than "black jack". On the poorer sites "yellow jack" appears to maintain its superiority but the difference in strength values is not so pronounced.

Hardness

Jack pine is quite extensively used as a railroad tie species in some areas, this is especially true in

Canada, therefore it would seem that the property of side hardness is of considerable importance. An examination of the data obtained indicates that "yellow jack" is again superior in this strength property to "black jack". (See graph on page 52). However, quality of site does not appear to be as influential in this case as in the case of the strength functions determined from the static bending test. It will also be observed that the side hardness values for the "yellow jack" grown on the poor site appears to exceed the values for the material grown on the more desirable site.

Compression Parallel to Grain

The information obtained from this test is presented graphically on page 53 and in tabulated form on page 45-46. Although the strength values shown are not consistantly in the favor of "yellow jack" it appears that when the "yellow jack" is grown on a good site it is almost twice as strong as "black jack". It is also apparent that the material grown on the poor site, both types, is about of the same, or equal strength, in compression-parallel-to-grain.

Other Tests Completed

Specific Gravity

The data obtained in this test indicates that "yellow jack" is the heavier of the two woods. This appears to be true for the material collected from both areas. (See graph on page 54 and tabulation on page 43. Sample computations are shown on page 59.

Nail Holding Capacity

Although the tests made on the nail holding capacity of the two woods were not of sufficient number to justify a conclusion that either wood is superior to the other in this respect, the results obtained do appear to indicate that the statements made by many farmers and lumberjacks who have used both materials on the farm and in woods camp construction have some merit. As stated previously (page 1) it is generally said that "yellow jack" will hold nails better than "black jack". (See page 44 for results obtained).

Extractives

Fungi, it is said, are very much like trees in that they exhibit a tendency to be selective; that is, all fungi do not grow equally well on a single host anymore than all trees grow equally well on the same type of site. For this reason, if one is to obtain reliable information when studying the growth of fungi, one should prepare a great many cultures and accept the average result as the final indication of the growth of the fungus being studied.

Since it was quite impossible in the case of this experiment to prepare the required number of cultures which would make possible a well-founded conclusion, it is felt that too much weight should not be placed on the results obtained. In short, there was not a sufficiently pronounced difference in the growth of either fungus used to justify a stand either for or against the decay resistance of either type of pine.

Microscopic Examination of Cell Structure

A study of the slides prepared from each type of wood revealed that the summerwood cell structure of "yellow jack" is slightly different from that of "black jack". That is, the "yellow jack" secondary cell walls appear to be of a greater dimension (thicker) than the summerwood cell walls of "black jack". The difference in eell wall thickness may also be seen in the springwood, but not so pronouncedly. However, the most interesting observed difference between the two woods when examined under the microscope was the apparent "serrated" inner margins of the secondary cell walls of the summerwood of "yellow jack" and the total absence of any such condition in the cells of "black jack". Although this feature does not appear to be constant in all cells of the summerwood it is quite prevalent in "yellow jack"* (For an illustration of the cell feature referred to, see page 69).

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*First detected by Professor William Kynoch.

CONCLUSIONS

The data obtained in this study of certain of the strength and related properties of "yellow jack" and "black jack" jack pine appear to indicate that:

1. There was an appreciable difference in the strength properties of the two woods studied. The "yellow jack" proved to be the stronger wood in most respects.
2. Generally speaking it may be said that for most farm uses and for use as railway crossties, "yellow jack" appears to be superior to "black jack".
3. The site conditions, or the sum of the factors influencing the growth of the tree, appear to be of quite some importance in some respects and more limited in their affect upon other strength factors. However, since the strength properties revealed in static bending and hardness are of the greatest importance, it would seem that site is an important donsideration in

the growth of "yellow jack" and not so important to "black jack".

4. A definite, distinguishable difference in bark character exists between "yellow jack" and "black jack", thus making it possible to distinguish the trees in the field.

5. There exists a possibility that there may be definite structural differences in the cell walls of the summerwood of the two types of jack pine.

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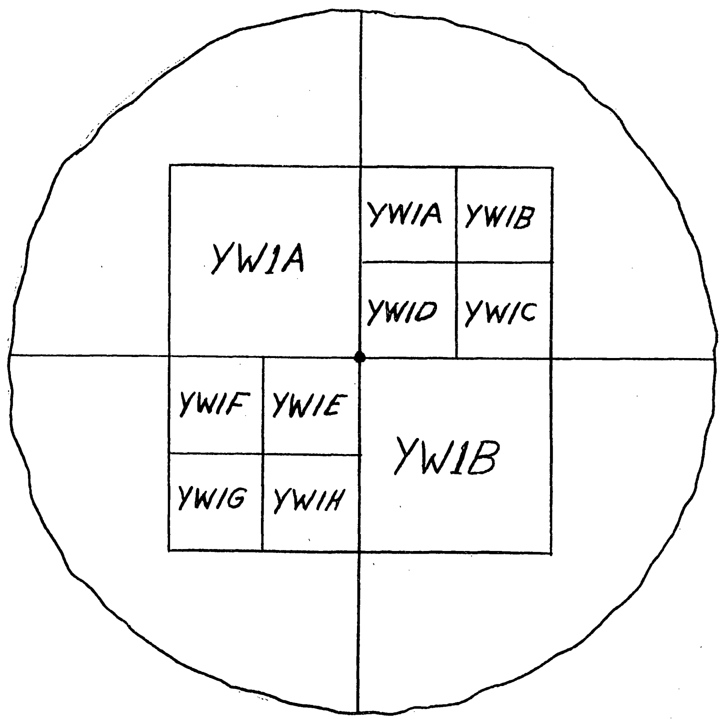
APPENDIX

Explanation of Symbols Used

It will be noted upon examination of the various Tables and Graphs used in this report that specimens are referred to by means of a system of letter and number designations. In all cases where the letter "Y" is used in connection with a designation for a test specimen it indicates that the specimen bearing this letter is "yellow jack"; the letter "B" indicates that the specimen is "black jack"; the letter "W" indicates that the material came from the West Branch area; the letter "C" that it came from Curran; the number "1" following either "W" or "B" indicates that the material was cut from the butt bolt; a letter following the bolt number indicates the position of the blank in the bolt from which it came; a number following the last letter in the specimen designation indicates that the test specimen was one which was cut frmm a particular position within the blank. Thus, the first specimen cut from the blank bearing the number "YW1H" in the sawing diagram would be specimen number "YW1H-1".

DIAGRAMS AND TABLES



The Above Sketch Illustrates the Method Used

To Prepare Each Bolt For

Sawing

AVERAGE INCREASE (OR DECREASE) IN VALUE EFFECTED BY LOWERING (OR RAISING) THE MOISTURE CONTENT 1 PERCENT

Property:	Percent
Static Bending:	
Fiber stress at proportional limit.	5
Modulus of rupture, or cross-breaking strength	4
Modulus of elasticity or stiffness.	2
Work to proportional limit.	8
Work to maximum load or shock-resisting ability . .	½
Impact Bending:	
Fiber stress at proportional limit.	3
Work to proportional limit.	4
Height of drop of hammer causing complete failure .	-½
Compression parallel to grain:	
Fiber stress at proportional limit.	5
Maximum crushing strength.	6
Compression perpendicular to grain:	
Fiber stress at proportional limit.	5½
Hardness, end grain.	4
Hardness, side grain.	2½
Shearing strength parallel to grain.	3
Tension perpendicular to grain.	1½

Table No. 1 - A Tabular Presentation of the Strength Values Obtained for Each Specimen of "yellow jack" and "black jack" Tested in Static Bending. All Values Given Are For a Moisture Content of 12% Based on the Oven Dry Weight.

Specimen	Dimension	Defects	Maximum Load at Failure (Pounds)	Deflection at Failure (Inches)	Stress at Prop. Limit (lbs. per sq.")	Modulus of Rupture (lbs. per sq.")	Modulus of Elasticity (1000 lbs. per sq.")
YW1D	1"x1"x10"	None	1035	.341	7239	13694	1327
YW1G-1	"	"	1090	.188	8643	14538	1757
YW1G-2	"	"	920	.174	8336	11923	1382
YW2A	"	"	920	.271	7128	12023	1451
YW2D	"	"	1015	.257	7054	12607	1480
YW2E-1	"	"	765	.232	6148	10245	1161
YW2E-2	"	"	785	.257	6055	10386	1186
YW2E-3	"	"	810	.328	7477	10804	1130
YW2G-1	"	"	1010	.198	9901	13253	1522
YW2G-2	"	"	1025	.217	9901	13451	1522
YW2H-1	"	"	1090	.186	10483	14892	1800
YW2H-2	"	"	1190	.240	9823	15358	1833
YW2H-3	"	"	975	.138	10135	12900	1738
YW2H-4	"	"	985	.196	10619	13670	1562
YW3E-1	"	"	945	.138	9615	11993	1514
YW3E-2	"	"	1165	.224	10225	15602	1616
YW3E-3	"	"	1095	.143	10840	14901	1776
YW3E-4	"	"	1100	.222	9489	14731	1652
YW3F-1	"	"	1030	.190	9285	12848	1570
YW3F-2	"	"	1190	.268	8647	14973	1690
				Average	8852	13240	1538

Table No. 2 - A Tabular Presentation of the Strength Values Obtained for Each Specimen of "yellow jack" and "black jack" Tested in Static Bending. All Values Given Are For a Moisture Content of 12% Based on the Oven Dry Weight.

Specimen	Dimension	Defects	Max. Load at Failure (Pounds)	Deflection at Failure (Inches)	Stress at Prop. Limit (lbs. per sq.")	Modulus of Rupture (lbs per sq.")	Modulus of Elasticity (1000 lbs per sq.")
BW1B-1	1"x1"x10"	None	795	.264	7314	10604	830
BW1B-2	"	"	665	.140	5862	8728	920
BW1B-3	"	"	835	.266	6247	11228	828
BW1B-4	"	"	670	.182	6179	9009	813
BW1C-1	"	"	805	.320	7202	10607	990
BW1C-2	"	"	767	.345	6772	10728	1036
BW1F-1	"	"	855	.453	5741	11035	803
BW1F-2	"	"	760	.217	5520	9193	968
BW2A-1	"	"	830	.264	6383	10891	1076
BW2A-2	"	"	770	.203	6227	10603	1107
BW2E-1	"	"	665	.142	5994	8439	1062
BW2E-2	"	"	715	.160	6124	9228	1071
BW3A	"	"	830	.232	5465	10936	1100
BW3B-1	"	"	755	.318	6642	10397	985
BW3B-2	"	"	627	.132	6582	8431	1014
BW3B-3	"	"	740	.287	6334	10150	1042
BW3B-4	"	"	755	.322	6714	10315	957
BW3B-5	"	"	715	.255	6345	9190	990
BW3E	"	"	610	.165	5472	8005	797
BW3F	"	"	830	.311	6446	10802	860
				Average	6278	9926	962

Table No. 3 - A Tabular Presentation of the Strength Values Obtained for Each Specimen of "yellow jack" and "black jack" Tested in Static Bending. All Values Given Are For a Moisture Content of 12% Based on the Oven Dry Weight.

Specimen	Dimension	Defects	Max. Load at Failure (Pounds)	Deflection at Failure (Inches)	Stress at Prop. Limit (lbs. per sq. ")	Modulus of Rupture (lbs. per sq. ")	Modulus of Elasticity (1000 lbs. per sq. ")
YC1A-1	1"x1"x10"	None	955	.297	7910	12326	1384
YC1A-2	"	"	855	.180	7288	10481	1178
YC1B-1	"	"	825	.395	7574	11316	1179
YC1B-2	"	"	870	.215	7888	11980	1313
YC1B-3	"	"	855	.273	6265	10712	1195
YC1D	"	"	800	.296	7636	11146	1026
YC2A	"	"	850	.321	7069	10878	1212
YC2D-1	"	"	895	.255	7685	12421	1223
YC2D-2	"	"	870	.280	6880	10899	1118
YC2G	"	"	795	.249	7810	10862	1138
YC2H-1	"	"	915	.309	7290	11365	1073
YC2H-2	"	"	810	.278	7749	11154	1030
YC2B-1	"	"	915	.239	7995	11760	1181
YC2B-2	"	"	1030	.330	8290	12125	1204
YC3A-1	"	"	875	.223	8554	11435	1068
YC3A-2	"	"	765	.162	8590	10411	1214
YC3B	"	"	750	.177	6644	10002	1121
YC3D	"	"	935	.249	8468	12270	1171
YC3G	"	"	760	.385	6678	10014	919
YC3I	"	"	765	.219	7857	10080	1128
				Average	7606	11182	1154

Table No. 4 - A Tabular Presentation of the Strength Values Obtained for Each Specimen of "yellow jack" and "black jack" Tested in Static Bending. All Values Given Are For a Moisture Content of 12% Based on the Oven Dry Weight.

Specimen	Dimension	Defects	Max. Load at Failure (Pounds)	Deflection at Failure (Inches)	Stress at Prop. Limit (lbs. per sq.")	Modulus of Rupture (lbs. per sq.")	Modulus of Elasticity (1000 lbs. per sq.")
BC1A-1	1"x1"x10"	None	825	.309	6784	11183	1070
BC1A-2	"	"	815	.313	7020	11003	1031
BC1B-1	"	"	835	.398	6851	11408	1195
BC1B-2	"	"	935	.349	8482	12926	1248
BC1B-3	"	"	870	.255	8523	12074	1201
BC1G-1	"	"	900	.370	5670	10935	925
BC1G-2	"	"	860	.344	7722	11981	928
BC1G-3	"	"	845	.250	7310	11048	952
BC2D-1	"	"	790	.254	6797	10239	1138
BC2D-2	"	"	845	.266	7697	11508	1107
BC2E-1	"	"	855	.307	7791	11497	1098
BC2E-2	"	"	870	.434	8065	12028	1091
BC2E-3	"	"	830	.291	8005	11250	1112
BC3A	"	"	875	.228	6334	12002	1322
BC3C	"	"	805	.205	7536	10998	1099
BC3D	"	"	700	.202	7787	9677	1121
BC3G-1	"	"	650	.125	7722	9056	1000
BC3G-2	"	"	810	.205	6679	10673	1081
BC3H	"	"	785	.238	6804	9750	924
BC3I	"	"	855	.320	6472	11728	1169
				Average	7302	11148	1092

Table No. 5 - Specific Gravity and Hardness Values Obtained for Each Specimen of "yellow jack" and "black jack" Tested. All Values Given are For a Moisture Content of 12% Based on the Oven Dry Weight. All Specimens 2" X 2" X 6".

Specimen	Specific Gravity (O.D. Volume)	Side Hardness (Pounds)	End Hardness (Pounds)		Speciman	Specific Gravity (O.D. Volume)	Side Hardness (Pounds)	End Hardness (Pounds)
BW1A-1	.43	593	787		BC1A	.49	549	721
BW1A-2	.46	740	726		BC1B-1	.49	564	629
BW1B	.48	687	719		BC1B-2	.49	614	678
BW2A-1	.43	556	768		BC2A-1	.48	544	745
BW2A-2	.41	483	729		BC2A-2	.48	545	702
BW2A-3	.40	489	726		BC2B-1	.46	566	610
BW2A-4	.42	506	707		BC2B-2	.46	532	588
BW2B-1	.42	535	705		BC2C-1	.47	563	706
BW2B-2	.42	519	758		BC2C-2	.48	575	698
BW3A	.41	519	643		BC3A	.45	528	626
Average	.43	563	727		Average	.47	558	670
YW1A-1	.59	790	771		YC1A-1	.53	643	678
YW1A-2	.57	778	803		YC1A-2	.56	709	682
YW1B	.52	714	818		YC1A-3	.57	671	670
YW2A-1	.51	607	663		YC2A-1	.51	633	652
YW2A-2	.52	697	780		YC2A-2	.54	722	695
YW2A-3	.51	646	689		YC2B	.49	648	655
YW2B-1	.52	600	600		YC2C-1	.58	834	703
YW2B-2	.50	601	593		YC2C-2	.57	757	733
YW3A-1	.49	573	604		YC2C-3	.57	742	696
YW3A-2	.49	612	637		YC3A	.45	467	608
Average	.52	662	696		Average	.54	683	677

Table No. 6 - A Tabular Presentation of the Results Obtained From the Tests Made on the Nail Holding Capacity of Each Type of Pine. All Nails Were Driven to a Uniform Depth at Right Angles to the Surface of the Wood.

Specimen	Nail size	Surface Nailed	Maximum Load Test No. 1 (Pounds)	Maximum Load Test No. 2 (Pounds)	Average Load (Pounds)
YW-1	8d	Tangential	245	250	245
YW-2	"	"	235	225	230
YW-3	"	"	260	255	258
YW-4	"	"	210	245	228
YW-5	"	"	230	195	213
				Average	236#
BW-1	8d	Tangential	210	200	205
BW-2	"	"	225	205	215
BW-3	"	"	240	230	235
BW-4	"	"	225	215	220
BW-5	"	"	225	220	223
				Average	219#

Table No. 7 - A Tabular Presentation of the Strength Values Obtained for Each Specimen of "yellow jack" and "black jack" Tested in Compression Parallel to Grain. Values Reflect the Strength at 12% Moisture Content Based on Oven Dry Weight.

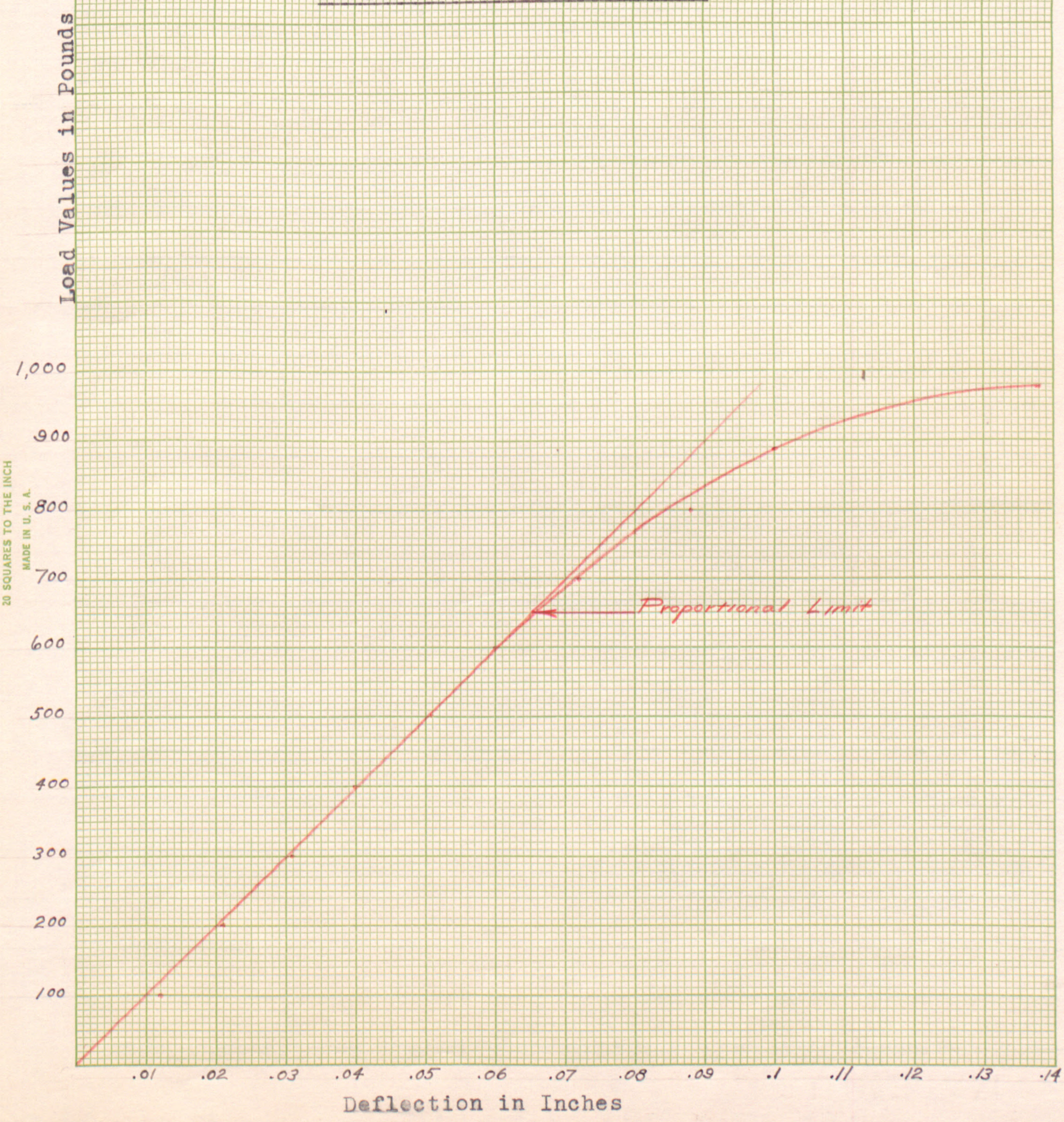
Specimen	Dimension (Inches)	Defects	Maximum Crushing Strength (lbs. per sq. in.)		Speciman	Dimension (Inches)	Defects	Maximum Crushing Strength (lbs. per sq. in.)
YW1B-1	1"x1"x4"	None	8405		BW1B	1"x1"x4"	None	4891
YW1B-2	"	"	8794		BW1C-1	"	"	5151
YW1D-1	"	"	10646		BW1C-2	"	"	5034
YW1D-2	"	"	7923		BW1F-1	"	"	4772
YW1D-3	"	"	9116		BW1F-2	"	"	5228
YW1G	"	"	9854		BW2A-1	"	"	5630
YW2A-1	"	"	10090		BW2A-2	"	"	5414
YW2A-2	"	"	9410		BW2A-3	"	"	5563
YW2C	"	"	9969		BW2B-1	"	"	4509
YW2D-1	"	"	9842		BW2B-2	"	"	5068
YW2D-2	"	"	9313		BW2C-1	"	"	5132
YW2E-1	"	"	10993		BW2C-2	"	"	4351
YW2E-2	"	"	11805		BW2D	"	"	5328
YW2G-1	"	"	10174		BW2E-1	"	"	5024
YW2G-2	"	"	9113		BW2E-2	"	"	5197
YW2H	"	"	11878		BW2E-3	"	"	4427
YW2I	"	"	10081		BW3A-1	"	"	5602
YW2D	"	"	7350		BW3A-2	"	"	4691
YW2E	"	"	9333		BW3B	"	"	5119
YW2F	"	"	10445		BW3F	"	"	5716
		Average	9727				Average	5092

Table No. 8 - A Tabular Presentation of the Strength Values Obtained for Each Specimen of "yellow jack" and "black jack" Tested in Compression-Parallel-to-Grain. Values Reflect the Strength at 12% Moisture Content Based on Oven Dry Weight.

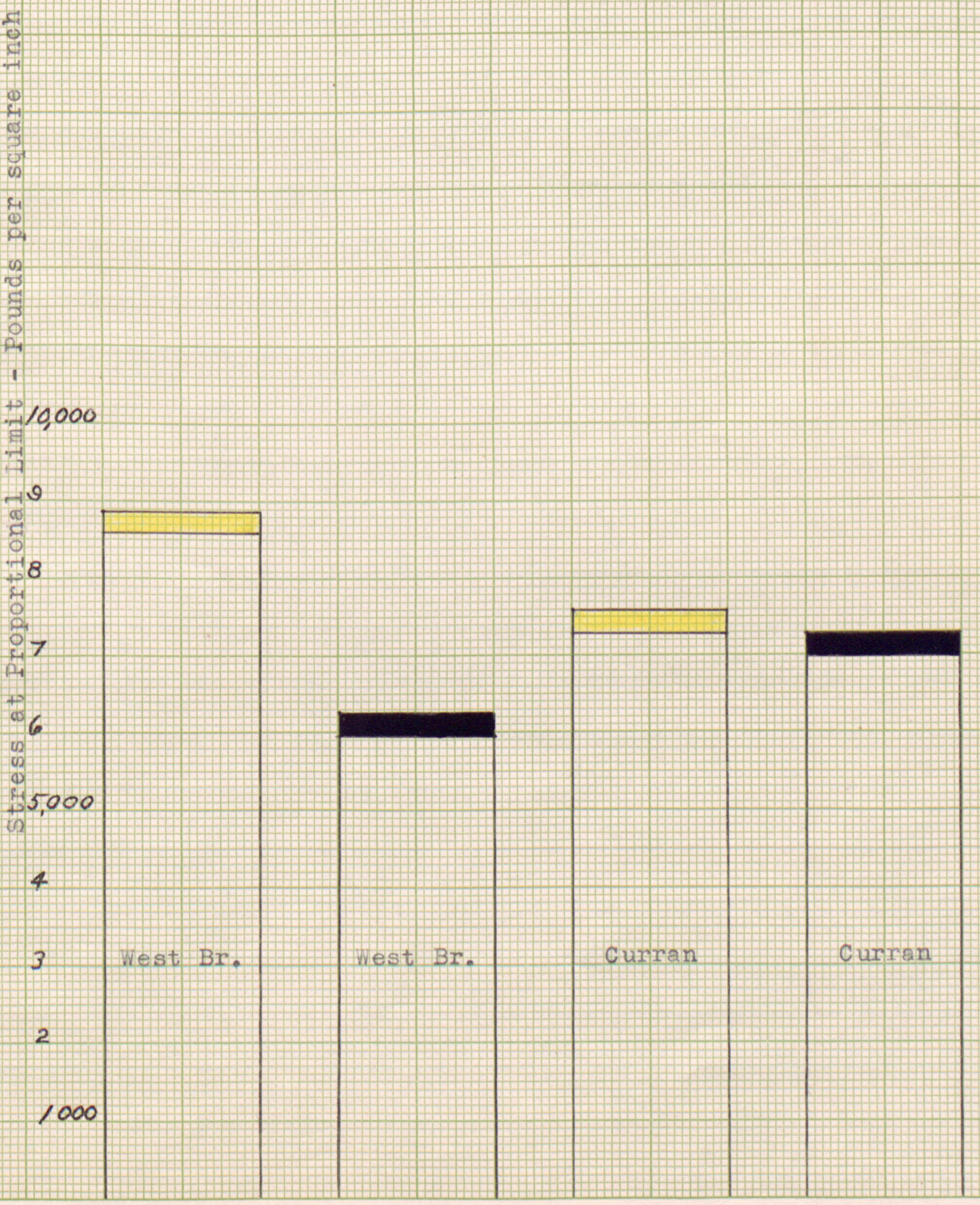
Specimen	Dimension (Inches)	Defects	Maximum Crushing Strength (lbs.per sq.in.)	Specimen	Dimension (Inches)	Defects	Max. Crushing Strength (lbs.per Sq.in.)
YC1A-1	1"x1"x4"	None	6602	BC1A	1"x1"x4	None	5523
YC1A-2	"	"	6457	BC1B-1	"	"	6423
YC1B-1	"	"	6376	BC1B-2	"	"	6731
YC1B-2	"	"	6147	BC1C-1	"	"	6458
YC1B-3	"	"	6002	BC1C-2	"	"	6496
YC2D-1	"	"	6432	BC2A	"	"	6791
YC2D-2	"	"	6131	BC2E-1	"	"	6690
YC2D-3	"	"	5772	BC2E-2	"	"	6699
YC2G	"	"	5412	BC3A-1	"	"	6922
YC2H-1	"	"	5820	BC3A-2	"	"	6454
YC2H-2	"	"	5588	BC3A-3	"	"	5859
YC3A-1	"	"	6031	BC3C-1	"	"	5924
YC3A-2	"	"	4988	BC3C-2	"	"	5456
YC3A-3	"	"	6310	BC3F	"	"	5417
YC3D-1	"	"	6164	BC3G-1	"	"	5768
YC3D-2	"	"	5960	BC3G-2	"	"	6159
YC3D-3	"	"	5700	BC3H-1	"	"	5859
YC3D-4	"	"	6725	BC3H-2	"	"	6230
YC3G-1	"	"	5020	BC3H-3	"	"	5706
YC3G-2	"	"	6358	BC3I	"	"	5364
		Average	5995			Average	6146

GRAPHS

GRAPH SHOWING THE RELATIONSHIP BETWEEN LOAD AND DEFLECTION IN STATIC BENDING

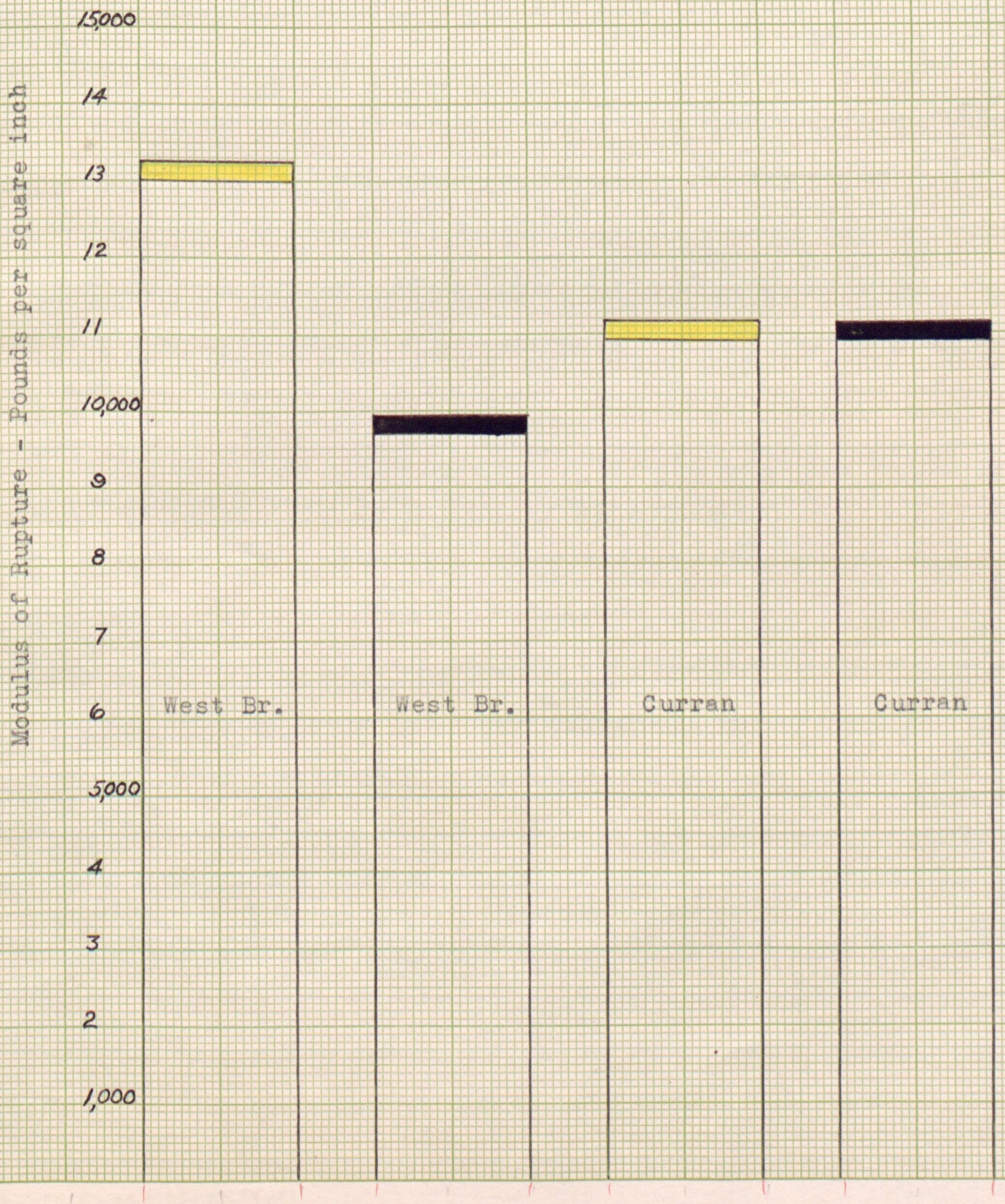


Average Values of Stress at Proportional Limit(static bending) for "yellow jack" and "black jack"



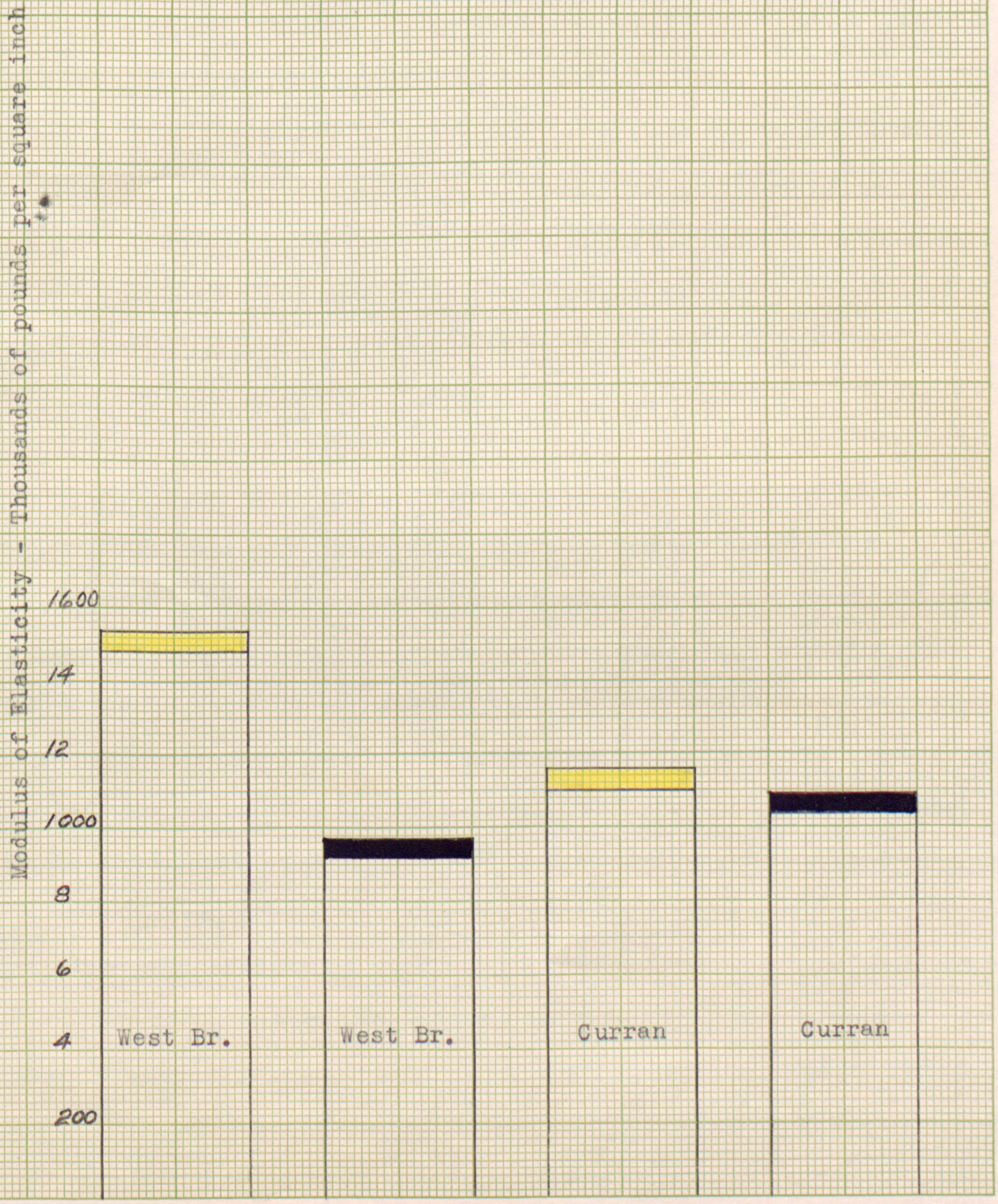
Average Values of Modulus of Rupture (static bending)

"yellow jack" and "black jack"



Average Values of Modulus of Elasticity (static bending)

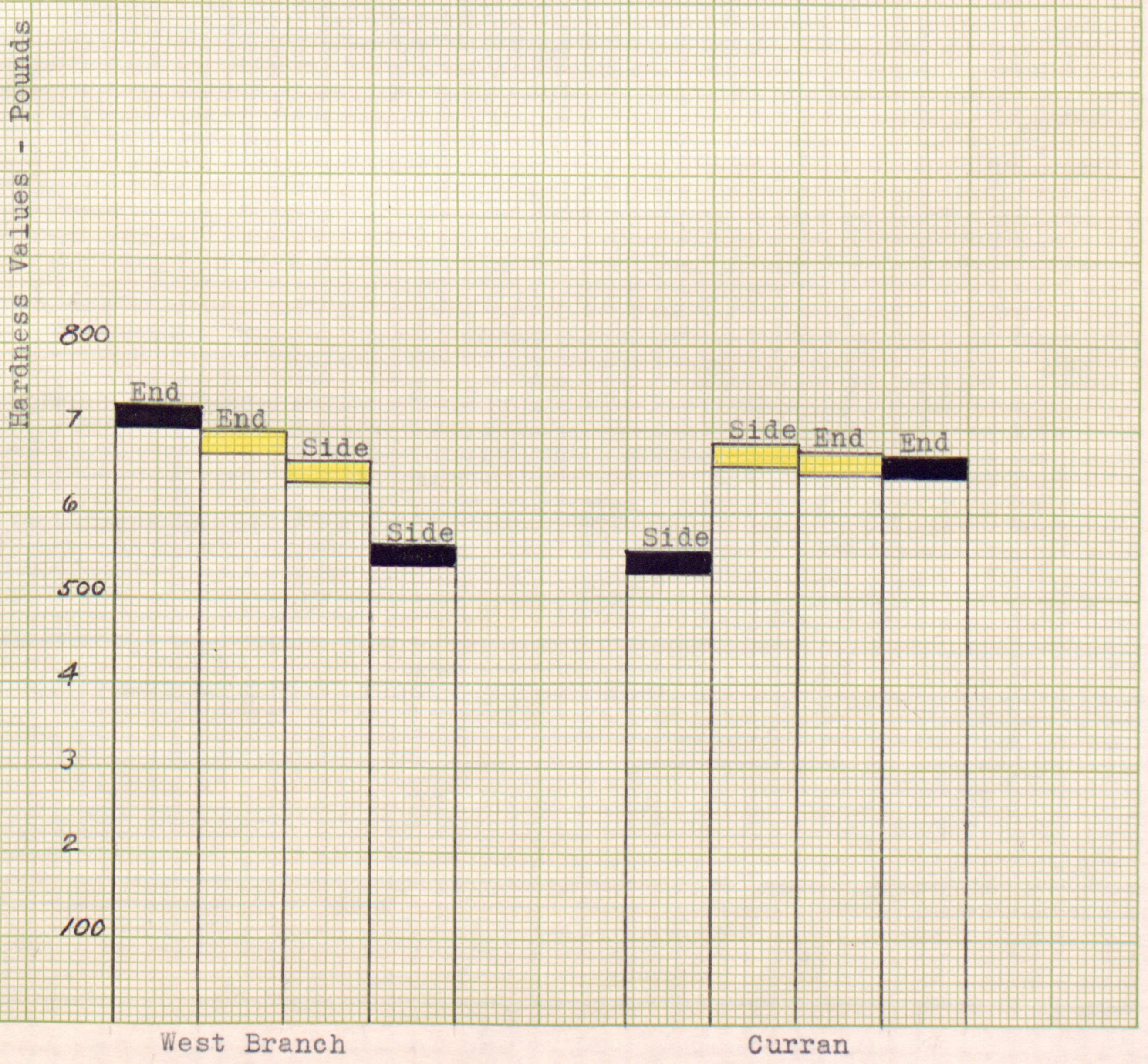
"yellow jack" and "black jack"



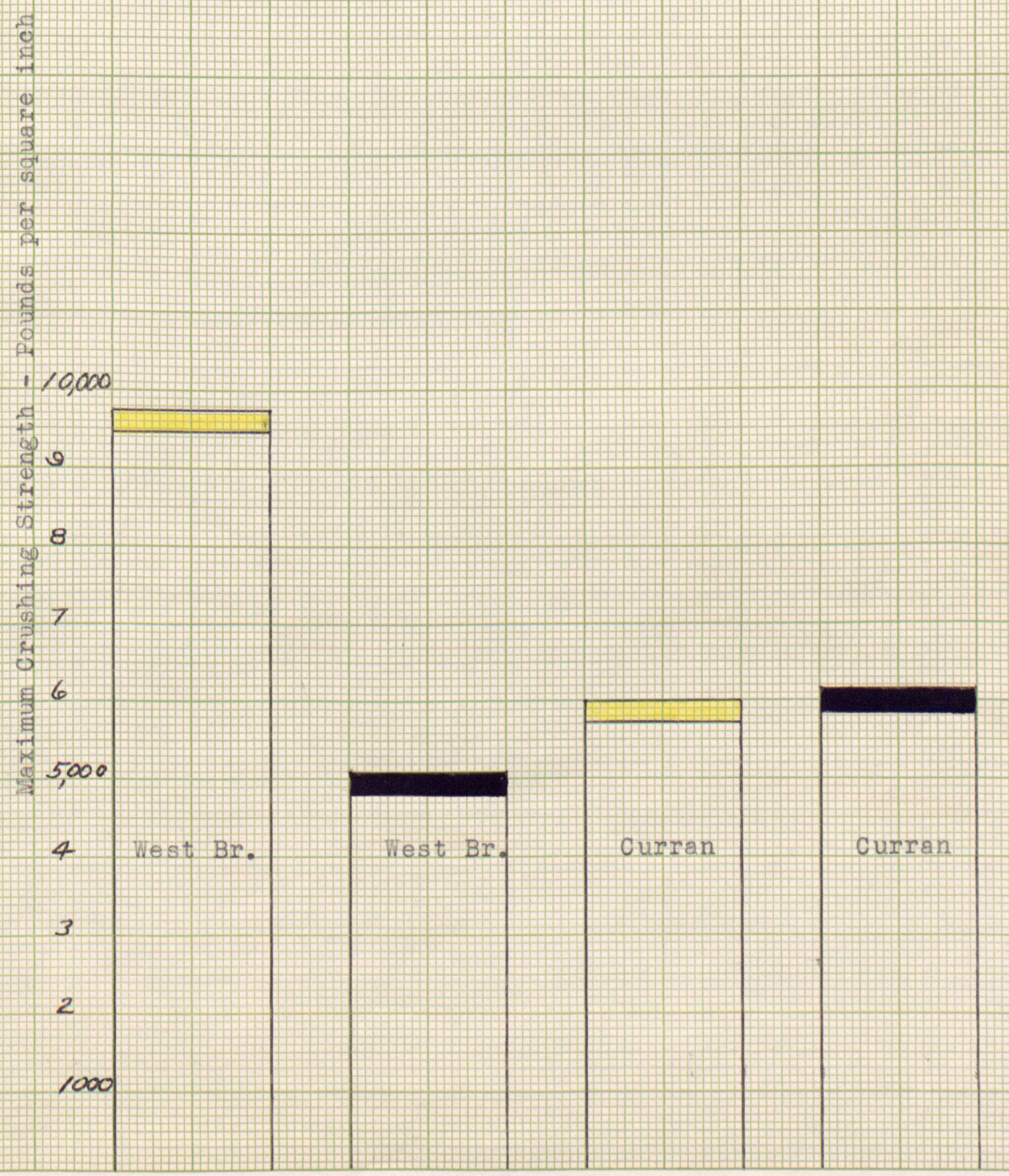
No. 5780-20
20 SQUARES TO THE INCH
MADE IN U. S. A.

Average Values of Hardness for the Wood of

"yellow jack" and "black jack"

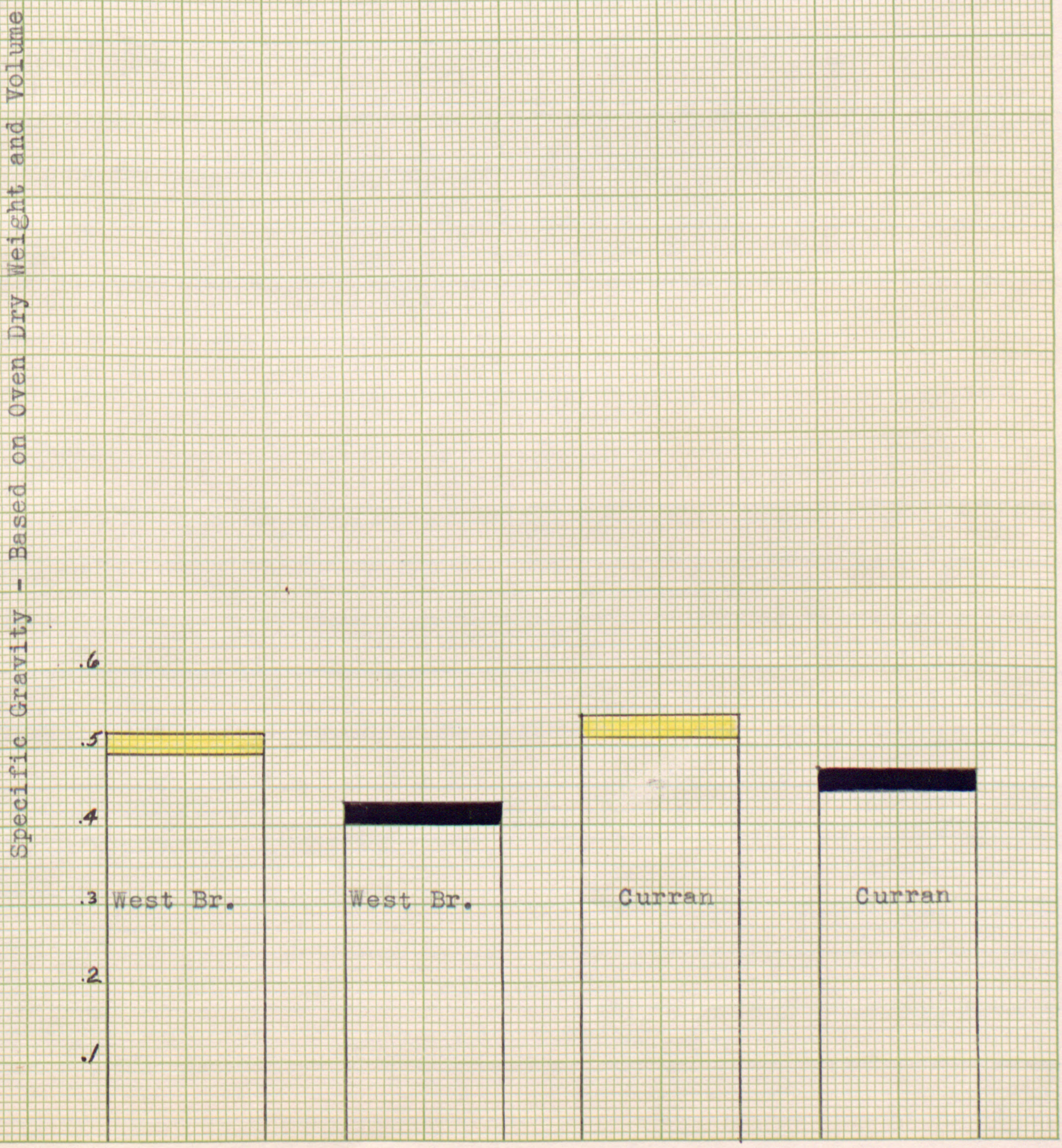


Average Values of Maximum Crushing Strength (compression parallel to grain)-"yellow jack"-"black jack"



Average Values of Specific Gravity of the Wood

of "yellow jack" and "black jack"



SAMPLE COMPUTATIONS

Method of Computing Moisture Content Based on Oven Dry Weight

1. Sample weighed to closest hundredth gram.
2. Sample placed in electric oven at 212° F. and weighed at intervals of several hours until there is no additional loss of weight.
3. Final dry weight recorded to closest hundredth gram.
4. Values obtained inserted in formula:

$$M.\ C.\ \% = \frac{W_1 - W_{o.d.}}{W_{o.d.}}$$

W_1 = original weight as in (1) above.

$W_{o.d.}$ = Final dry weight as in (3) above.

Sample Computation Illustrating the Method by Which Values of Stress at Proportional Limit are Obtained in Static Bending and the Method Used to Adjust the Values to the Corresponding Values Which Would be Obtained at 12% Moisture Content.

$$S_{PL} = \frac{3 \times P' \times L}{2 \times b \times d^2}$$

From the graph on page (P') = 650 pounds.

$$S_{PL} = \frac{3 \times 650 \times 9}{2 \times 1 \times 1^2} = \frac{17750}{2} = 8775 \text{ lbs. per sq. inch.}$$

Assuming that the moisture content of the speciman tested was 11.3%, it becomes necessary to adjust the value 8775 pounds to the corresponding strength value which would have been obtained(approximately)had the speciman been at a moisture content of 12% based on its oven dry weight. From the table of values given on page 38 it may be seen that for each degree change in moisture content a change in the value of the strength at proportional limit (stress) is effected to the extent of about 5%. We also know that below the fiber saturation point (25%-35% moisture content in most native woods) wood becomes stronger as the moisture content decreases. Therefore, since our test speciman was at a moisture content of 11.3% it actually was stronger than it would be if the moisture content were 12%. For this reason we are correct in subtracting from 8775 pounds a value equal to .7(.05 X 8775) or 307 pounds. This leaves us a value of 8468 pounds as the value for stress at proportional limit for the speciman at 12% moisture content.

Sample Computation Illustrating the Method by Which Values of Specific Gravity, Based on the Volume of Each Test Speciman When Oven Dry, were Obtained.

$$\text{Specific Gravity} = \frac{\text{Oven Dry Weight of Test Speciman}}{\text{Weight of an Equal Volume of } H_2O}$$

Assume that the oven dry weight of the speciman is 160 grams, and that its dimensions are 1.95" X 1.97" X 6".

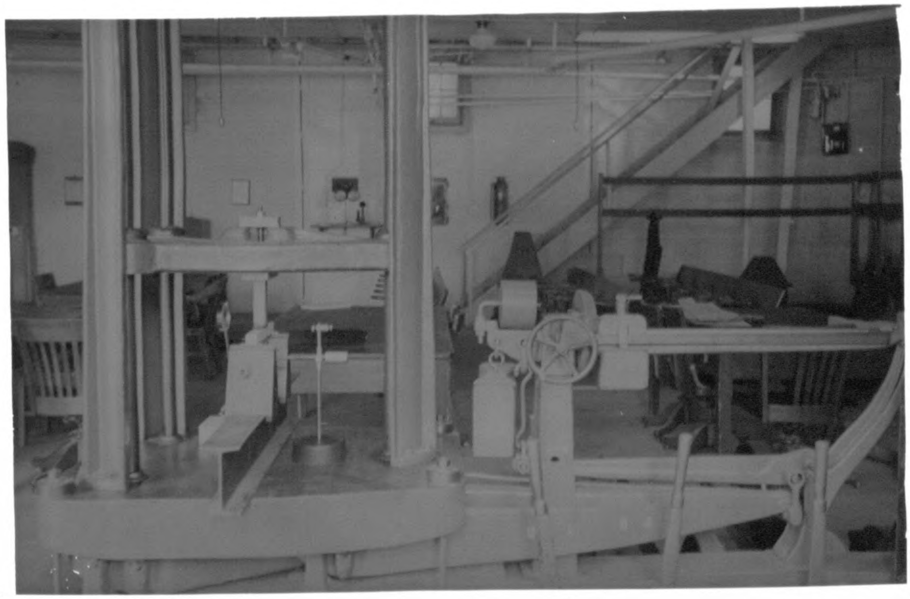
Volume of speciman (cubic inches)=1.95" X 1.97" X 6" or 23.3 cu. inches.

Volume of speciman in cubic centimeters 23.3 X 16.39 or 381 cu. centimeters.

Therefore, since 1 c.c. of H_2O weighs 1 gram it may be said that a volume of water equal to 381 c.c. would weigh 381 grams.

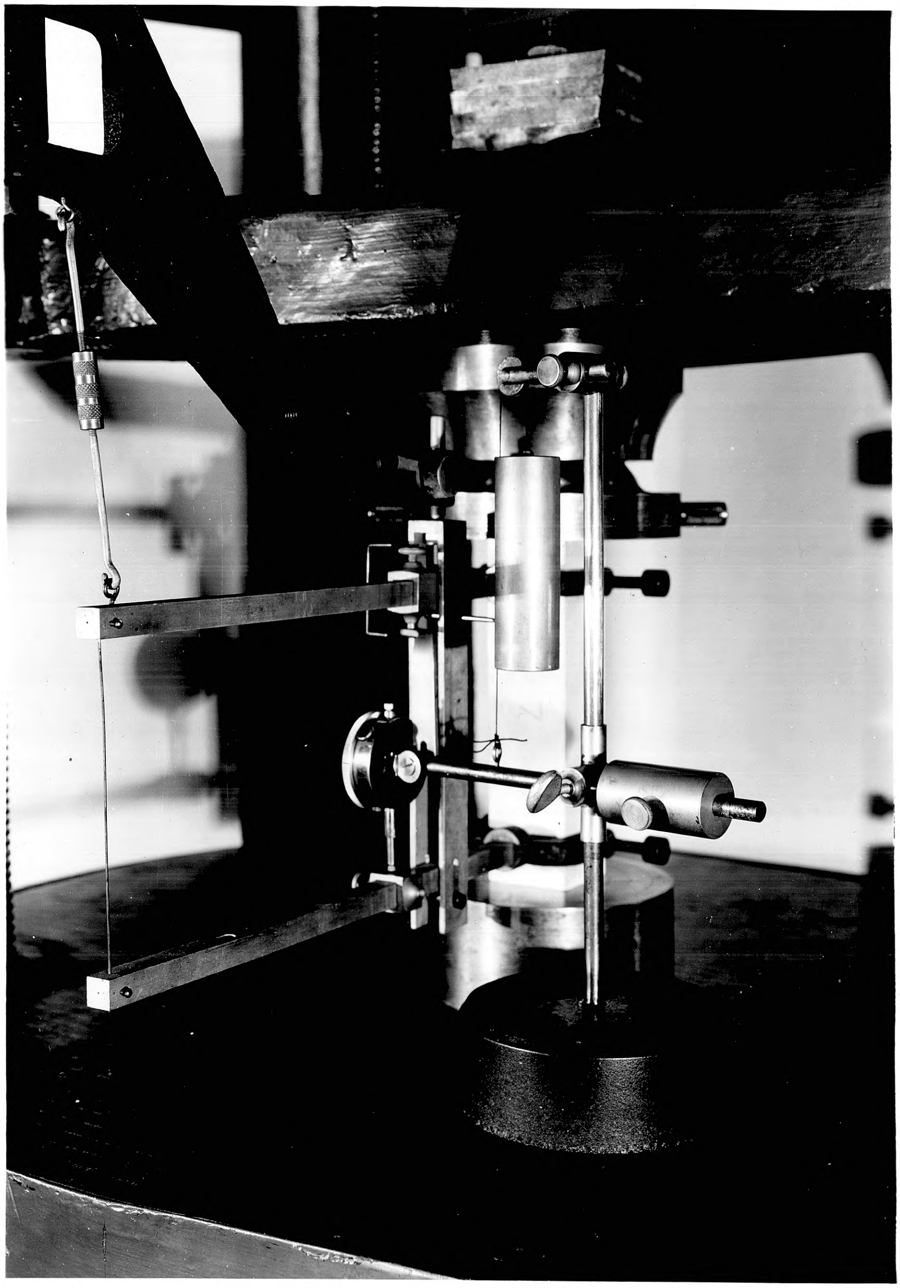
$$\text{Specific Gravity} = \frac{160 \text{ gms.}}{381 \text{ gms.}} = .42$$

PICTURES



Side View of the Testing Machine

Set-Up for Static Bending



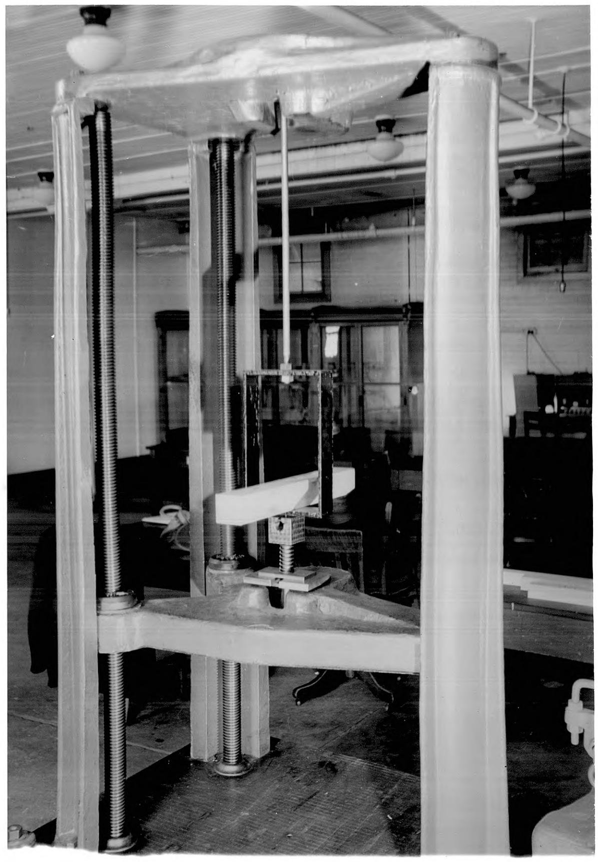
Compression Parallel

To Grain

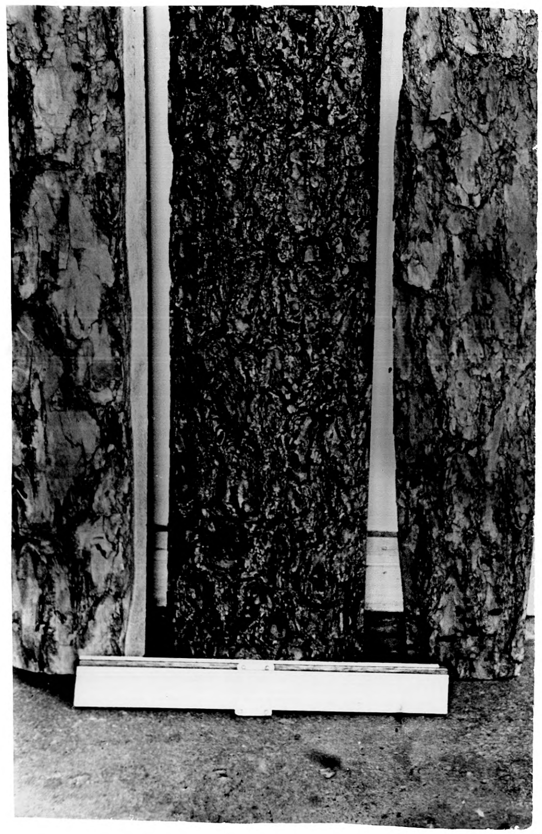
Compression Parallel To Grain

Side Hardness Set-Up

End Hardness Set-Up



Nailholding



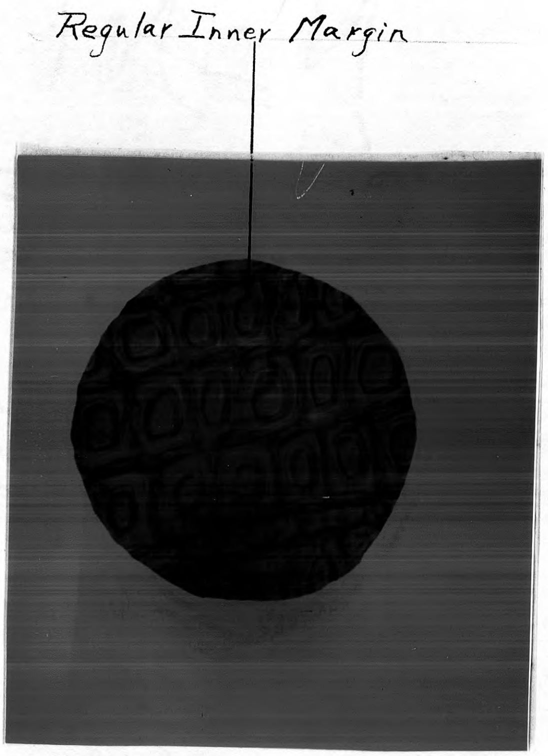
Bark Characteristics

("yellow jack"on the

right and left)

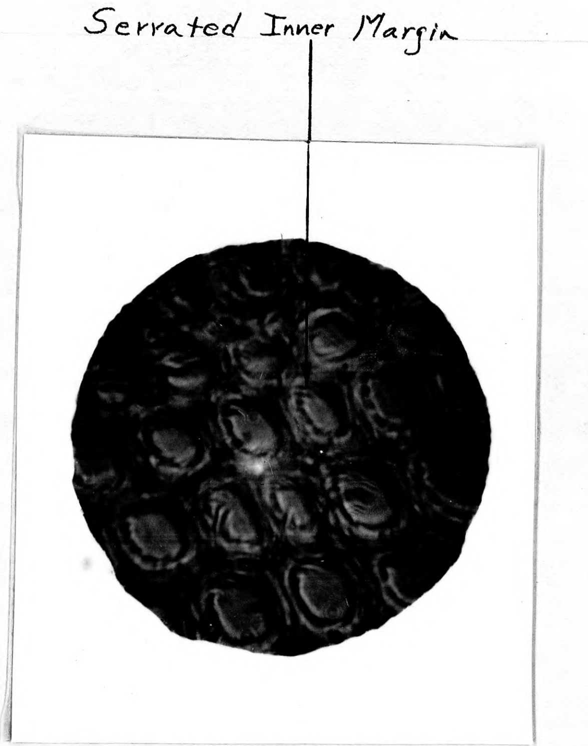
Discs of "yellow jack" and "black jack"

(yellow jack on left)



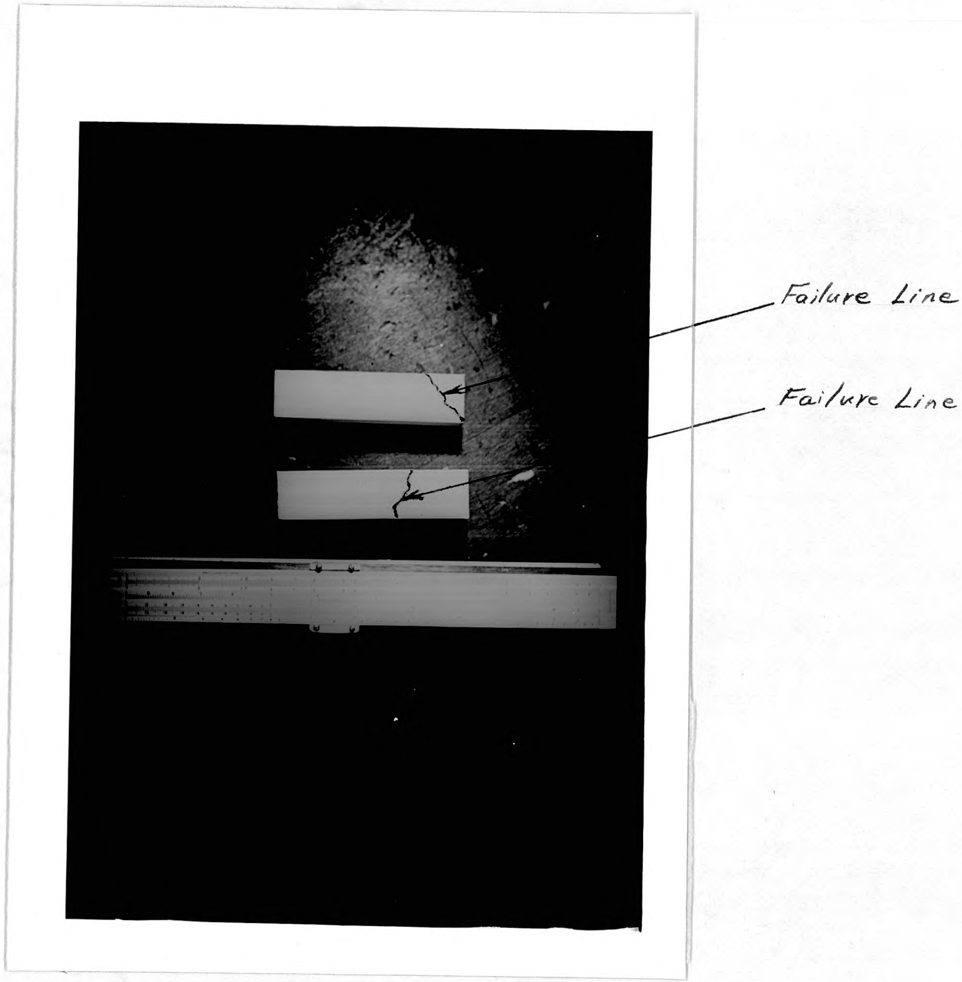
<u>Summerwood Cells</u>

("bl. jack")



<u>Summerwood Cells</u>

("yel. jack")



Wood Failure in Compression

Parallel to Grain

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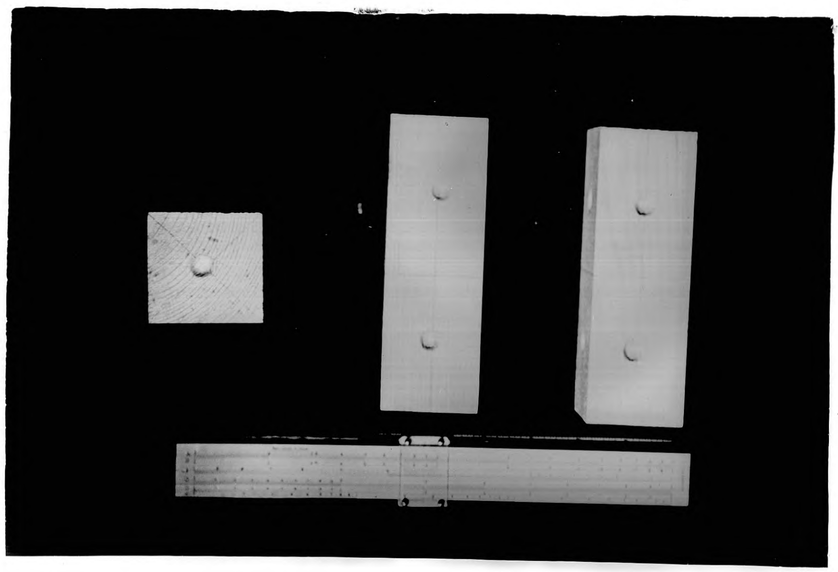
in Original Volume



Hardness

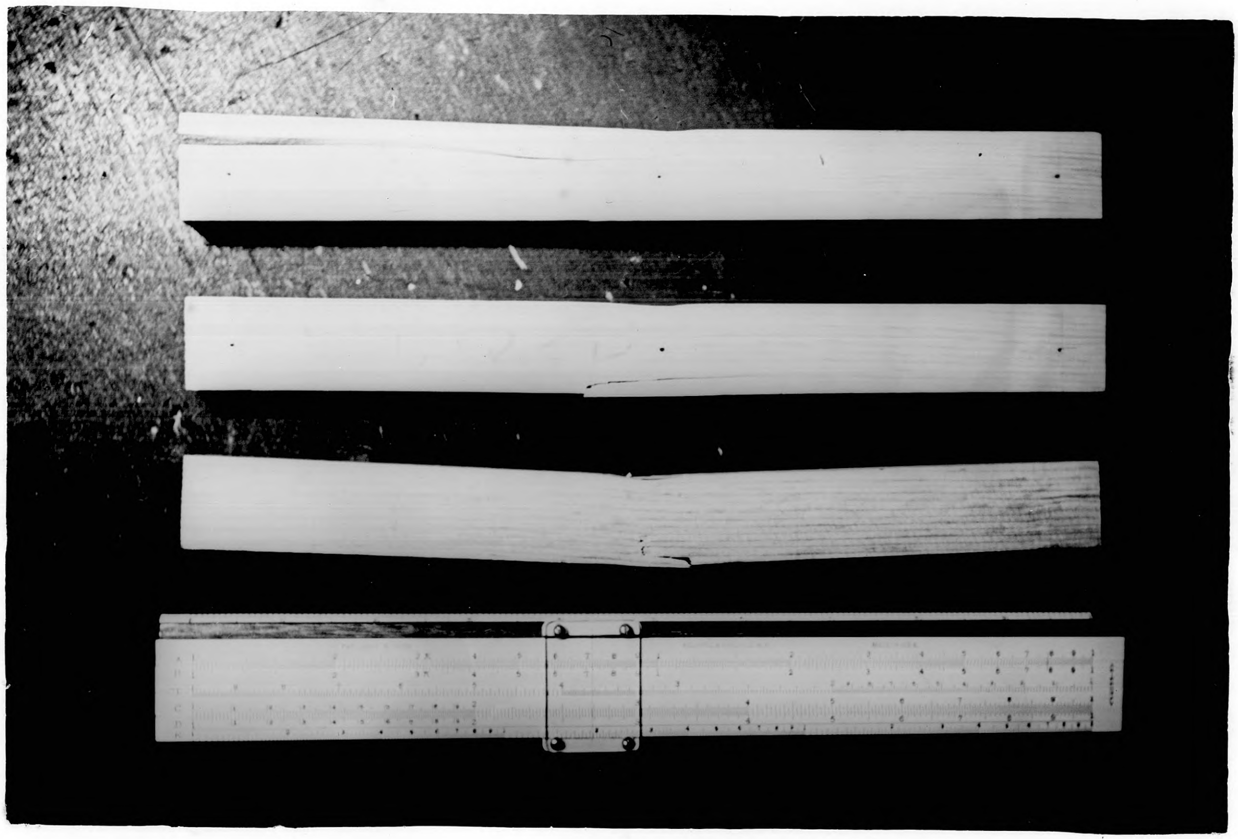


Illustration of Types of Failure in Static Bending