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Mechanical testing of small, clear timber

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Abstract
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1. To investigate the technological methods employed in mechanical testing of small clear timber.

2. To discover the uses, importance, and need for mechanical testing within the wood industry.

3. To experiment with the construction and development of various types of testing equipment similar to that being used by industry.

4. To explore the possibility of adapting mechanical testing of wood samples to the junior or senior high industrial arts wood laboratory

MECHANICAL TESTING OF

SMALL, CLEAR TIMBER

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Paul V. McClannahan

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CHAPTER I

INTRODUCTION

According to most definitions of industrial arts which are presently accepted and used, a major goal is to introduce students to as many different aspects of modern industry as possible (Melo, 1966, p. 28).

Industry has not waited for industrial arts educators to catch up with its level of achievement, and as a result, educators have all too often failed to keep abreast of actual industrial practice.

As the summer session at University of Northern Iowa began, the writer was faced with selection of a research topic. His particular teaching assignment for the 1970 fall term had been changed from the area of metal and electricity to classes in a 9th grade woodshop. Since the writer believes strongly in the industrial arts definition stated above, he began to search for appropriate methods of applying industrial technology to the 9th grade wood laboratory.

Upon examination of our modern industrial complex, it seems apparent that research and experimentation have played an outstanding part in its development. Why, then, should they not also serve an equally important role as an educational method for interpretation of our highly technical society?

Dr. Arthur W. Earl, Professor of Industrial Arts at Montclair State College, New Jersey, has stated the same opinion:

> Research and experimentation courses structured around the materials and products of industry, could readily serve to develop in young people a desire to inquire, search, create, investigate, and explore many new concepts. . . industrial arts, by adopting the research and experimentation methods of teaching to its existing program, would expand its offerings, enlarge its sphere of influence, increase its value to general education, and continue its professional development (Earl, 1960, p. IX).

In examining the problem it seemed to the writer that schools can no longer duplicate the actual equipment of industry in the industrial arts facility, since physical size, complexity, and cost makes this prohibitive. However, we can see no reason why simplified, scaled-down (often instructor-created) equipment cannot be developed to take its place.

With the above considerations in mind, and because of a personal need to develop a curriculum consistent with the educational philosophy relevant to woodworking, the topic, "Mechanical Testing of Small Clear Timber" was selected.

Statement of the Problem:

What is mechanical testing in relation to wood and the wood industry?

The purposes of the research project were:

1. To investigate the technological methods employed in mechanical testing of small clear timber.
2. To discover the uses, importance, and need for mechanical testing within the wood industry.
3. To experiment with the construction and development of various types of testing equipment similar to that being used by industry.
4. To explore the possibility of adapting mechanical testing of wood samples to the junior or senior high industrial arts wood laboratory.

Importance of the Problem:

The versatility of wood as a structural material has made it indispensable to man throughout history. It has provided him with shelter, served as his weapons, warmed him when used as a fuel, and was probably shaped into the first wheel. Scientific research and the technological advancement of man has not led to a decrease in its use, but rather, its applications have become increasingly sophisticated and diversified. "In fact, it is easy to demonstrate that the higher the level of economic development and the higher the standards of living, the greater the per capita consumption of wood, . . ." in its vast variety of forms (Panshin, 1964, p. 3).

If you were to ask a metallurgist, "What is steel?" he would quickly give you a specific, technical and concise answer. If you ask a lumberman or carpenter, "What is wood?" the chances are that he would be so vague as to be practically meaningless.

This has been true because wood has always been easily obtained and, historically, its practical utilization has not required a great deal of special skill or technical knowledge. In fact, the "trial and error" approach to wood utilization has been a hindrance to its competition with other materials (Ward, 1960, p. 3). In the words of Frank Lloyd Wright, "We may use wood with intelligence only if we understand wood" (Panshin, 1964, p. 362). In other words, if wood is to be correctly utilized as a true engineering material, research and investigation must be conducted to determine all of its characteristics under a variety of conditions. Unfortunately, acquisition of this basic information is made difficult by a number of factors.

First, wood is a product of many species, all of which have different physical characteristics. Secondly, trees, of course, are living organisms and, as such, are affected by external environmental factors during growth. Third, wood characteristics are dramatically affected by conditions after cutting, such as moisture content or methods of drying. All of these factors contribute to the fact that wood is a material of greater complexity than any other major engineering material, and, as such, requires a great deal of scientific investigation and research in order to utilize it most effectively.

Mechanical testing has proven to be one major method of investigating the physical characteristics of wood and has permitted researchers to write accurate specifications for specific species.

Limitations of the Study:

TYPES OF TESTS. Eleven separate and distinct mechanical tests are commonly being conducted. They include, (1) static bending, (2) compression parallel to grain, (3) impact bending, (4) toughness, (5) compression perpendicular to grain, (6) cleavage, (7) shear parallel to grain, (8) shear perpendicular to grain, (9) tension parallel to grain, (1) tension perpendicular to grain, and, (11) nail withdrawal.

Unfortunately, time and equipment requirements preclude investigation of all eleven tests. This researcher has selected six of the eleven tests for study. These six tests were selected because of the possibility of conducting all six tests with one piece of equipment that could be quickly adapted to each case.

DEFECTS: The study has been limited to samples of a small, clear variety. Lumber defects, such as checks, decay, stain, knots, wane and warp,

are all conditions which add to the unique complexity of mechanical testing of wood. The study is, therefore, limited to working only with samples free of any type of defect (Tsoumis, 1968, p. 201).

MOISTURE and TEMPERATURE: Moisture content and temperature are also important variables in testing.

Although it is realized that these factors can drastically affect test results, the study has assumed all tests to be conducted at "room temperature", or approximately 72^{o} F. Moisture content is assumed to be 6 percent to 15 percent or within the limits of material normally found within a school wood laboratory.

SIZE OF SAMPLES: The samples have been reduced in size to one-half the specifications given by the American Society for Testing and Materials, whenever this could be applied to the especially-designed test equipment.

DEFINITION OF TERMS

Compression:	Deformation of wood resulting from excessive pressure.
Cross-Break:	A separation of wood across the grain.
Density:	The weight of a body per unit volume.
Flitch:	A portion of a log sawed on two or more sides and intended for re-manufacture into lumber.
Bolt:	A section of log with its bark usually still intact and ranging in size from four to twelve feet.
Static Loading Device:	Any machine used to apply pressure to timbers being tested.
Compressometer:	A device used to measure the amount of compression applied during tests.
Grain:	The direction, size, arrangement, appearance or quality of the fibers in wood or lumber.
Shear:	Slipping, or breaking apart of a piece of wood along the grain.
Strength:	The ability of wood to resist any type of force or load.
Stress:	Force applied per unit of area.
Mechanical Testing:	Standardized method of discovering the physical properties of wood by use of mechanical evaluation instruments.

Sampling: Accepted method of selecting timber specimens for study.

CHAPTER II

HISTORY OF WOOD RESEARCH AND MECHANICAL TESTING

Investigation concerning the qualities of wood dates back to the beginnings of man. However, these trial and error methods were not what we would term "research" or "testing" today. They lacked controls and produced no data that could be preserved and transmitted to other generations (Boolger, 1902, p. 2). Perhaps the actual beginning of wood research should be dated from the publication of strength tests conducted by the French Academy of Sciences in 1707. Limitations of time and space do not permit a comprehensive historical survey of European wood research; however, it may be noted in passing that another publication of importance was completed in Germany. H. Hordlinger, Professor of Forestry in Wortleberg, wrote a book entitled, "Technical Properties of Timber" in 1860, and during the period from 1860 to 1890, noteworthy studies were done by such men as L. Tetmajer, Zurich; Gabriel Janker, Mariabrunn; and, V. Bauschinger, Munich (Tiemann, 1951, p. 235).

The late 1800's saw the development of professional forestry in this country. America had been slow to see the need primarily because her timberlands were so extensive as to seem inexhaustable. A tiny division of forestry already existed under the United States Department of Agriculture, but no experimentation was conducted until 1884, when Bernhard Fernow, the country's first professional forester, began crude experiments concerning wood use.

During the 1890's, the Forestry Division continued its experiments with timber and broadened its scope to include studies of wood chemistry. Gradually, universities such as California, Oregon, and Purdue, began cooperative research with scientists such as Lee F. Hawley and Arthur D. Little, who were conducting experiments in Boston pulp mills.

The twentieth century saw the beginning of what has been called, "the Golden Decade of Conservation". Gifford Pinchot, now the head of a separate government bureau called the Division of Forestry, convinced Teddy Roosevelt of the necessity for "preservation of the forest through wise use". With Roosevelt's help, Pinchot was able to shape the development of the United States Forest Service, and with it, a branch of "Forest Products" created especially for the purpose of research and testing.

Although poor management and complete stripping of forests was occurring across the country, the Products Division of the Forest Service had difficulty obtaining financial help and cooperation. What help was available came primarily from large universities. The result was that many related studies were carried out in different locations without exchange of ideas, standardization of methods, or sharing of results (50 Years of Service Through Wood Research, 1960, p. 5).

In 1908, William L. Hall, Chief of the Forest Products Division, along with Pinchot, went to Congress and asked for a laboratory where research and testing could be centralized. Congress was reluctant to appropriate the funds until McGarvey Oline and Howard F. Weiss, both employees of the Forest Products Office, suggested that one of the universities might be convinced to provide the lab in order to centralize the research on its own campus.

Charles R. Van Hise, a nationally-known conservationist and president of the University of Wisconsin, offered a new building with utilities provided. The offer was accepted, and in 1910, the world's first such facility was opened. Mr. H. F. Weiss appropriately became its first director, and staffed it with forty-five engineers, chemists, physicists, pathologists, and foresters.

Succeeding Congresses were more generous, and in 1930 a permanent three-quarter million dollar building was constructed on a 10-acre section of the Madison, Wisconsin campus.

Historically, the Forest Products Laboratory has contributed so greatly to the development and standardization of wood tests and testing devices that it is impossible to separate it from the history of the entire field. The efforts of the Forest Products Lab in combination with the research and investigation of other organizations, such as the American Society for Testing and Material, Materials Research and Standards, the lumbering industry, the pulp and paper industry, and many others, have led to knowledge of wood as an engineering material, standardization of lumber specifications, and uniformity of testing methods throughout the world.

Wood, because of its great variety, is unique in the complexities it presents to those who would establish methods of testing and standard specifications for it. The future should bring new and exciting methods of determining strength and other characteristics. Research is already well underway to devise non-destructive methods of testing its physical properties.

CHAPTER III

TECHNICAL INFORMATION

The need for mechanical testing and study of the mechanical characteristics of wood is being met by the research efforts of government, private and university-supported studies all over the world. The extensiveness of this research is an indication of the awareness by all concerned that wood utilization must compare favorably with technological standards being employed in most other major industries. This is true even for industries where the supremacy of wood is not questioned, such as the pulp and paper industries. These groups have also discovered that competition for the best timber, rising costs of production, and the demand for superior products, have necessitated improvements in manufacturing techniques, and ultimately, more scientific knowledge of the raw material involved (New Methods of Measuring Wood-Fiber Properties in Small Samples, 1968, p. 75).

Mechanical testing may be defined as evaluation of the strength properties of any species of wood or the properties that enable wood to resist applied force. These properties are truly representative only when obtained from tests on small, clear pieces of wood, because the effects of defects are then eliminated (Wood Handbook, 1955, p. 67).

Mechanical tests may be applied to a piece of timber of any size. They may even be used to test completed products or manufactured items; however, it is customary to conform to specific standards concerning size, selection, and method of testing. This is especially true since mechanical testing is a destructive method.

The Purposes of Mechanical Tests:

Testing of small clear timber specimens are made for the following reasons:

1. to collect data which will allow comparison of the mechanical properties of various species.
2. to collect data concerning the amount of force a particular-sized timber can withstand, thus allowing calculation of permissible structural stresses,
3. to collect data regarding the effects of such factors as density, locality of growth, position in a cross section, height of timber in a tree, change of properties with seasoning, and change from sapwood to heartwood, for the purpose of determining how these variables are related to mechanical

strength.

4. to collect data which will give insight into machinability, ease of splitting, dimensional stability, and hardness as these factors affect practical application and workability of wood.

Collecting Materials:

An obvious first step in a scientific experiment is the follection of materials to be used in the test. Adequate sampling techniques, or methods of selecting random specimens which are truly typical of all timber of a particular species, are very difficult to achieve. Mr. J. A. Lisha, Chief of the Wood Engineering Research section at Forest Products Laboratory in Madison, Wisconsin, believes this to be one of the main reasons for lumbermen's occasional refusal to accept the results obtained by the Forest Products Lab. They have felt that their particular timberlands were not similar to those being selected and tested in Madison. To ameliorate this problem, specimens are now selected by randomly pinpointing certain locations on a forest map, and then selecting only trees within that area.

First, the tree must be authentically identified according to its species. In most cases, this is a relatively simple task; however, some species are so nearly identical that only a trained botanist can determine the difference. If specimens difficult to identify are encountered, the forester who is cutting the tree must also collect herbarium samples of such things as the leaves, fruit, twigs, and bark.

Secondly, five trees that are representative of the species must be selected. From each of these specimens, a bolt eight feet in length is selected from different heights within the trees. This gives information about variations in mechanical properties that might change with the height in the tree. If the bolts are over sixty inches in diameter, a single flitch taken through the pith of the tree in a north-south direction, and representative of the full diameter of the log, can be substituted. When a special species of tree that grows in many different geographical areas is being tested, sample trees must be selected from each of the areas where the species commonly grows (ASTM Standards, 1954, p. 61).

Third, the tree must be carefully labelled and designated. Particular species are identified by arabic numbers. Each bolt is identified by a small letter, starting with 'a', which indicates it was taken closest to the stump. Each successive letter indicates that the sample was taken from a higher position in the tree. The north side of each sample is also marked. Normally, all these designations are marked on the butt ends of logs, using steel dies. Shipment numbers indicating that a number of samples were taken at the same time from the same place, are often included with the other designation numbers (ASTM Standards, 1964, p. 63).

Fourth, the preparation and shipment of samples must be handled according to standardized methods, to prevent the deterioration or weaking of the specimens. These methods include such practices as leaving the bark intact, sealing the ends of logs, storing timber in water to prevent checking, and protecting from any artificial heat.

Fifth, special methods of sawing the bolts are also important. The bolts are sawed into sticks 2½ x 2½, as illustrated by the marking and sawing diagram, Fig. No. 1, page 18.

Manufacturers of wood products may already have a supply of lumber. In this case random samplings are taken from the already surfaced and dried lumber, and testing is done to determine its particular mechanical properties.

Mechanical Testing Machines:

The range of machines that are produced for the testing of the mechanical properties of materials is enormous (O'Kane, 1969, p. 63). Some types are powered by levers or screws; some use pneumatic methods of supplying

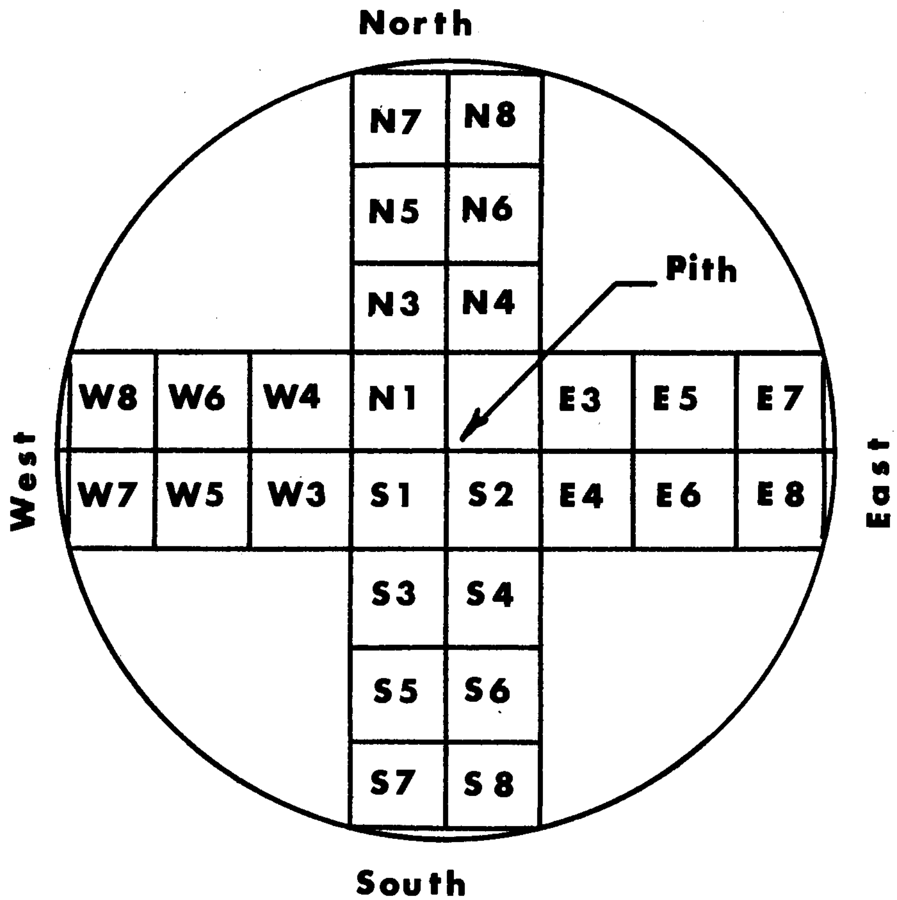


FIGURE 1

Sketch showing one method of cutting up bolts and marking sticks.

the pressures needed, while still others use hydraulics. Basically, mechanical testing machines contain these features: (1) a loading frame assembly which usually consists of a number of rigid columns with adjustable fittings; (2) a device (such as a hydraulic pump and ram) which applies pressure to the material being examined, and (3) accurate measuring instruments which allow the operator to determine exactly what load he is applying to the material (Scott Engineering Sciences, 1968, Advertisement).

Figure No. 2 provides a more detailed description of the nature of the testing machine.

Compression Testing:

Compression is the deformation of wood fibers resulting from an excessive force being applied either along the grain or to end grain. This condition often occurs in nature. Abnormal wood, called compression wood, is frequently formed on the lower sides of branches and on inclined trunks of softwood trees. Compression wood is easily identified because of its eccentrically-formed wide annual rings, and because it contains large amounts of summerwood. It is considered undesirable because it shrinks excessively lengthwise (Wood Handbook, 1958, p. 480).

The amount of compression parallel to the grain of timbers prior to crushing plays an important role in the utilization of wood as a building material. Tests are

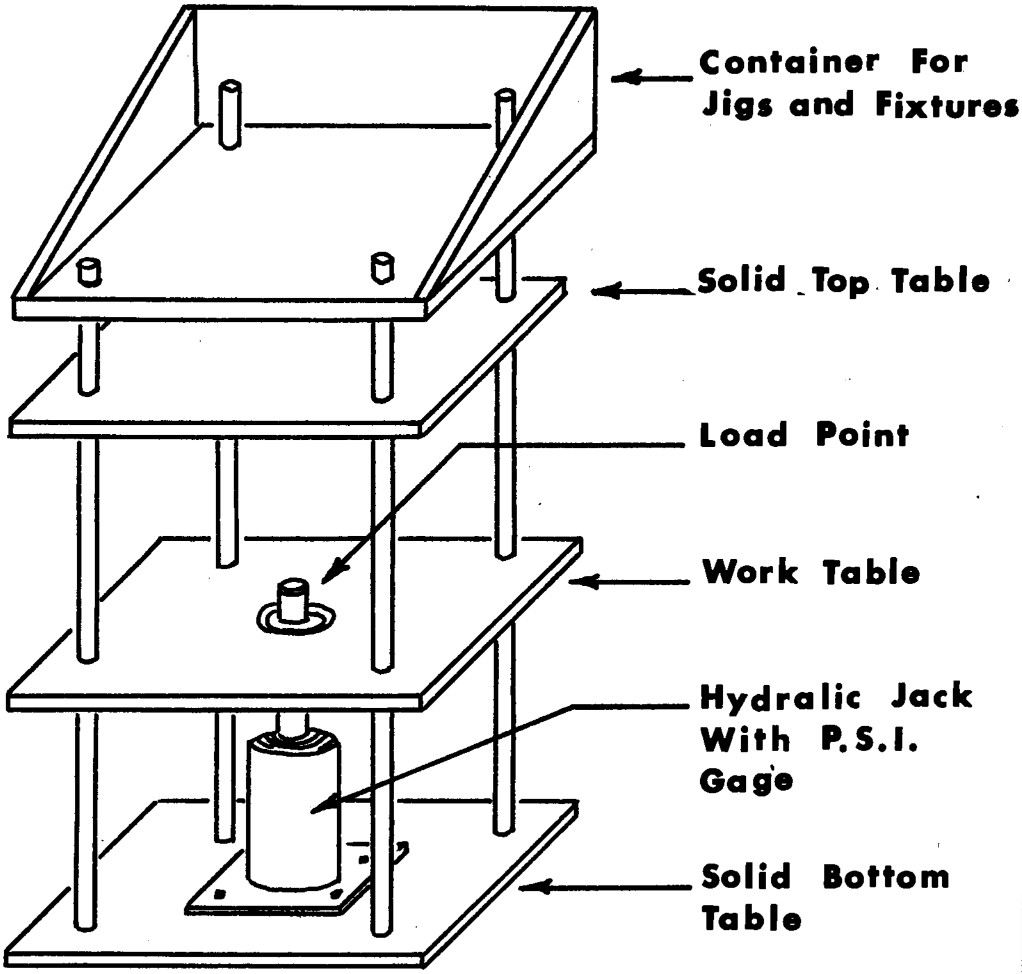
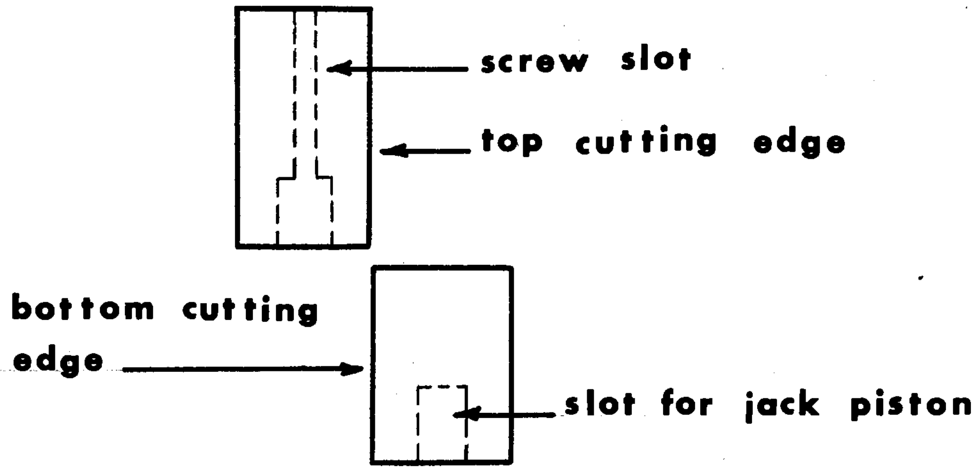
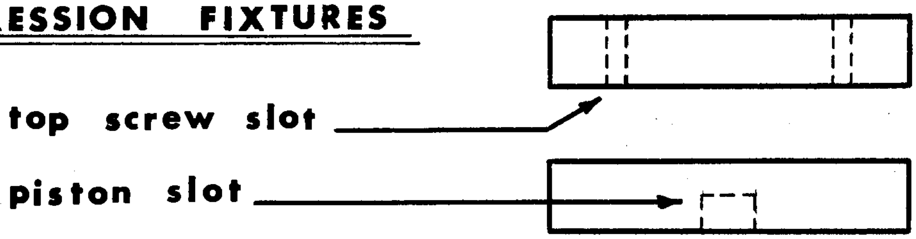

Container For
Jigs and Fixtures
Solid Top Table
Load Point
Work Table
Hydralic Jack
With P.S.I.
Gage
Solid Bottom
Table

FIGURE 2

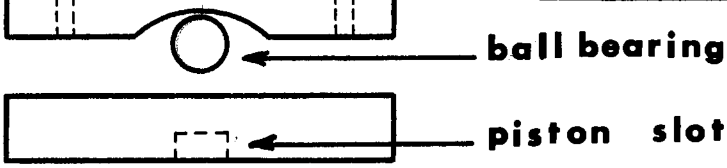
SHEAR FIXTURES



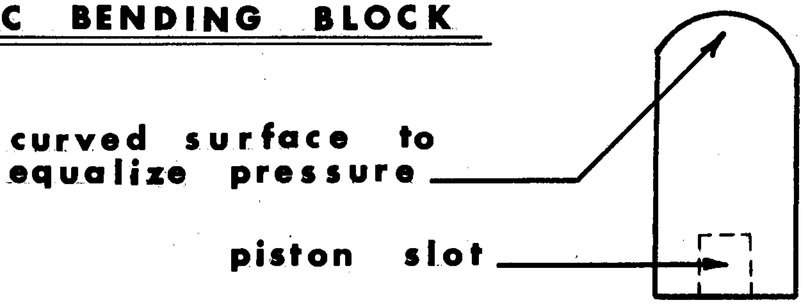
COMPRESSION FIXTURES



HARDNESS TESTER



STATIC BENDING BLOCK



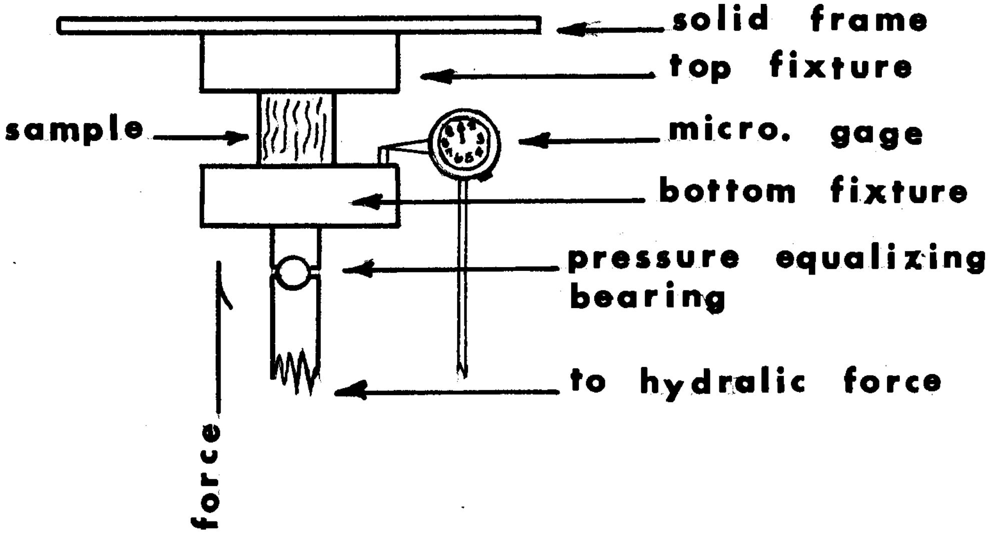
usually conducted on short wood columns or even cubes. The test permits conclusions concerning the maximum crushing strength wood will withstand under various conditions.

A universal type of static testing machine, and some type of compressometer are required. At least one plate of the testing machine must be equipped with some sort of spherical bearing so that pressure will be distributed evenly over the entire cross section of timber (Kollman, 1968, p. 386). The rate of loading has been established by A. S. T. M. at 0.003 inch per inch of specimen length per minute (ASTM, 1964, p. 74).

In simple language and for shop testing purposes, the rate of compression can be found by comparing the size of the load in pounds per square inch to the change in size of the specimen measured in thousandths of an inch. This can best be shown by a graphic representation, such as Figure 3, where the axis of the graph shows load, and the axis shows change in size.

Similar procedures and methods are followed when testing specimens for compression perpendicular to the grain. This type of testing is also done to obtain information useful to construction. An example in which perpendicular crushing strength would be important as in railroad ties.

COMPRESSION TESTING



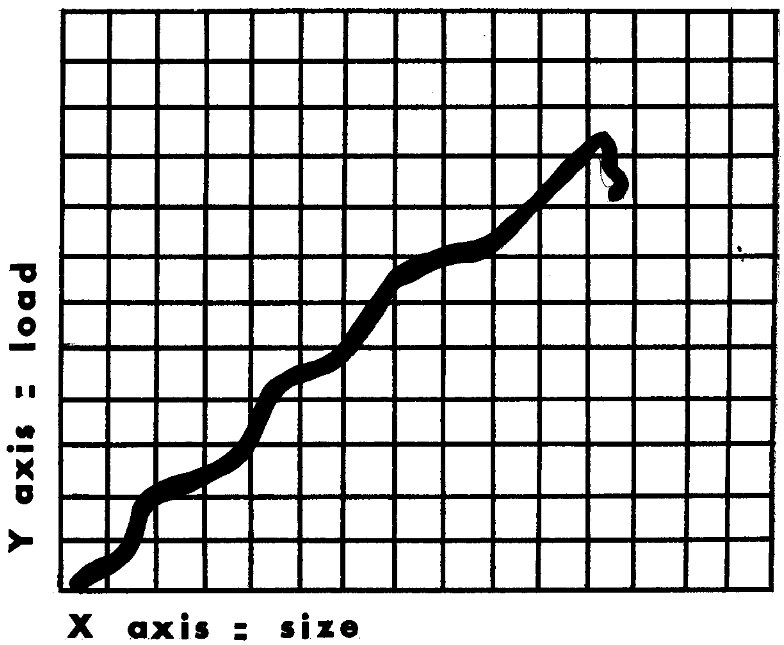


FIGURE 3

Both types of compression testing are often continued until the specimen fails. These failures can be classified according to six types, as illustrated in Fig. No. 4 (ASTM, 1964, p. 74).

a. Crushing: This term shall be used when the plane of rupture is approximately horizontal.

b. Wedge Split: The direction of split should be noted.

c. Shearing: The plane of rupture makes an angle of more than 45° with the top of the specimen.

d. Splitting: This defect results from internal defects in the specimen, and should be eliminated from test results.

e. Shear Parallel to Grain: The failure results from cross-grain, and is a basis for eliminating the specimen.

f. Brooming or End-Rolling: Associated with either excessive moisture content or improper cutting of specimen. It is not an acceptable type of failure and indicates the necessity of remedial measures.

There are many influences which affect the crushing strength of timbers. The <u>gain angle</u> affects results to a tremendous degree since even rather small angles between fiber direction and direction of force reduce the

TYPES OF COMPRESSION FAILURE

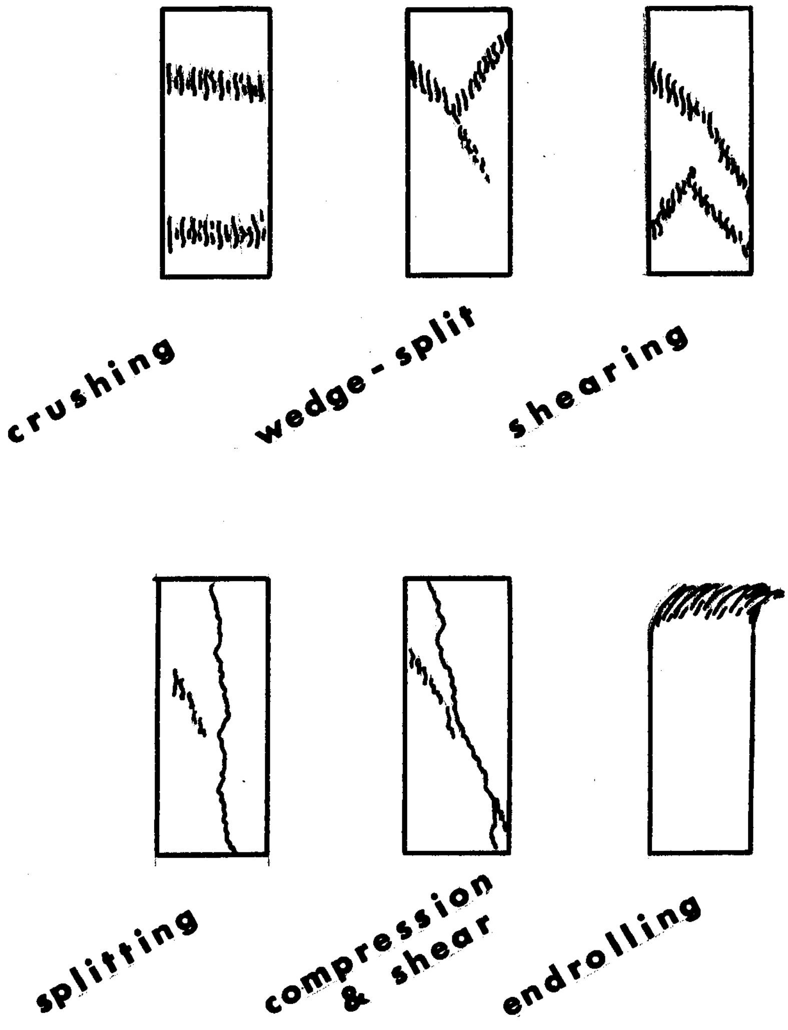


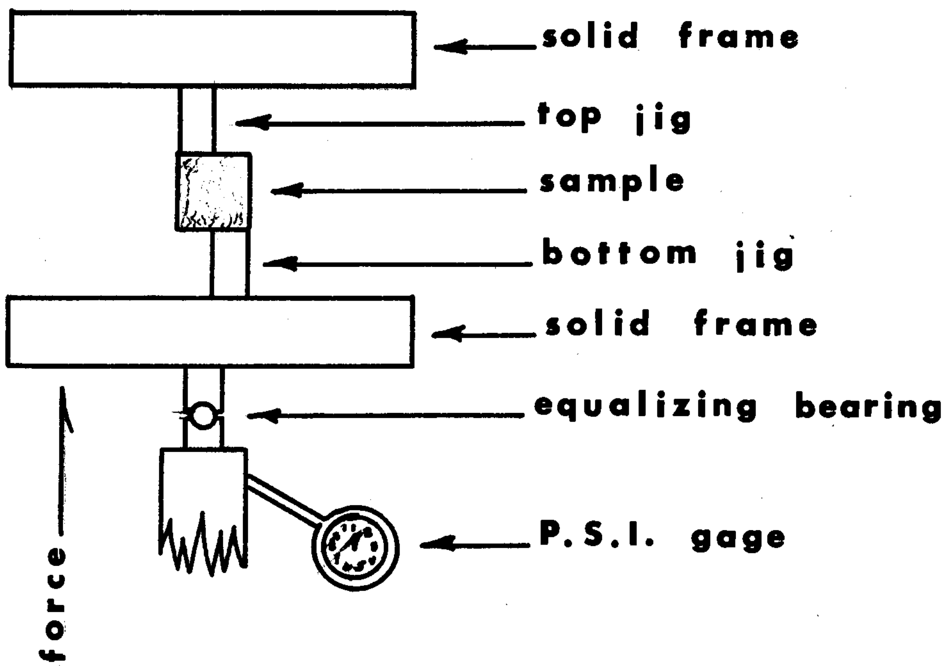
FIGURE 4

strength remarkably. The compression strength increases with density, not only for a given species, but for the differences in density among different species. Moisture content also affects crushing strength. Generally speaking, the dryer a wood, the higher its compression strength. Increases in temperature, even below the level of thermal decomposition, tend to decrease crushing strength (Kollman, 1968, p. 349). Knots, notches, and other defects also affect strength.

Shear Testing:

Shear strength is a measure of the ability of timber to resist slipping of one part upon another. When the shear is parallel to the grain, it actually gives some indication of the difficulty of splitting wood. Shear tests are seldom conducted perpendicular to the grain, as this cuts through the fiber rather than giving any information about slipping (Wood Handbook, 1955, p. 69). Figure No. 5 shows the set-up of a universal static pressure machine for shear testing.

When recording shear values, all that is considered is the maximum load in pounds per square inch required to fracture the specimen. This information might be graphed on a comparative basis for several species.



FORMULA

MAXIMUM LOAD DIVIDED BY SHEARING AREA EQUALS SHEARING STRENGTH IN LB. PER SQUARE INCH.

FIGURE 5

__Static Bending__:

Basically, static bending tests simply involve applying a constant load to a stick of wood while keeping a record of the amount of pressure required, and the amount of bend or deflection the timber will withstand until it breaks. Two terms often used in relation to static bending tests are:

1. Modulus of Rupture: is a measure of the ability of a beam to support a slowly applied load for a short time. It is an acceptable criterion of strength, although it is not a true stress, since the formula by which it is computed is valid only to proportional limits.
2. Modulus of Elasticity: is a measure of the stiffness of wood, or its rigidity. It is measured by a beam's resistance to deflection (Wood Handbook, 1955, p. 68).

The American Society for Testing and Materials has provided a diagram of a static bending set-up. (See Figure No. 6).

The American Society for Testing and Materials recommends specimens 2x2x30 inches, with the load directly in the center and a span length of 28 inches. The machine must be equipped with some type of roller bearings so that

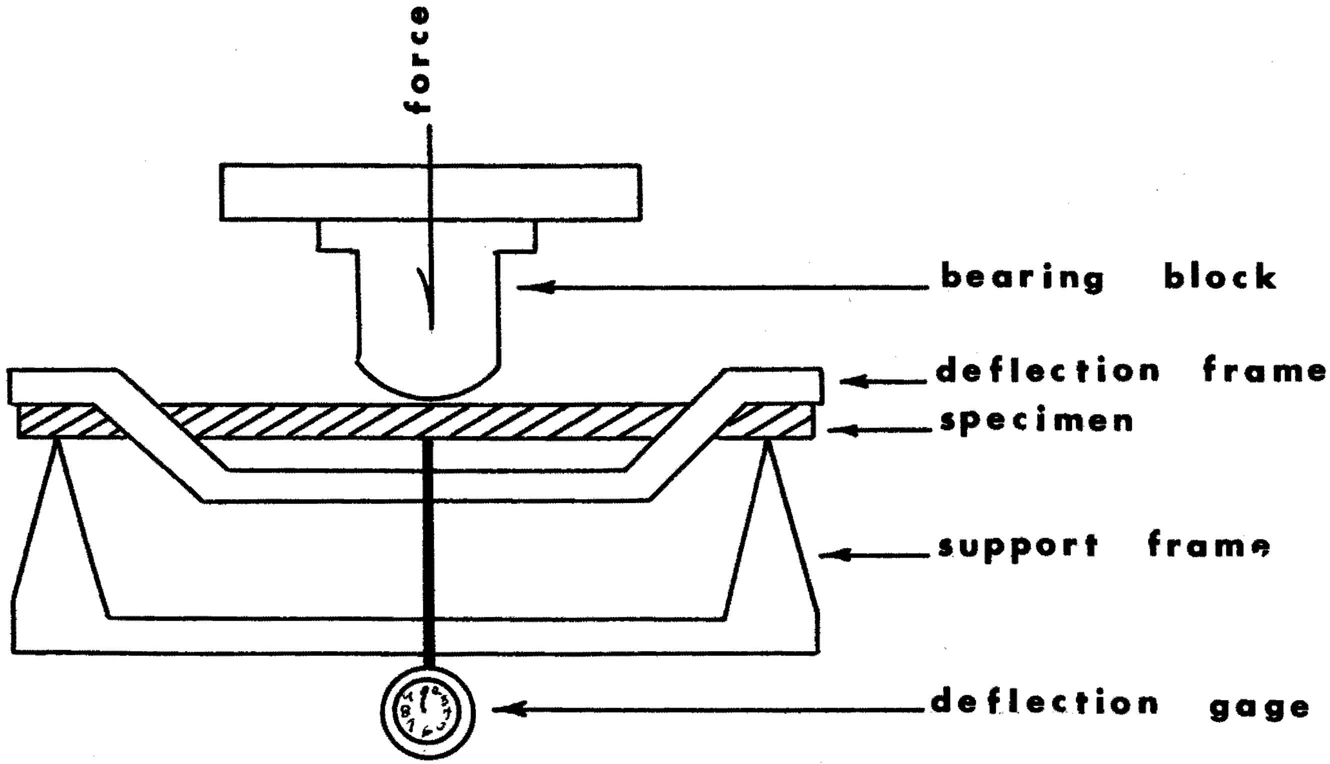

force
bearing block
deflection frame
specimen
support frame
deflection gage

FIGURE 6

the sample can move freely as the timber bends. The load is applied at a rate of 0.1 inch per minute. German standards require different specimens size, and it has been found that specimen size, within limits, has little effect upon results (Kollmann, 1968, p. 363).

Rather than attempt to compute the modulas of elasticity or the modulas of rupture, both of which require rather complicated mathematical calculations, the shop lab approach could be a simple graphing of the relationship of height of deflection (x axis) to weight of load (y axis) until rupture occurs or until the limits of the static loading machine have been exhausted.

Hardness Tests:

The hardness of wood is defined as the amount of force required to impress a steel ball 0.444 inches in diameter into the surface of a test specimen. Similar tests called "Brinell Tests" have been applied to metals for some time with valuable resultant data. The information obtained by this method has not been as successfully applied to wood, because studies have shown that the workability of wood depends to a great extent upon the type of tools being used (Bodig, 1967, p. 450).

Busgen developed this method of testing in 1904, and although it has not been of great value in determining the workability of wood, it has been applied quite extensively to finished wood parts, to determine their ability to resist denting.

The test consists of driving a steel ball 0.444 inches in diameter into a specimen 2x2x6 inches in size, at a constant rate of 6mm per minute. The amount of pressure required gives a figure which can be used comparatively, as a hardness rating (ASTM, 1964, p. 80). Figure No. 7 illustrates a hardness testing fixture.

HARDNESS TESTER POINT

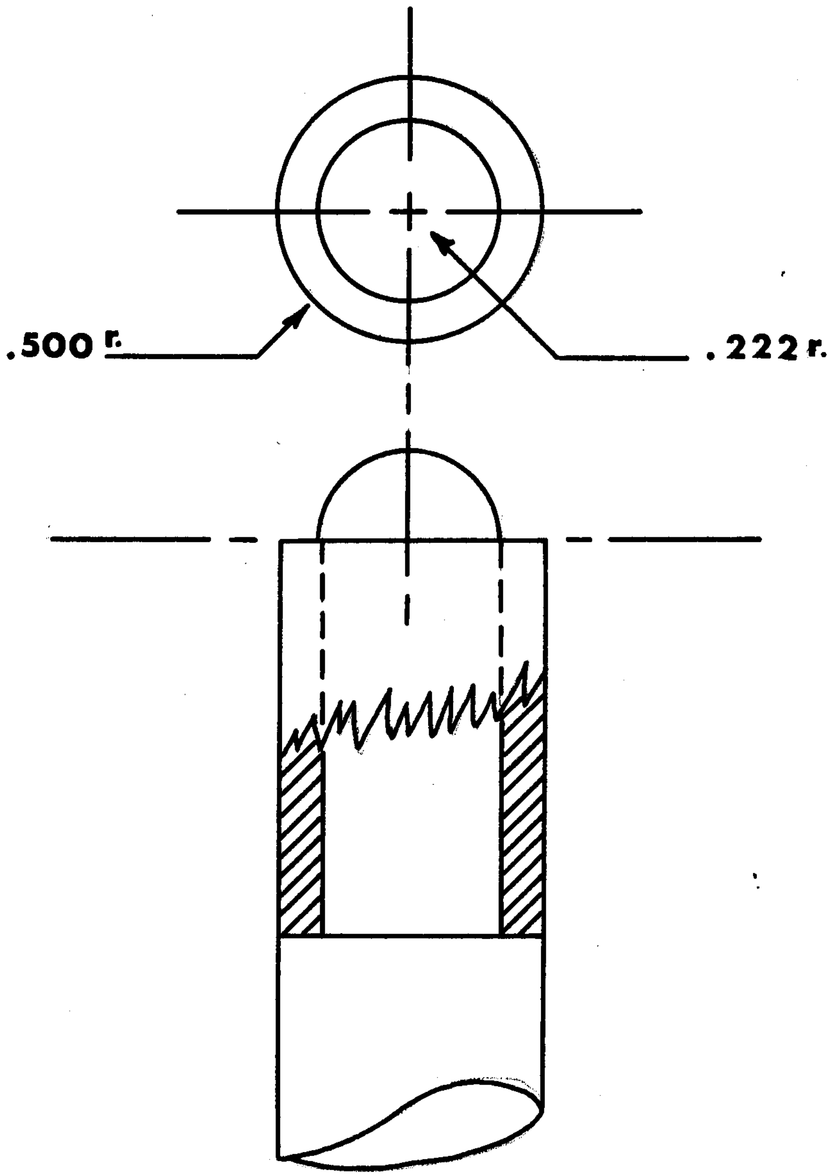


FIGURE 7

CHAPTER IV

RELATED INFORMATION

Industrial-Geographical Information:

The raw material, (wood) is of such diversity in type that any geographical information concerning it is of necessity extremely general. The maps (Appendices A1, A2) show forest regions of the United States.

Major users of wood testing equipment, and wood research methods are the lumber industry, the woodworking industry, and wood research organizations. (Appendices A1, A2 and A3).

Woodworking industries are so varied and diverse that it seems safe to say that they can be found in nearly every part of the world. Major companies are usually located near their supply of raw material.

Occupational Information:

Occupational information concerning specific applications of mechanical testing within the wood industry seems non-existent. Unlike the metals industry, where job titles such as "metallurgical engineer" are well accepted and well defined, wood research and testing is conducted by persons with various amounts of training and differing professional titles. Most research seems to be done by scientific research technicians, mechanical engineers, and civil engineers. Therefore, career and occupational information will be aimed toward these professions.

Engineering and Research Technicians:

Engineers develop methods of converting raw materials into useful products at a reasonable cost. Many conduct research and test materials to supply the basic technological data necessary for improvement in practical utilization of a material. Their job differs from that of the scientist only in the sense that their emphasis is on application of scientific principles rather than their discovery. They conduct tests and experiments aimed at calculating all the factors which affect the products or materials being used. Research technicians do approximately the same job as engineers. The difference lies in the amount of educational background and ability to work on their own.

Engineering is the second largest professional occupation, with 975,000 employed in the United States in the mid-1960's. One-half are employed by manufacturing industries, one-fourth by State, Federal, and local governmental agencies. The remainder work for educational institutions or are employed by non-profit research organizations (Cowles Guide to Careers and Professions, 1968, p. 86).

The United States Bureau of Labor Statistics and the National Science Foundation report that 105,300 research technicians were employed in the engineering field during the late 1950's. This number has doubtless increased (The Institute for Research, 1959, p. 7).

The average starting salary for graduate engineers was $7,425 in 1964, and $10,500 to $12,700 for engineers with the doctoral degree, while engineering technicians' starting salaries range anywhere from $5,000 to $10,000 per year.

Working conditions in these fields are excellent. Laboratories are generally well equipped. There is great opportunity to encounter and solve problems, and industry generally encourages employees to publish results of their work in trade journals, where some personal recognition is attainable.

Employment is not localized in any specific area of the nation. Jobs are available in every large city, in many small towns, and even in some rural areas.

Possibilities for advancement are great, and the swift development of new industries and products indicates job opportunities will continue to be plentiful.

Three types of employers can be found for mechanical engineers and engineering technicians within the area of wood:

1. Manufacturers of wood products: salaries and working conditions are comparable to

those in the field, as a whole. Employment is found in all areas. Jobs are more readily available to technicians than engineers.

2. The lumbering industry: locations of employment are somewhat limited. (See Appendix A1). All major mills and corporations are possible employers.
3. Private and Governmental Research organizations: These are usually located only on university campuses or in large metropolitan areas. (See Appendix A3).

<u>Financial</u> <u>Trends</u>:

Far from becoming an obsolete material, wood products are becoming more and more essential in many areas of the industrial complex. As the woodworking areas have had to compete effectively with other industries, such as synthetic resin and plastic materials, research has tended to expand its uses and importance (Desch, 1968, p. 335).

The writer has attempted to divide the industries concerned with mechanical testing into four major groups:

1. Research and testing organizations;
2. Lumber industry;
3. Woodworking industry, and
4. Testing machine or instrumentation industry.

Since many research institutions are non-profit organizations, supported by government, university, and private funding, no financial reports on this area will be given. The following information is a financial breakdown of one major industrial firm in each of the other three areas.

The Lumber Industry: The Weyerhaeuser Company, founded in 1900, is one of the largest and best-known of the lumber concerns in the United States. It is a diversified enterprise with major holdings in forest stands, lumber mills, pulp and paper industries, particle board, and the packaging industries.

Their 1968-69 financial record is:

	December	
	1968	1969
Net Sales	$ 1,053,035,000	$ 1,239,168,000
Net Income	106,388,000	131,362,000
Earnings per common share	$ 1.75	$ 2.11
Number of common shares	60,710,933	60,784,771

The company experienced a stock split in 1967, with two for one being issued to holders. The earnings comment for 1970 states that Weyerhaeuser anticipates a 15% increase in earnings over 1969, and plans to begin a long-term (four year) expansion and modernization program. The plan includes capital expenditures of one million dollars in the areas of plant modernization, paper and particle board packaging, and pollution control (Moody's Industrial Stock

Report, 1970, p. 982, obtained at the library of Francis I. DuPont, Waterloo, Iowa).

The Woodworking Industry: The American Forest Products Corporation, also a diversified company, manufactures furniture and wood parts. Other divisions of the company include veneer, paper, plywood, corrugated boxes, and wood ladders. American Forest Products also distributes its own products.

	1 9 6 8	1 9 6 9
Net sales	$111,607,201	$143,026,138
Net income	2,564,244	6,144,897
Earnings per share	$2.10	$5.00
Number of shares	1,051,001	1,086,388

The company also owns its own saw mills and holds timber reserves of 2,032,000,000 board feet (Moody's, 1970, p. 932).

The Instrumentation Industry: The Pettibone Mulliken Corporation has eight major divisions, many of which are related to the foundry and casting industry. One of its divisions is concerned with the manufacture of hydraulic static loading devices for testing. There appear to be no separate financial breakdowns for the subsidiary, "Hydraulic Power Equipment Corporation"; however, the company in its entirety seems to be doing well.

	1 9 6 8	1 9 6 9
Net Sales	$117,314,086	$124,137,957
Net Income	4,161,541	5,462,111
Earnings per share	$3,05	$4.81
Number of common shares	1,296,550	1,091,160

(Moody's, 1970, p. 136).

Patent Information:

The following outline has been developed as a guide to patenting. Volumes of material have been written on patenting. The purpose here is not to add to that literature, but to answer a few of the most common questions, and suggest sources of additional information.

A. What is a patent?

1. "A patent is a legal document issued by the United States Government to an inventor. . . they define 'invention' and grants the right to prevent others from making, using, or selling it in the United States" (Brink, 1959, p. 34).
2. An invention is something not previously known or in existence which was discovered, or contrived, and produced by the exercise of independent investigation and experiment.
3. An inventor is a person who has made an invention.

B. Who may obtain a patent?

1. Anyone who can meet the requirements given above for an inventor.

2. Persons having legal power to act for another, i.e., executors, administrators, legal guardians, or attorneys.

C. What can be patented?

1. In order to patent, the inventor must be able to classify his work in one of six categories:

   a. mechanical device for the use or conversion of energy, i.e., motors, engines, nuclear reactors, turbans, chemical reactors.

   b. Composition of matter, i.e., chemical reaction the product of which was unknown.

   c. Article of manufacture, i.e., a better mousetrap.

   d. A process, i.e., a series of steps or procedures used to obtain a specific result.

   e. Specialty, i.e., effective changes in the appearance, ornamentation, or design of an object.

   f. Plant, i.e., only asexual propogated varieties; seed hybrids, or wild plants do not qualify.

2. The invention must have: utility, novelty, and inventiveness.

   a. Utility: workable and of some practical use.

b. Novelty: never having been patented, invented, or generally known before.

c. Inventiveness: not immediately obvious to anyone trained in the area of invention (superior material or variation of parts do not qualify).

D. How should a Patent be Applied For?

The application and filing of patents is of such a complex nature that few laymen should try to take on the job themselves. The best method is to hire a patent attorney or contact a development commission. In Iowa, "The Iowa Development Commission, Inc., Center of Industrial Research and Service", 202 Building East, Iowa State University, Ames, Iowa, can be of help for a small percentage of the royalties earned by the invention. The following six steps briefly describe the method of obtaining a patent:

1. Official request: A formal request should be addressed to the United States Patent Office, United States Department of Commerce, Washington, DC 20035, requesting a petition to file. (Information about patenting can also be obtained here).

2. Disclosure: A description of the invention giving exact specifications that are clear, concise, and complete, and written in legal terminology.

3. Claims: Describe all those parts of the

invention the applicant wishes to protect and claim as his own original discovery. All claims must be stated as the object of a sentence. (We claim, or I claim).

4. Drawings: Are almost always required instead of working models. They must describe every detail being patented and meet prescribed drafting standards.
5. Oath: Applicant must swear to be the inventor of everything in the claim.
6. Filing fees: If the patent is accepted, a charge of $30, plus $1 per claim for all those over 20, must be paid.

E. Helpful Terms to Know when Patenting:

1. Pending: A patent application found to be acceptable but not yet issued.
2. Copending: Two applications on the same invention, one filed while the other was pending.
3. Abandoned: Applicant has surrendered all rights to his invention.
4. Forfeited: An application which has not had the filing fee paid within the time limit.

F. References Found to be Helpful:

Calvert, Robert, "Patent Practice and Invention", Reinhold Publ. Corp., New York, 1964.

Jones, Stacy V., "You Ought to Patent That", Dial Press, Inc., New York, 1962.

Brink, Richard E., "An Outline of U. S. Patent Law", Interscience Publ., Inc., New York, 1959.

U. S. Department of Commerce, "Patent Laws", U. S. Government Printing Office, Washington, DC 20035, 1965.

Field Trips:

The writer contacted the Forest Products Laboratory in Madison, Wisconsin, and after talking with Mr. J. A. Liska, Chief of Wood Engineering Research, made an appointment to visit there. The laboratory conducts fundamental and applied engineering research on wood. The research relates specifically to the evaluation of the physical, mechanical, engineering, and related properties of nearly every known wood species. The Forest Products Laboratory is a governmental agency and, as such, its research is directed toward the best possible utilization of all forest products.

Mr. Liska and Mr. Boller, a mechanical engineer at the laboratory, were extremely generous with their time. They spent more than four hours answering questions concerning all aspects of mechanical testing, and demonstrating and explaining many of their specific tests and equipment.

The writer wishes to express his thanks to these two men and to the Forest Products Laboratory for their valuable assistance.

The writer also visited Hydraulic Service and Supply Company in Des Moines, Iowa. Mr. D. Johnson talked with the writer and answered questions concerning testing machine construction, as well as many other questions about the industry.

CHAPTER V

EDUCATIONAL PACKAGE

As previously mentioned (see Introduction) it is the writer's feeling that industrial arts woodworking programs have retained a traditional approach, while the wood industry has been adapting itself to a more technically oriented society. Applications of scientific testing are being applied by the wood industry. In keeping with the goals of industrial education, the introduction of a unit in mechanical testing of timber seems a necessity (Ward, 1960, p. 5).

The Instructional Unit:

The writer envisions a unit on mechanical testing of wood timbers as an ideal way of beginning a semester course in woodworking. It might, if properly handled, eliminate units presently being taught in the identification and characteristics of wood. The following objectives, information, and activities provide a possible unit outline. They should not be thought of as complete or as the only possible solutions.

Objectives:

1. To develop an understanding of what mechanical testing is, and how it is applied to the woodworking industry.

2. To develop interest in solving problems by the research and experimentation method.
3. To develop students' ability to recognize various woods and know their correct uses (consumer knowledge).
4. To develop a working knowledge of correct machine skills with testing equipment.
5. To inform students of job or occupational opportunities within the area of mechanical testing.
6. To develop good work habits and safety consciousness.

__Unit Outline__:

I. Introduction of Mechanical Testing

A. History

1. prehistoric applications
2. first scientific attempts
3. in the U. S., Forest Products laboratory.

B. Applications to present industrial practices

1. the construction industry
2. makers of testing equipment
3. the lumber industry
4. the woodworking industry

II. Methods of Sampling.

III. Methods of Testing:

A. Compression

B. Shear

C. Static Bending

D. Hardness

E. Although these are the only tests covered in this report, many others should be included, such as: nail withdrawal, abrasion, toughness, and cleavage.

IV. Occupational Information:

A. Explanation of jobs that apply,

1. working conditions
2. location
3. wages
4. skills required

B. Jobs involving mechanical testing outside the wood area.

V. Introduction to the shop testing equipment:

A. Safety for workers

B. Safety for the equipment.

VI. Laboratory experience.

VII. Evaluation.

<u>General Safety</u>:

Safety rules for laboratory work with mechanical testing of wood is similar in most aspects to those rules generally applied to all industrial arts activities. Safety glasses are most certainly a MUST. The following list suggests other areas where attention should be given to safety (Feirer, 1963, p. 28).

1. clothing and personal dress
2. housekeeping

3. condition of tools
4. correct use of tools
5. special protective devices and guards
6. lifting heavy materials
7. using ladders
8. horseplay
9. combustible materials
10. First-aid equipment.

For additional information on establishing a successful and comprehensive safety program, see:

> Silvius, Harold G., "Teaching Successfully in Industrial Education", McKnight-McKnight, Bloomington, IL, p. 399-457.

Safety in Using Testing Machines:

Nearly any type of machine used will be producing loads or forces of one kind or another. Many times these forces will be very large. For example, compression loads often go as high as 10,000 lb/sq. in. Since wood is a material that tends to resist force until a maximum is reached and then break suddenly, extreme care must be used in positioning the operator of testing equipment. Guarding devices around the specimen being tested should be used whenever possible.

The equipment, although designed to withstand extreme pressure, contains many measuring devices, such as gauges or scales, which are delicate instruments, care must always be taken to protect them from sudden jolts or falls.

Pupil Evaluation:

The first and only fair method of evaluation is to establish clearly in the minds of both the students and the instructor, what information, skills, and attitudes are desirable, and what is to be evaluated. In other words, behavioral objectives must be established and made clear to everyone involved in the evaluation. The following paragraphs contain suggested methods of evaluating student progress according to the objectives previously established for a mechanical testing unit.

Self Evaluation: The student should learn to form sound judgments concerning his own work. He is then in a position to better understand his deficiencies and to improve his quality and proficiency. To some extent, the grading effort should be cooperative between the teacher and the student. Self-rating scales have been found by the writer to be an effective method of self-evaluation.

EXAMPLE:

	Poor	Needs Improvement	Satisfactory	Outstanding
0	5	10	15	20

(1) To what degree do you feel comfortable operating testing equipment?

(2) Do you feel you have a comprehensive understanding of the methods for compression testing?

(3) To what degree was the data you obtained on your mechanical test specimens accurate as compared with professional results previously obtained?

Formal test items: A major point to remember is that no test item should be included until after students have had ample opportunity to familiarize themselves with the material. Review sessions are helpful. Formal test questions could be essay, multiple choice, true-false, or matching type questions. The objectiveness of this type of evaluation is of great importance.

EXAMPLE:

1. Write a short paragraph explaining the historical development of mechanical testing of wood specimens.

2. A test used to tell how far a test specimen will bend before breaking is called:

   a. shear   c. static
   b. compression   d. hardness

3. The moisture content of wood affects its strength. The greater the moisture content of a specimen, the stronger it will be.

   ____ True   ____ False

4. Match the test with what is actually being done to the specimen.

   1. specimen is sliced into parts
   2. specimen is squeezed together
   3. specimen is punctured
   4. specimen is bent

   a. static
   b. hardness
   c. compression
   d. shear

Evaluation of Manipulative Skills:

Manipulative skills have traditionally been evaluated in terms of take-home project. Mechanical testing in the wood lab provides no such project. Subjective grading on the part of the teacher is therefore required. The student's competencies can best be evaluated on the basis of critical observation of his actual performance in applying scientific principles at his work station.

Attitude Evaluation:

Most instructors feel the need to evaluate this aspect of their students. It has the advantage of allowing the student who tries hard, but is not very capable, of experiencing some success. The major drawback is that it may be applied in a vindictive manner by some instructors. Whenever possible, objectivity should be increased through the use of such devices as rating scales, sociograms, and standardized methods.

Percentage of Importance:

Without doubt every teacher will insist upon deciding the importance of each type of evaluation method for himself. Teachers should, however, make the percentage of importance known to their students. The grading pie might be sliced to resemble this formula:

Self evaluation. 15%
Formal tests 30%
Manipulative skills. 40%
Attitude 15%

Text Books:

After a careful investigation, the writer has been unable to discover any single text which is suitable as a textbook for students at the junior high level. There seems to be a real need for texts which apply scientific investigation and research methods to industrial arts at a level of difficulty commensurate with general secondary education.

The following texts have been of great value to the writer, and should make excellent resource materials in teaching the unit:

American Society for Testing of Materials, Part #16, ASTM, 1916 Race Street, Philadelphia, PA, 1964 (issued annually), price $15.

Wood Handbook, U. S. Department of Agriculture, U. S. Government Printing Office, Washington, DC, 1955, price $2.25. (No. 72).

A-V Materials of Possible Value:

1. "Lumber for Houses", Visual Instruction Service, Iowa State University, Ames, IA 50010. (N.S. - 734)

2. "The Meaning of P.S.I.", Visual Instruction Service, Iowa State University, Ames, IA 50010. (N.S. - 411)

3. "Fixed Gages", (Op. cit.)

CHAPTER VI

SUMMARY

The writer feels that the study has been successful within limits. The area of wood research is developing amazingly and unique utilizations of the oldest of raw materials, through better understanding of its characteristics. Unfortunately, time and circumstances will not allow a comprehensive investigation of all wood testing and research being undertaken. However, the present investigation has convinced the writer of the merits of including this topic as a unit of instruction in industrial arts education.

The writer eagerly awaits the challenge of attempting to apply mechanical testing of timber to a junior high school curriculum. The possibilities for further investigation and study are also appealing.

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Desch, H. E., "Timber, Its Structure and Properties", Macmillan, New York, 1968.

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Feirer, J. L., "Woodworking for Industry", Charles A. Bennett Co., Inc., Peoria, IL. 1963.

Kollman, Franz F. P., "Principles of Wood Science and Technology", Springer-Verlag, New York, 1968.

Melo, Louie, "Industrial Materials: An Important Augment to Industrial Arts", p. 28, IAVE, October, 1966.

"New Methods of Measuring Wood and Fiber Properties in Small Samples", Forest Biology Lab. Committee, N. & N. & Tappi/Jan. 1968, Vol. 51, No. 1, p. 75a.

O'Kane, J. R., "The State of the Art in Destructive Material Testing", Materials Engineering, July, 1969, p. 63.

"50 Years of Service Through Wood Research", Publ. No. 820, U. S. Department of Agriculture, Forest Service, April, 1960.

Silvius, Harold G., "Teaching Successfully in Industrial Education", McKnight, Bloomington, IL. 1967.

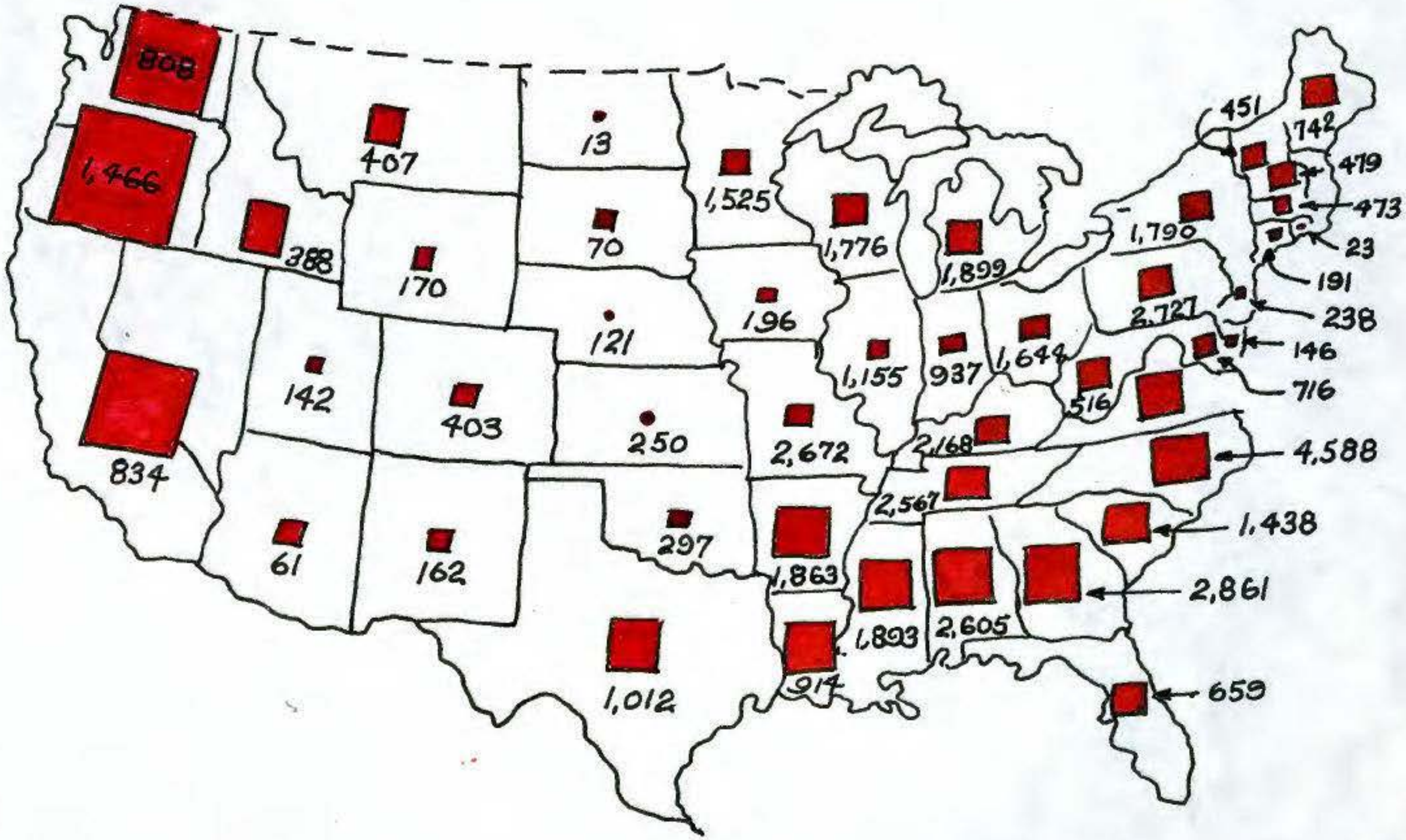
Tiemann, Hary D., "Wood Technology", Pitman Publ. Corp., New York, 1951.

Tacoumis, George, "Wood as a Raw Material", Pergamon Press, London: N. Y., 1968.

Ward, Darrell, "How Many Things Can You Make of Wood?" Reprint from Hitchcock's Woodworking Digest, July, 1960.

"Wood Handbook", U. S. Department of Agriculture, No. 72, U. S. Government Printing Office, Washington, DC, 1955.

APPENDICES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2,861
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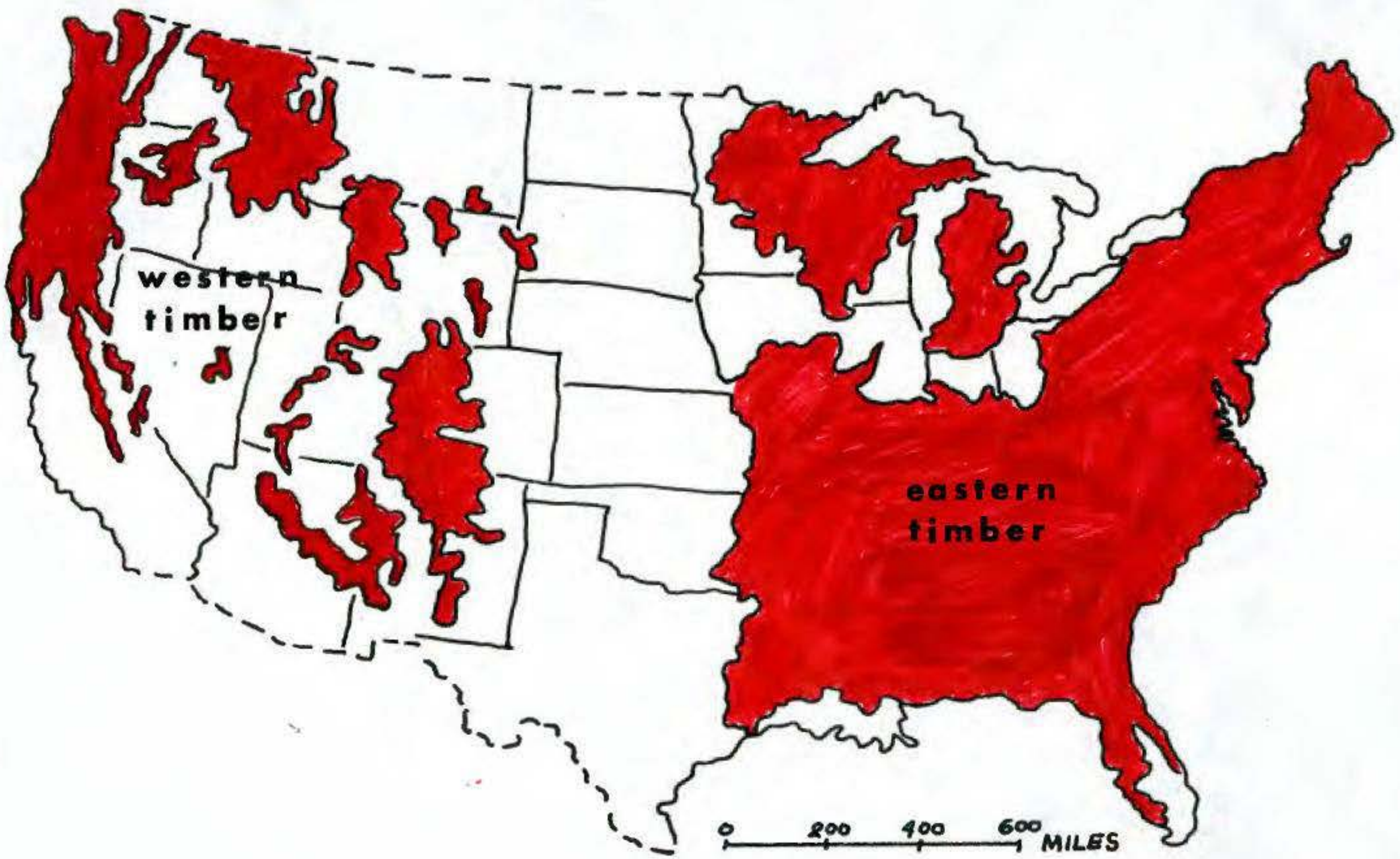
APPENDIX A1



APPENDIX A2

APPENDIX A3

Research organizations concerned with timber and plywood. (For a more complete listing, world-wide, see (Booth, 1967, pp. 225-260).

I. American Institute of Timber Construction
1757 K Street
Washington, DC

II. Forest Products Laboratory
Madison, Wisconsin

III. Virginia Polytechnic Institute
Wood Research Institute
P. O. Box 361
Blacksburg, Virginia

IV. Oregon Forest Research Center
P. O. Box 571
Corvallis, Oregon

V. National Forest Products Association
1619 Massachusetts Avenue, N. W.
Washington, DC

VI. Canadian Institute of Timber Construction
200 Cooper Street
Ottawa, Ontario, Canada

VII. British Columbia Lumber Manufacturer's Association
1477 West Pender Street
Vancouver, B. C., Canada