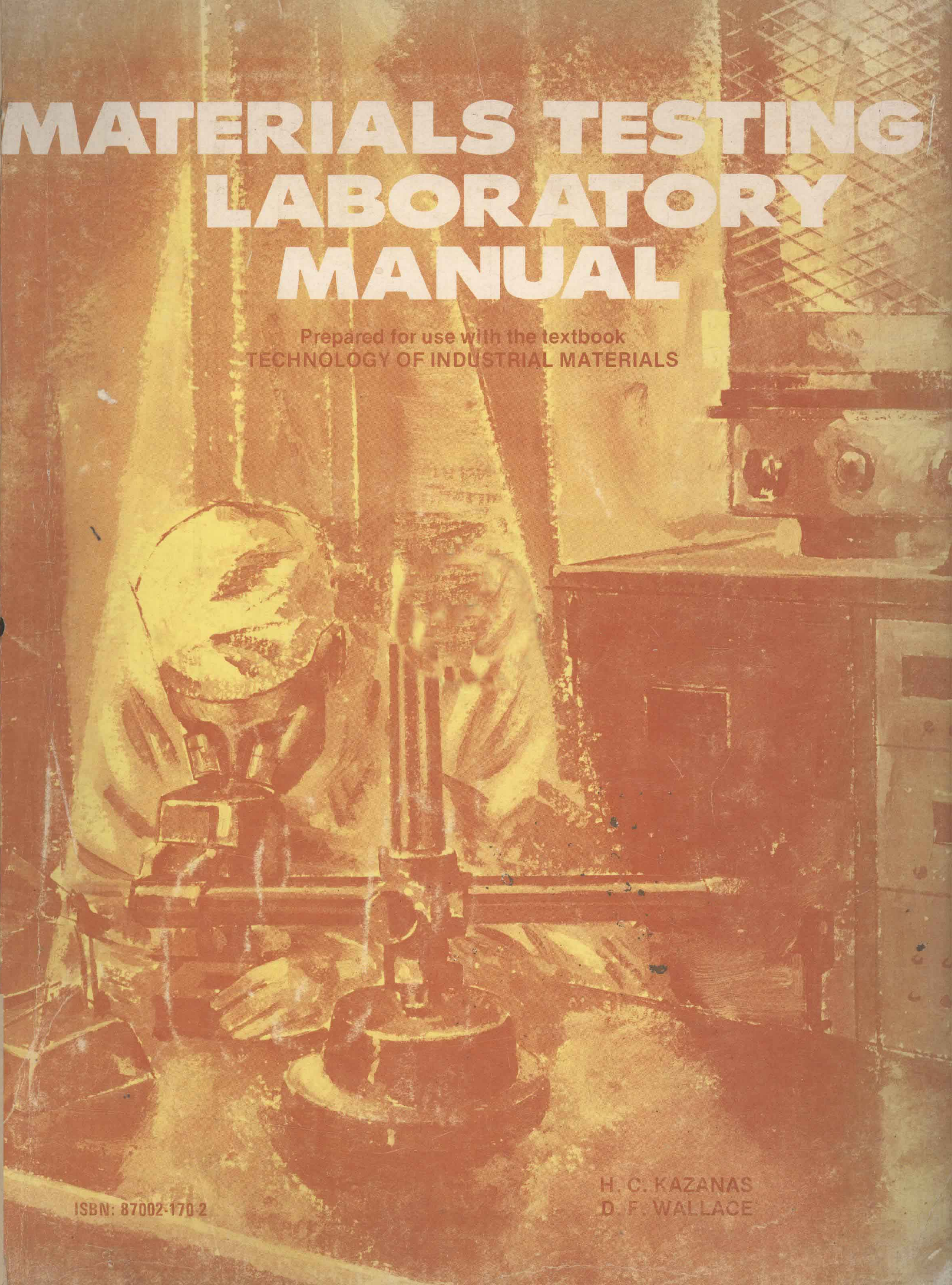
MATERIALS TESTING LABORATORY MANUAL

Prepared for use with the textbook
TECHNOLOGY OF INDUSTRIAL MATERIALS



H. C. KAZANAS
D. F. WALLACE

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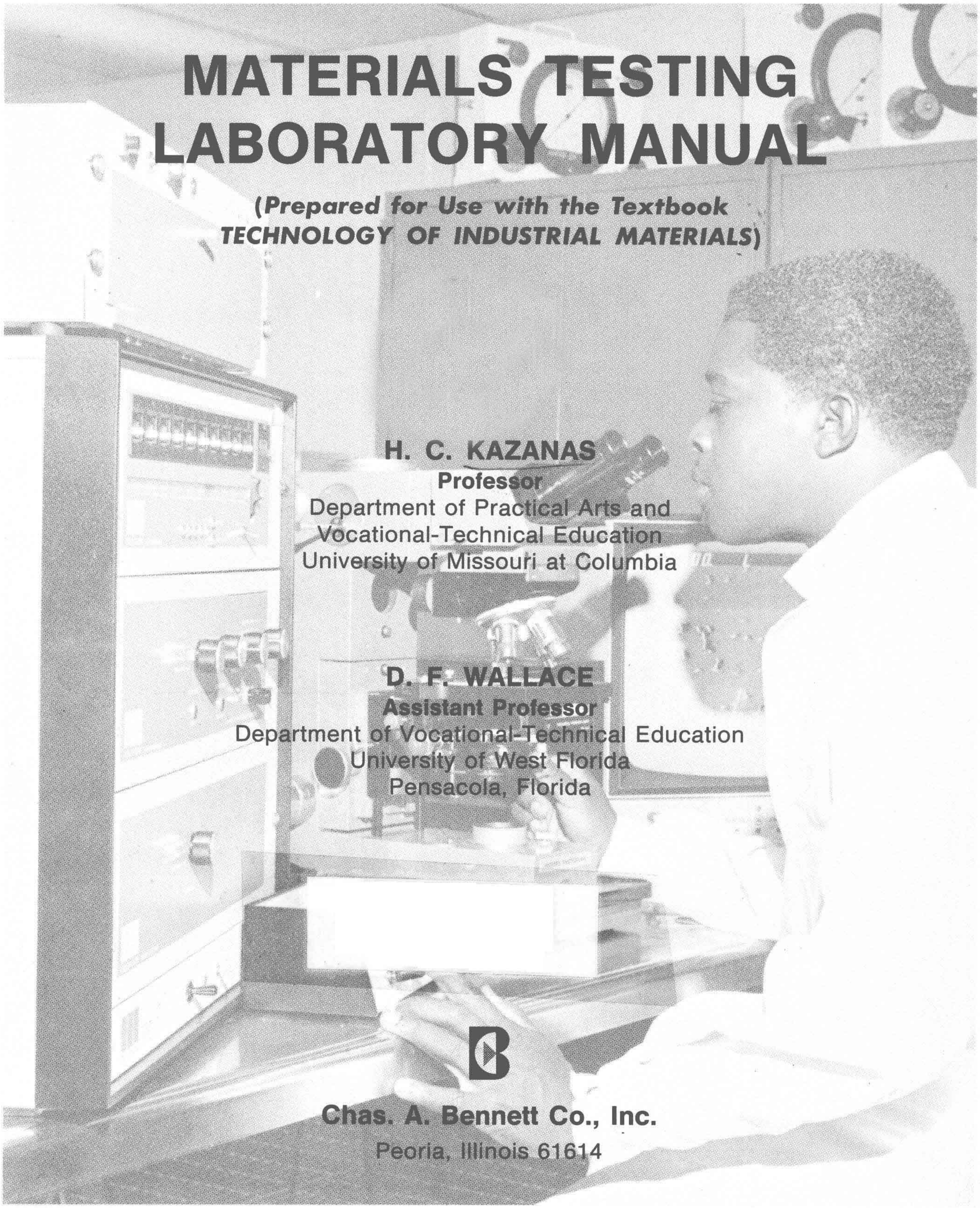

MATERIALS TESTING LABORATORY MANUAL

(Prepared for Use with the Textbook TECHNOLOGY OF INDUSTRIAL MATERIALS)

H. C. KAZANAS
Professor
Department of Practical Arts and
Vocational-Technical Education
University of Missouri at Columbia

D. F. WALLACE
Assistant Professor
Department of Vocational-Technical Education
University of West Florida
Pensacola, Florida

Chas. A. Bennett Co., Inc.
Peoria, Illinois 61614

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INTRODUCTION

This laboratory manual is designed to enable the student to study, observe, and experiment with the testing of various materials. The testing activities included in the manual will allow the student to develop skills in performing commercially accepted tests on a wide variety of common materials. Although each testing activity contains sufficient information to be performed with minimal outside reading, the student is advised to use this manual in conjunction with the textbook *Technology of Industrial Materials.* Most of the activities in this manual are based on the materials covered in that textbook. However, there are a number of questions and problems in each activity which require extra reading beyond the manual and the textbook. The instructor may choose to ignore these, or he may designate them as assignments for extra credit. All questions and problems can be solved or answered by reviewing the sources cited with each activity. Furthermore, because commercially accepted tests are stressed, the testing activities are based on recognized standards developed by professional standardizing agencies.

Several standardizing agencies have been organized, and it is desirable for anyone studying materials testing to have some familiarity with the nature and the publications of these agencies:

1. American Society for Testing and Materials (ASTM), 1916 Race St., Philadelphia, Pa. 19103. *ASTM Standards,* developed and issued annually, consists of 32 parts containing all current formally approved ASTM standards and tentative specifications, methods of testing, recommended practices, definitions, and other related material.

2. American National Standards Institute (ANSI), 1430 Broadway, New York, N.Y. 10018, develops and issues many standards including material specifications. Many of its material specifications are taken entirely from ASTM standards, and the institute often works in conjunction with ASTM in developing new standards.

3. Society of Automotive Engineers (SAE), 2 Pennsylvania Plaza, New York, N.Y. 10001, develops and issues the *Standard Specifications for Steels* consisting of a comprehensive series of specifications for steels which has been widely used in industry.

4. Other agencies involved with standards are:
   American Railway Engineering Association
   American Petroleum Institute
   American Concrete Institute
   American Plywood Association
   U.S. Department of Agriculture, Forest Service
   U.S. Department of Commerce, National Bureau of Standards

The *ASTM Standards* are referenced in many of the testing activities in this manual. Each part of *ASTM Standards* is available from the American Society for Testing and Materials as a separate publication or bound in book form in 32 parts (books). When ordering, the ASTM standard designation, quantity desired, and shipping instructions should be sent to the above address.

Wherever feasible, dimensions and temperatures are given in both customary and metric units. A table of temperature conversions is included in the appendices. In this way, the laboratory activities can help to acquaint the student with the metric system.

The laboratory testing activities presented in this manual require that the student use costly and delicate instruments, hazardous chemicals, and power equipment. All possible precautions should be taken to protect the health and safety of the student involved in the activity.

There should be a conscious attempt on the part of the instructor and student to develop a "safety awareness." The aim of this awareness should be to condition the student to recognize an element of danger. Accidents are caused; they do not just happen. It has been established that approximately ninety percent of all accidents result from unsafe acts by the person involved. A safety awareness on the part of the student will help insure that the student realizes the human element in most accidents.

ACCURATE OBSERVATIONS AND RECORDINGS

The accuracy of observations and recordings determines the value of any laboratory test. Usable data depends on accurate observations, and the accurate observations in turn depend on the proper assembly, setup, and use of the testing apparatus.

Only after the laboratory testing activity has been read and the purpose of the test understood should the student proceed with assembling and setting up the apparatus. Care must be exercised when using the testing equipment to insure the safety of the student and to minimize measurement errors.

Being able to read the testing instruments and knowing the units of measure associated with the testing instruments are prerequisites for any laboratory activity. Testing instruments usually exhibit a dependable range, and observations near either extreme of travel should be avoided. For example, dials are likely to be less accurate as either limit of the dial hand motion is approached.

The required data should be recorded accurately and neatly in the student's report. The units of measure should be indicated, and sketches showing the arrangement of the testing apparatus should be utilized. On the data sheet provided, each student or laboratory group should record:

- The name of the student(s).
- The date of the laboratory activity.
- The data suggested in the laboratory activity.
- A description of any special equipment used.
- The range of the instruments used.
- Sketches as required.
- The types of specimens studied.

For all activities, an original data sheet initialed by the instructor at the time of the test will be a required part of the formal report. This data sheet is to contain all of the essential data taken during the experiment. The student should try to develop a scientific approach in tabulating results accurately and completely so that a reader of the report can fully understand the procedure and results or duplicate the experiment if need be.

Upon completion of the experiment, all equipment must be cleaned and returned to its storage space in good condition. Each student is responsible for the condition of returned equipment he used, and he is liable for any willful damage. Once the equipment is put into use, the current user is assumed responsible for any damage. It is important, therefore, to inspect equipment carefully before checking it out.

REPORTING THE EXPERIMENT

Reports should be typed or clearly printed on standard $8\frac{1}{2} \times 11''$ paper. Organization, completeness, accuracy, clarity, legibility, and neatness will be considered in grading the report.

To be effective, reports should be arranged in sections under logical headings. The following form is suggested for reporting an experiment. However, variations may be necessary and are to be made whenever justified.

TITLE____

____

Experiment Number________________ Individual's Name________________

Group Number________________ Date ________ Course________________

I. OBJECTIVES

A statement of the objectives to be attained through the completion of the experiment.

II. MATERIALS

A list of all materials to be tested, specifying kind, size, shape, and condition.

III. EQUIPMENT

A list of the tools and/or apparatus, each piece concisely and accurately described. (Any apparatus that is defective or accidentally damaged should be reported immediately so that necessary repairs may be made and the apparatus readied for future use.)

IV. PROCEDURE

A statement of the essential details of the testing procedure. It is not necessary to include nonessential details of manipulation and measurement.

V. DATA

The original, signed data sheet, which is included with the formal report.

Additional pages of the report should have the individual's name and the page number in the top right-hand corner as shown below:

Individual's Name______________________________

Page Number______________________________

VI. GRAPHS

The necessary curves for the results plotted on graph paper. Draw a smooth curve through the plotted points to give an average of these points. Properly identify each curve and the graph's coordinates and title each graph. Use standard graph paper whenever possible.

VII. CALCULATIONS

The computed results of the data. Make one sample calculation of each result, beginning each calculation with the proper formula.

VIII. DISCUSSION

A brief discussion of the theories involved. List and acknowledge each reference with its title, author, and page. Be consistent in reporting references.

IX. QUESTIONS AND PROBLEMS

Answer briefly all questions and solve any problems given in the laboratory manual pertinent to this particular report.

X. CONCLUSIONS

A statement of the conclusions which may be drawn from the results. Draw no conclusions not supported by the results; state the theory or law which supports your conclusions. Be brief and precise.

After the report has been completed, it is to be turned in for grading and credit. Reports are to be turned in at the regular intervals specified by the instructor, not all at once.

Laboratory Activity Number 1

TENSILE TESTING OF MATERIALS

(Data sheet is on page 91.)

I. OBJECTIVES:

The objectives of this activity are: (1) to study, observe, and experiment with tensile testing of various common materials; (2) to develop skills in performing commercially accepted tensile tests on various materials; and (3) to interpret data and prepare a technical report.

II. SPECIFIC REFERENCES:

(Specific references in these activities are listed by number. See the bibliography at the back of this manual for the complete entries.)

18: pp. 11–12, 283–292.
3: *Standards*, A370, E4, E8, E111, E132, D143, D897, D1761, D683, D757.
10: pp. 95–117.
15: pp. 22–46.
17: pp. 42–47.
21: pp. 19–33, 37–47, 51–62.
30: pp. 5–8.
31: pp. 15–33.

III. BACKGROUND INFORMATION:

The tensile test is one of the most common tests used to determine the following mechanical properties of materials:

- Proportional limit.
- Yield point.
- Yield strength.
- Ultimate tensile strength.
- Breaking (or fracture) strength.
- Ductility.
- Modulus of elasticity.

The *proportional limit* is the maximum stress a material can withstand without permanent deformation or deviation from proportionality of stress to strain. It can be determined graphically on the stress-strain curve. On the curve, the proportional limit is the point at which the curve departs from a straight line in the elastic region.

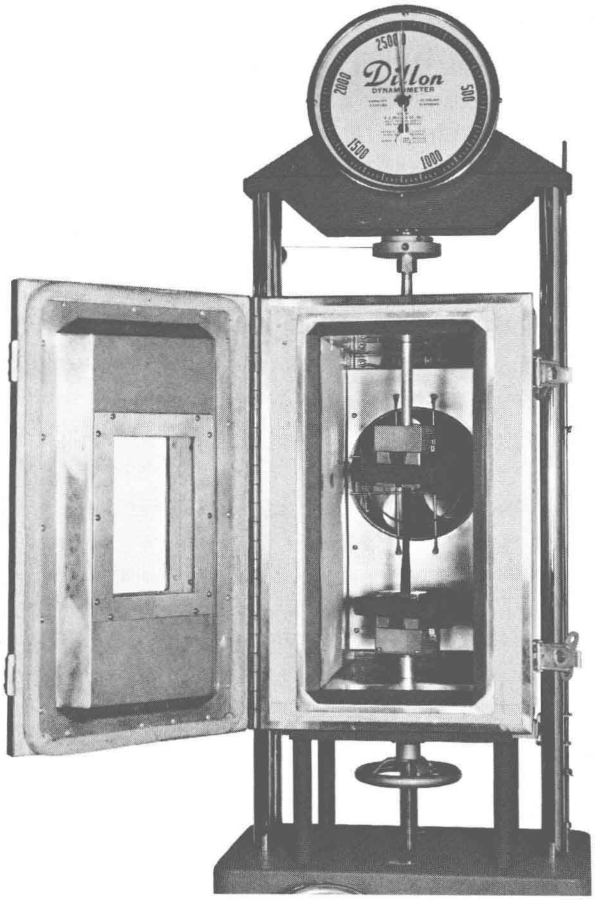
The *yield point* is the stress at which an increase in strain occurs without corresponding increase in the stress on the specimen. The yield point can be determined by the "dividers" method, "halt of the gage" method, "flaking of the scale" method, or with the use of a strain gage (extensometer). On the other hand, the *yield strength* is the load at which a specific limited permanent deformation occurs. The yield strength can be determined by the offset method. (These methods for determining yield point and yield strength are explained in Chapter 8 of the text.)

Ultimate tensile strength of a material is the maximum load it can withstand in tension divided by the original cross-sectional area of the specimen.

Breaking (*or fracture*) *strength* of a material is the load required to break that material divided by the original cross-sectional area.

Ductility refers to the ability of a material to deform plastically without fracturing. Ductility is determined in terms of the percentages of elongation and reduction of area of the specimen. The percent of elongation is estimated by subtracting the original gage length of the specimen from its final length after testing, dividing by the original length, and multiplying by one hundred. On the other hand, the percent of reduction of area is estimated by subtracting the final cross-sectional area of the specimen from its original, dividing by the original area, and multiplying by one hundred. (Selected values of reduction of area, and areas of circles, are given in Appendices A and B.)

The *modulus of elasticity* is a measure of "stiffness" and is expressed as the ratio of unit stress to unit strain of a material under load. In tensile testing, the modulus of elasticity (Young's Modulus) is estimated within the elastic region. Figs. 1-1 and 1-2 show two of the more sophisticated pieces of tensile testing equipment. The first figure shows the tensile test taking place in a control cabinet, and the second figure shows an automatic recorder.

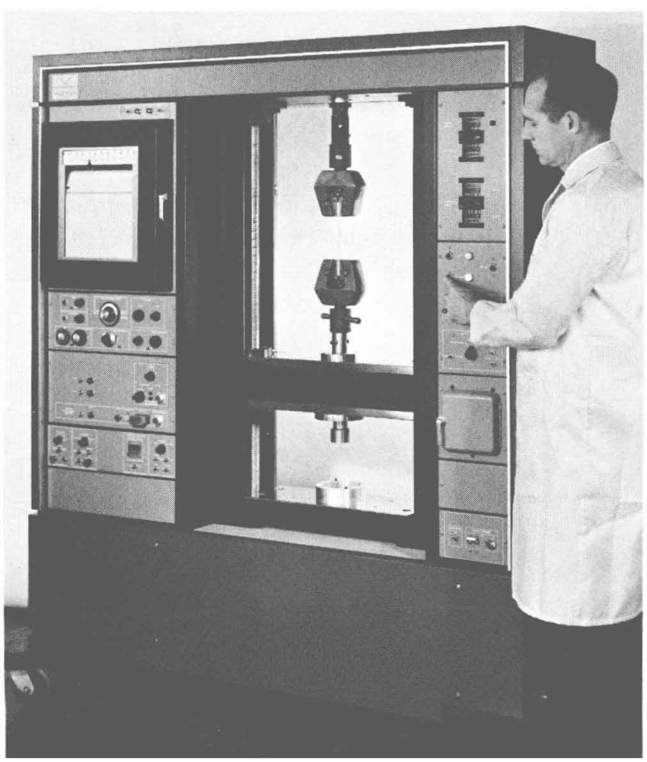


W. C. Dillon and Company

1-1. Tensile tester and control chamber.

1-2. Tensile tester with automatic recorder.

Unitron Company



IV. EQUIPMENT AND SUPPLIES:

1. Universal tensile testing machine.
2. Extensometers. (If no stress-strain recording unit is used, a dial-type extensometer is helpful.)
3. Reduction of area gage for determining the percent of reduction of area. (Reduction of area may be calculated by measuring the cross-sections of the specimen with a micrometer or vernier caliper.)
4. Percentage gage for determining the percent of elongation. (Percent of elongation may be calculated by using a pair of dividers and a scale.)
5. Specimens: appropriate cast iron, ductile metal, and/or plastic specimens of the dimensions shown in Fig. 1-3.

V. PROCEDURE:

1. Measure and record on your data sheet the original cross-sectional area and condition of the specimen.
2. Using the appropriate center punch, place the gage length marks at approximately the center of the specimen. Do not make the marks too deep because they may cause the specimen to fracture at the point. This step applies specifically to metallic materials and can be omitted if other materials are being tested.
3. Select the proper type of grips and accurately mount them on the machine. If wedge-type grips are used, make sure they fit well and are free of foreign matter.
4. Adjust the cross-heads to appropriate length for mounting the specimen. If a motorized hydraulic testing machine is used, start the machine and allow it to run for a minute before adjustments are made.
5. Set the machine within an anticipated range of load. To determine the anticipated range of load, multiply the expected tensile strength by the cross-sectional area of the specimen. Adjust the pointer to "O" load.
6. Mount the specimen in the grips. (Make sure the right type of grips are used and the specimen is gripped to full length to avoid non-axial gripping.) By means of the manual adjusting crank, adjust the head until all slack in the grips and specimen is eliminated. If an extensometer is used, attach it on the specimen.

7. Start applying the load at a rate of about 20,000 psi per minute or at the rate specified by ASTM for that particular test. After the yield load has been reached, remove the extensometer to prevent it from being damaged when the specimen breaks.

8. Observe carefully and record the yield load, maximum load, and breaking load. Continue loading the specimen until it breaks.

9. Measure and record the final gage length and cross-sectional area. Study and record the type of fracture. If no other tests are to be performed, turn off all controls on the machine and clean; then properly store the accessories used in the test.

VI. RESULTS:

1. On the basis of the data collected in this activity, use the following formulas to calculate the yield, tensile, and breaking strength, the percent of elongation, and the percent of reduction of area. These results, along with the answers provided to the questions included in this activity and other personal observations made during the test, must form the basis for your technical report.

2. Basic Formulas:

$$\text{Yield Strength} = \frac{\text{Yield Load (lbs.)}}{\text{Original Area (sq. in.)}}$$

$$\text{Tensile Strength} = \frac{\text{Maximum Load (lb.)}}{\text{Original Area (sq. in.)}}$$

$$\text{Breaking Strength} = \frac{\text{Breaking Load (lbs.)}}{\text{Original Area (sq. in.)}}$$

$$\text{Elongation (\%)} = \frac{\text{Final Length (in.)} - \text{Original Length (in.)}}{\text{Original Length (in.)}} \times 100$$

$$\text{Reduction of Area (\%)} = \frac{\text{Original Area (sq. in.)} - \text{Final Area (sq. in.)}}{\text{Original Area (sq. in.)}} \times 100$$

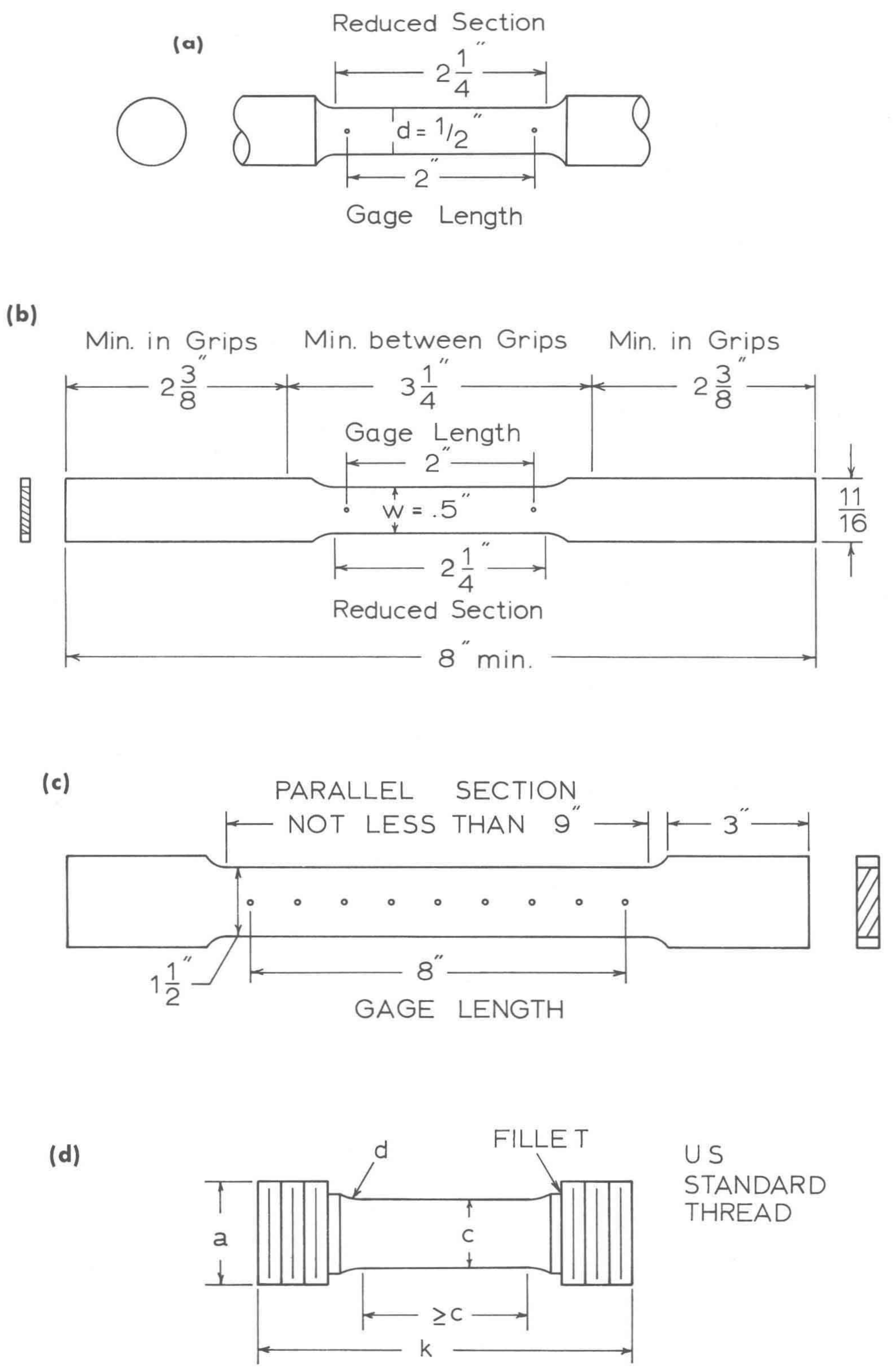
VII. APPLICATIONS:

The general procedure described in this activity can be applied to test metals, plastics, wood, cements, leathers, fibers, fabrics, and many other materials. However, before testing each type of material, the appropriate ASTM Standard may be consulted for additional specimen details and specific points of procedure.

VIII. QUESTIONS AND PROBLEMS:

(Answer any of the questions and problems below as specified by your instructor.)

1. What is the difference between load and stress?
2. What is the difference between stress and strain?
3. Why is it important that a tensile specimen be symmetrical and aligned properly for testing?
4. Define the following properties and give the unit of measurement: (a) tensile strength; (b) ductility; (c) stiffness and (d) elasticity.
5. Which of the following materials would have the most pronounced yield point? (a) low-carbon steel; (b) cast iron; (c) concrete; (d) wood.
6. What is the difference between yield strength and yield point?
7. Describe two methods used to calibrate tensile testing machines.
8. What values indicate ductility in a tensile test?
9. What is an extensometer used for in tensile testing?
10. What are the two types of deformation a material undergoes under tensile testing?
11. By what means is the applied load measured in the universal tensile testing machine?
12. In what two groups can materials be classified in terms of the amount of elongation and reduction of area present during tensile testing?
13. Can the breaking strength be higher than the tensile strength of a material?



Unitron Company

1-3. Standard tensile specimens recommended by ASTM: (a) round; (b) rectangular with 2" gage length; (c) rectangular with 8" gage length; and (d) round for cast iron.

Laboratory Activity Number 2

TENSILE TEST OF ADHESIVE BONDS

(Data sheet is on page 93.)

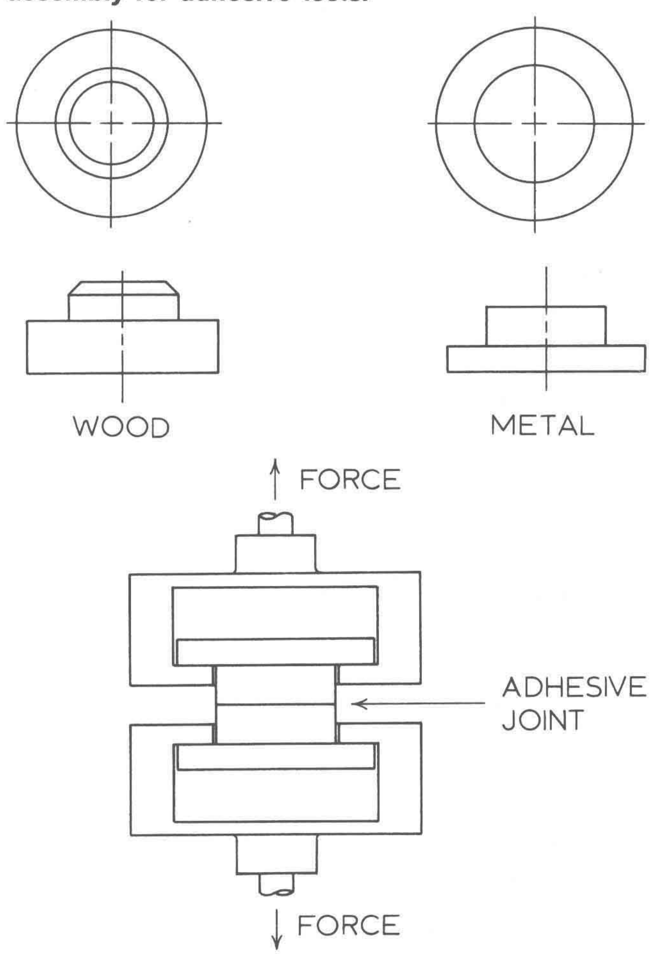
I. OBJECTIVES:

The objectives of this activity are: (1) to study, observe, and experiment with the testing of adhesive bonds; (2) to develop skill in performing commercially accepted tests; and (3) to interpret data and prepare a technical report.

II. SPECIFIC REFERENCES:

(Specific references in these activities are listed by number. See the bibliography at the back of this manual for the complete entries.)

2-1. Standard specimens and grips recommended by ASTM: wood and metal specimens; assembly for adhesive tests.



18: p. 234.
3: *Standard* D897.
14: pp. 337–351.
31: pp. 77–81.

III. BACKGROUND INFORMATION:

An adhesive is any glue or cement product that is used to bond materials together. Modern adhesives exhibit a great deal of strength and are used as a principal means of joining materials in various industries. With many adhesives for wood, if the joining has been properly made and the adhesive used as prescribed, the joint will be stronger than the wood itself.

Testing the adhesive bond may take the form of a shear test, breaking test, or a tensile test. The tensile test is important because of the type of loading to which the bonded part may be subjected. It is a relatively easy test to perform and serves as a standard means of comparing the tensile properties of adhesive bonds. The tensile strength of a bond, expressed in pounds per square inch, is the maximum tensile load per unit area of the area bonded by the adhesive.

IV. EQUIPMENT AND SUPPLIES:

1. Universal tensile testing machine.
2. Grips for holding the test specimen. Note: The grips should be of the self-aligning type. The grip shown in Fig. 2-1 has been found satisfactory and can be built in the school shop to fit the tensile machine available.
3. Specimens (at least ten of each material to be tested):
   a. Wood: Hard maple is preferred and should be free from defects as shown in Fig. 2-1.
   b. Metal: Any metal may be tested as shown in Fig. 2-1.

V. PROCEDURE:

1. Glue the specimens in accordance with the procedure outlined by the manufacturer of the adhesive. Note: For wood specimens, glue the

specimens together with the grain of the wood parallel in each piece.

2. Place the specimen in the grips of the testing machine. Note: Take care to align the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine.

3. Apply the load at a rate of 1200 to 1400 lbs. per minute.

4. Record the maximum load carried by the specimen at failure. For wood-to-wood adhesives, record the percentage of glue failures, wood failures, and contact failures as based on visual inspection. For metal-to-metal adhesives, record the percentage of cohesion, adhesion, and contact failures as based on visual inspection.

VI. RESULTS:

The report of this activity should include:

1. A description of the type of adhesive tested.
2. The data suggested in the above procedure.
3. A brief comparison of the different classifications of adhesives.
4. Answers to the questions included in this activity.

VII. APPLICATIONS:

This test covers the determination of comparative tensile properties of the adhesive bonds tested on standard specimens under specified conditions. The method compares the adhesives using the application prescribed by the manufacturer.

VIII. QUESTIONS AND PROBLEMS:

(Answer any of the questions and problems below as specified by your instructor.)

1. In reference to wood-to-wood testing, explain what is meant by:
   a. Adhesive failure.
   b. Wood failure.
   c. Contact failure.
2. In reference to metal-to-metal testing, explain what is meant by:
   a. Cohesion failure.
   b. Adhesion failure.
   c. Contact failure.
3. What considerations must be made when gluing wood on the end grain rather than gluing with the grain?
4. Sketch the following adhesive joints:
   a. Scarf.
   b. Finger.
   c. Dovetail.
   d. Mortise-and-tenon.
5. In which of the above joints would you expect the adhesive tensile properties to be most important? Explain.

Laboratory Activity Number 3

TESTING METAL FASTENERS IN WOOD

(Data sheets are on pages 95 and 97.)

I. OBJECTIVES:

The objectives of this activity are: (1) to study, observe, and experiment with the testing of metal fasteners in wood; (2) to develop skill in performing commercially accepted tests; and (3) to interpret data and prepare a technical report.

II. SPECIFIC REFERENCES:

(Specific references in these activities are listed by number. See the bibliography at the back of this manual for the complete entries.)

3: *Standard* D1761.
14: pp. 635–639.

III. BACKGROUND INFORMATION:

The use of wood and wood-base materials in many applications often involves the use of metal fasteners, such as nails, screws, bolts, and various other metal connectors. Data on the strength and performance of such fasteners are frequently needed for design and for comparative purposes.

The use of standard methods for tests involving metal fasteners is recommended as a means of obtaining comparable data. This activity covers four standard tests for evaluation of metal fasteners: a nail and screw withdrawal test, a lateral nail or screw resistance test, a bolted joint test, and a tensile test of plate-type connector joints.

The nail or screw withdrawal test provides a basic procedure for evaluating the resistance of wood and wood-base materials to the direct withdrawal of nails and screws. The test also provides a basis for determining comparable performance of different types and sizes of nails and screws.

The lateral nail or screw resistance test is used to determine the resistance to lateral movement offered by a single nail or screw. The general method can also be used for evaluating two or more nails or screws and other types and sizes of fastenings either in wood or wood-base materials.

The bolted joint test provides a suitable procedure for evaluating the strength and rigidity of timber joints fastened with bolts. The test serves as a basis for developing design criteria for the strength and efficiency of the joint.

The tensile test of plate-type connector joints is used to determine the tensile strength and stiffness characteristics of fasteners known as "truss plates." The test has been designed to test joints that connect lumber such as that used in the construction of a house roof truss.

IV. EQUIPMENT AND SUPPLIES:

1. Universal tensile testing machine.
2. Grips:
   a. A gripping device shaped to fit the base of the nail or screw head such as shown in Fig. 3-1a.
   b. A gripping device such as shown in Fig. 3-1b for the lateral resistance test.
3. Dial indicator.
4. Specimens:
   a. 2″ by a depth greater than the length of the fastener by 6″ wood specimens for withdrawal tests.
   b. 2″ × 2″ × 12″ wood specimen for receiving the nail or screw in the lateral resistance test; ¾″ × 2″ × 12″ wood specimen through which the nail or screw is driven for the lateral resistance test.
   c. Wood specimens assembled as shown in Fig. 3-1b, c, and d.
   d. Wood joint composed of 2″ lumber as shown in Fig. 3-1e.

V. PROCEDURES:

Nail or Screw Withdrawal Test

1. Attach the specimen to one platen of the testing machine.
2. Attach the fastener head to a suitably designed grip.

Note: The grip should be fastened to the other platen through a universal joint.

3. Apply the load by separation of the platens at a uniform rate of approximately 1″ per ten minutes.
4. Record the maximum load required to withdraw the fastener from the wood.

Lateral Nail or Screw Resistance Test

1. Mount the assembled specimen in the tensile machine as shown in Fig. 3-1b.
2. Apply the load at a uniform rate resulting in movement of approximately 1″ per ten minutes.
3. Record the movement in inches and corresponding loads in pounds.
4. Record the first drop in load.

Testing Bolted and Timber Connector Joints

1. Mount the specimen assembly as shown in Fig. 3-1c and d.
2. Apply the load uniformly, reaching the maximum load in approximately ten minutes.
3. Record the deformations in inches and corresponding loads in pounds.

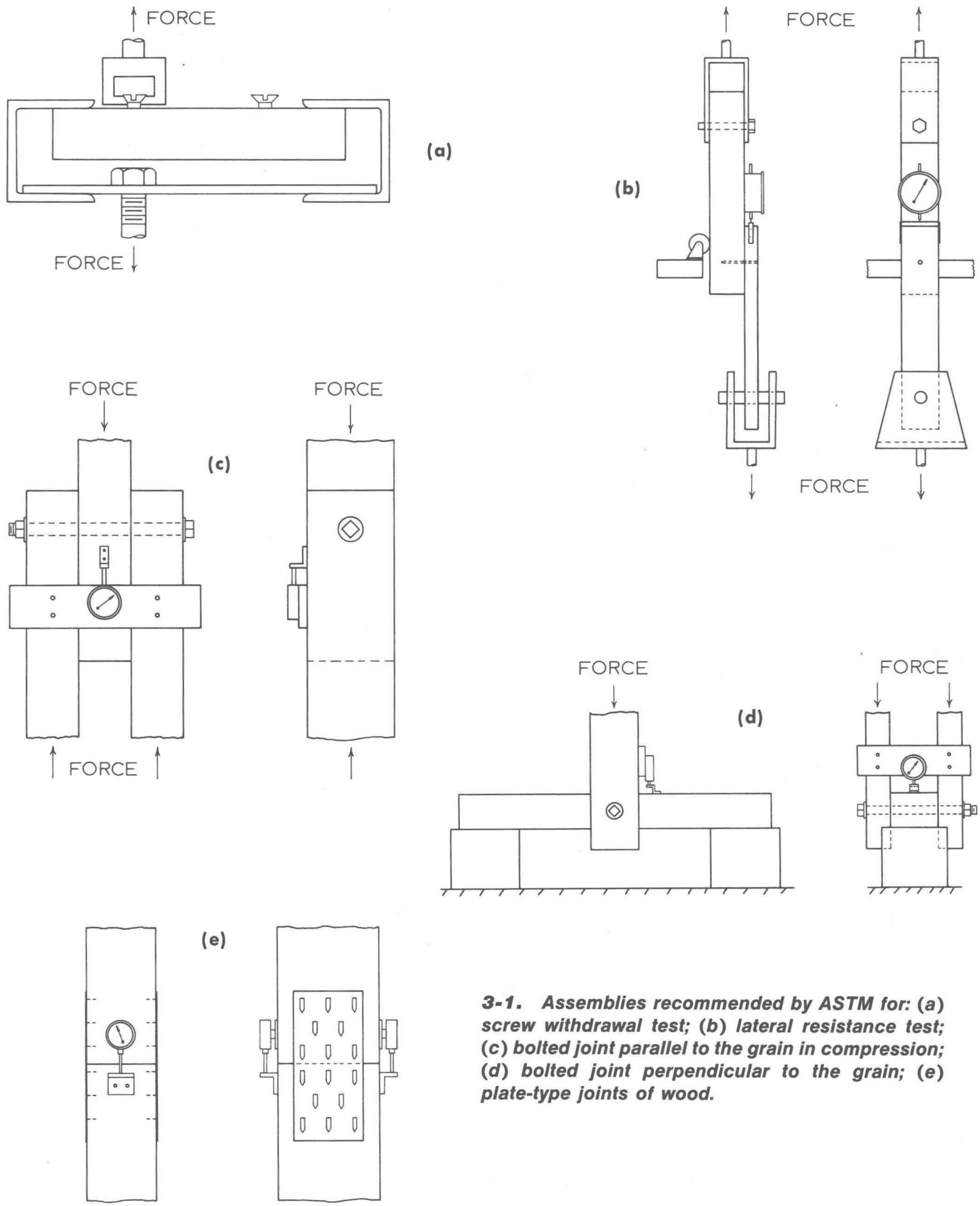
Tension Tests of Plate-Type Connector Joints

1. Mount the assembled specimen as shown in Fig. 3-1e.
2. Apply the load uniformly, reaching the maximum load in approximately ten minutes.
3. Record the deformations in inches and corresponding loads in pounds.

VI. RESULTS:

The report of this activity should include:

1. The data suggested under the procedures above.



***3-1.* Assemblies recommended by ASTM for: (a) screw withdrawal test; (b) lateral resistance test; (c) bolted joint parallel to the grain in compression; (d) bolted joint perpendicular to the grain; (e) plate-type joints of wood.**

2. A description of the general behavior of the joints under loading.
3. Member dimensions, including bolt-holes.
4. Details of loading procedure.
5. Plots of load versus deformation for each test except the direct withdrawal test.
6. Answers to the questions included in this activity.

VII. APPLICATIONS:

The methods covered by this activity apply to the metal connectors used for joining wood and wood-base materials. The general procedures can be modified to test joints with more than one fastener or with different combinations of fasteners.

VIII. QUESTIONS AND PROBLEMS:

(Answer any of the questions and problems below as specified by your instructor.)

1. What does the moisture content of wood have to do with the holding power of a nail?
2. List and explain the uses of various types of nails.
3. Make a sketch indicating what is meant by toenailing.
4. For a number 10 screw determine the proper size pilot hole for both soft and hardwood.
5. Sketch three types of roof truss designs.
6. Based on the results of this activity, explain which truss design you would expect to exhibit the greatest strength.
7. Explain how the lightness of the bolted joint affects the strength of the joint.

Laboratory Activity Number 4

COMPRESSION TESTING OF MATERIALS

(Data sheets are on pages 99, 101, 103, and 105.)

I. OBJECTIVES:

The objectives of this activity are: (1) to study, observe, and experiment with compression testing of various common materials; (2) to develop skills in performing commercially accepted compression tests on various materials; and (3) to interpret data and prepare a technical report.

II. SPECIFIC REFERENCES:

(Specific references in these activities are listed by number. See the bibliography at the back of this manual for the complete entries.)

18: pp. 12, 283–284, 293–294.
3: *Standards:* C4, C13, C14, C112, C133, C170, D48, D395, D575, D695, E9.
10: pp. 117–127.
17: pp. 48–53.
15: pp. 47–63.
31: pp. 43–51.

III. BACKGROUND INFORMATION:

Some materials are tested mainly in compression. Among these are brick, concrete, wood, cast iron, and tile.

Compression testing is the same in many ways as tension testing. The specimen shortens, however, instead of lengthening. Some physical properties that may be found from compression tests are: proportional limit, yield point, yield strength, and modulus of elasticity in compression. The ultimate compressive stress can be found for brittle materials tested in this way, but ductile materials often compress indefinitely without fracture. Up to and through the yield point, the compression stress-strain curve is similar to that for tension; beyond this point, however, the compression curve becomes steeper because of the increased cross-sectional area in compression.

Compression strength is the ability of a material to resist opposing forces tending to crush it. Ductile materials do not fail suddenly under compression load, but they gradually bulge and increase in area. The increased area is then able to support an increased load. Brittle materials do