Standard Specification for Tensile Testing Machines for Textiles[1]

This standard is issued under the fixed designation D 76; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the operating characteristics of three types of tensile testing machines used for the determination of the force-elongation properties of textile materials. These types of tensile testing machines are:

1.1.1 Constant-rate-of-extension, CRE.

1.1.2 Constant-rate-of-traverse, CRT.

1.1.3 Constant-rate-of-loading (force), CRL.

1.2 Specifications for tensile testing machines to measure other tensile-related properties of textile materials not covered by this standard are given in the ASTM standards using those machines.

1.3 The values stated in SI units are to be regarded as standard; the values in inch-pound units are provided as information only and are not exact equivalents.

1.4 The following safety hazards caveat pertains only to the test methods described in this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 123 Terminology Relating to Textiles[2]

D 580 Specification for Greige Woven Glass Tapes and Webbings[2]

D 885 Methods of Testing Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Man-Made Organic-Base Fibers [Metric][2]

D 1578 Test Method for Breaking Strength of Skeins[2]

D 2256 Test Method for Tensile Properties of Yarns by the Single-Strand Method[2]

D 3822 Test Method for Tensile Properties of Single Textile Fibers[3]

D 5034 Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)[3]

D 5035 Test Method for Breaking Strength and Elongation of Textile Fabrics (Strip Method)[3]

E 4 Practices for Force Verification of Testing Machines[4]

E 74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *bench marks, n*—marks placed on a specimen to define gage length, that is, the portion of the specimen that will be evaluated in a specific test.

3.1.2 *calibrate, v*—to determine and record the relationship between a set of standard units of measure and the output of an instrument or test procedure.

3.1.2.1 *Discussion*—This term is also commonly used to describe the checking of previously marked instruments, an operation more properly described as a description of verification.

3.1.3 *capacity, n—for tensile testing machines*, the maximum force for which the machine is designed.

3.1.3.1 *Discussion*—Capacity is the maximum force the tester-frame and the drive system can exercise on the specimen without inadmissible deformations of the tester-frame, etc. Within its capacity, there are available load-cells with different full-scale-ranges which may be chosen to select an appropriate full-scale-range for a special test.

3.1.4 *clamp, n*—that part of a testing machine used to grip the specimen by means of suitable jaws.

3.1.5 *constant-rate-of-extension (CRE) type tensile testing machine (CRE), n—in tensile testing*, an apparatus in which the pulling clamp moves at a uniform rate, and the force-measuring mechanism moves a negligible distance with increasing force, less than 0.13 mm (0.005 in.).

3.1.6 *constant-rate-of-load tensile testing machine (CRL), n—in tensile testing*, an apparatus in which the rate of increase of the force is uniform with time after the first 3 s and the specimen is free to elongate, this elongation being dependent on the extension characteristics of the specimen at any applied force.

3.1.7 *constant-rate-of-traverse tensile testing machine (CRT), n—in tensile testing*, an apparatus in which the pulling clamp moves at a uniform rate and the force is applied through

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[2] *Annual Book of ASTM Standards*, Vol 07.01.

[3] *Annual Book of ASTM Standards*, Vol 07.02.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

the other clamp, which moves appreciably to actuate a force-measuring mechanism, producing a rate of increase of force or extension that is usually not constant and is dependent on the extension characteristics of the specimen.

3.1.8 *effective carriage mass, n— in CRL-type tensile testing machine*, the force actually applied to a specimen by the mass of the carriage, plus any added weight.

3.1.9 *effective gage length*, *n— in tensile testing*, the estimated length of the specimen subjected to a strain equal to that observed for the true gage length.

3.1.9.1 *Discussion*—The effective gage length can be calculated using the following equation:

$$G_E = G_N \times \frac{E_N}{E_T} \tag{1}$$

where:

G_E = effective gage length,
G_N = nominal gage length,
E_N = percent elongation based on nominal gage length, and
E_T = percent elongation based on true gage length.

3.1.10 *grip*, *v—in tensile testing*, to hold, grasp, or secure, for example, to grip the specimen by the jaws of the clamps.

3.1.11 *jaw face*, *n—in tensile testing machines*, the surface of a jaw which in the absence of a liner contacts the specimen.

3.1.12 *jaw liner*, *n—in tensile testing machines*, any material placed between the jaw face and the specimen to improve the holding power of the jaws.

3.1.13 *jaws*, *n—in tensile testing machines*, the elements of a clamp which grip the specimen.

3.1.14 *least count*, *n—in tensile testing machines*, the smallest change in the indicated property that can customarily be determined (*see also sensitivity*).

3.1.14.1 *Discussion*—In tensile testing machines with close graduations for force or elongation indications, the least count may be the value of a graduation interval; with open graduations, or with magnifiers for reading, the least count may be an estimated fraction (rarely as fine as 0.1) of a graduation interval; and with verniers, the least count is ordinarily the difference between the scale and vernier graduations measured in terms of scale units. If the indicating mechanism includes a stepped detent, the detent action may determine the least count. (See also *sensitivity, in mechanical systems.*)

3.1.15 *nominal gage length*, *n— in tensile testing*, (*1*) the length of a specimen under specified pretension measured from nip-to-nip of the jaws of the holding clamps in their starting position at the beginning of the test, and including any portion of the specimen in contact with bollard or snubbing surfaces.

(*2*) the length of a specimen under specific pretension between frets, in instruments where the specimen is not held by clamps, for example, in a vibroscope.

(*3*) the length of a specimen measured between the points of attachment to the tabs while under specified pretension.

3.1.15.1 *Discussion*—The calculated percentage of elongation based on the nominal gage length may be in error due to extension of that part of the specimen which lies between the jaws of the clamps.

3.1.16 *response time*, *n— in tensile testing machines*, the time required by the indicating or recording device to reflect an instantaneous change in force, usually 0 to 90% of full scale.

3.1.17 *sensitivity*, *n— in electronic systems*, the minimum change in the input signal that produces a change in the output signal that can be reliably measured.

3.1.17.1 *Discussion*—Sometimes the term sensitivity is used for the ratio of the response or change induced in the output to a stimulus or change in the input. For this ratio "amplification" is a better term.

3.1.18 *sensitivity*, *n— in mechanical systems*, the smallest change that can be induced on a material by the system and be reliably measured. (See also least count.)

3.1.19 *stress*, *n*—the resistance to deformation developed within a material subjected to an external force.

3.1.20 *tensile testing machine*, *n*—an apparatus designed to impart, or transmit, force/extension, or stress/strain, to a material and to measure the effect of the action. (See also constant-rate-of-extension tensile testing machine, constant-rate-of-load type tensile testing machine, constant-rate-of-traverse tensile testing machine.)

3.1.21 *test skein*, *n*—a small skein which has a prescribed length of yarn and is used for the determination of linear density or breaking, or both.

3.1.22 *time-to-break*, *n*—the time interval during which a specimen is under prescribed conditions of tension and is absorbing the energy required to reach maximum load.

3.1.22.1 *Discussion*—Time-to-break does not include the time required to remove slack from the specimen.

3.1.23 *true gage length*, *n—in tensile testing*, a precise length between welldefined bench marks located on the specimen while under known tension in the unsupported portion between the holding clamps and free from contact with any snubbing surfaces or other sources which could result in nonuniform strain.

3.1.24 *verify*, *v*—(*1*) to determine whether a previously calibrated instrument, standard solution, or other standard is still properly calibrated, (*2*) to establish that an operation has been completed correctly.

3.1.25 For definitions of other textile terms used in this specification, refer to Terminology D 123.

3.2 *Abbreviations:*

3.2.1 CRE—constant-rate-of-extension.

3.2.2 CRL—constant-rate-of-load.

3.2.3 CRT—constant-rate-of-traverse.

4. Performance Requirements

4.1 Individual ASTM methods for tensile testing of textile materials that prescribe apparatus which conforms to this specification shall also include such other detailed specifications as may be necessary to describe the testing machine and its operation completely.

4.1.1 This specification shall not be construed as being intended to preclude the evolution of improved methods of testing or testing apparatus, which is recognized as being vital in an advancing technology.

4.2 Comparison of results from tensile testing machines operating on different principles is not recommended. When these machines are used for comparison testing however, constant time-to-break at 20 ± 3 s is the established way of producing data, but even then the data may differ significantly.

4.2.1 Comparison of test data from machines of the same type, especially two or more CRT-type or two or more CRL-type machines, requires consideration of the effect of individual machine characteristics; for example, inertia effects, capacity, sensitivity, type of loadcell, etc., which may cause significant differences in results even though uniform procedures are employed. Data from different CRE-type testing machines, however, should not be significantly different.

4.2.2 In any case, all types of tensile testing machines must satisfy the accuracy requirements as given in Section 7.

4.3 While changes in humidity affect the tensile properties of many textile materials, changes in humidity normally do not affect the testing machines themselves.

4.4 When machines are moved to different locations, their calibration shall be verified to make sure that they still meet the specified tolerances.

4.5 When each of the sub-systems (force, extension, clamping) has been individually calibrated, verified, or checked, it is recommended that the total system be verified using a standard material appropriate for the type testing to be carried out.[5] This testing of the total system is the established way of ensuring that the clamping system is operating properly.

5. Apparatus

5.1 *Tensile Testing Machines*—Tensile testing machines for textile materials are classified according to their operating principle as follows:

Type	Principle of Operation
CRE	Constant rate-of-extension
CRT	Constant rate-of-traverse (pendulum type)
CRL	Constant rate-of-load (inclined plane type)

5.1.1 *CRE-Type*—A testing machine in which the pulling clamp moves at a uniform rate, and the force-measuring mechanism (load cell) moves a negligible distance with increasing force less than 0.13 mm (0.005 in.).

5.1.2 *CRT-Type*—A testing machine in which the pulling clamp moves at a uniform rate and the force is applied through the other clamp, which moves appreciably to actuate a force-measuring mechanism, producing a rate of increase of force or extension which is usually not constant and is dependent on the extension characteristics of the specimen.

5.1.3 *CRL-Type*—A testing machine in which the rate of increase of the force is uniform with time after the first 3 s and the specimen is free to elongate, this elongation being dependent upon the extension characteristics of the specimen at any applied force.

5.1.4 *Multiple-Purpose Type*—Machines capable of being operated as both a CRE-type and a CRL-type may be used.

5.2 *Measuring Devices*—Machines shall be equipped with a suitable device for measuring the force and, when needed, a device to measure elongation. Preferably a force-elongation curve shall be recorded graphically, or the force and elongation data may be indicated on appropriate scales or displays.

5.2.1 Most testing machines record only force-elongation data. When the capacity of a testing machine is adjusted to fit the predetermined linear density or cross-sectional area of the specimen, the force recorded will be stress. When the machine is adjusted to record extension in terms of unit specimen length, the chart can be read directly in percent elongation or strain. When these conditions do not exist, the force-elongation curve must be converted to obtain stress-strain characteristics.

5.2.2 The force-indicating and force-recording devices shall be in conformance with the requirements of this specification as to accuracy, sensitivity, and response time, and shall permit calibration or verification by appropriate methods described or referenced herein.

5.3 *Clamping or Holding Devices*—Specimen clamping or holding devices shall be prescribed in the individual test methods in sufficient detail for all users to employ the same or comparable devices.

5.3.1 The prescribed specimen clamping or holding devices shall be designed to ensure that the pulling axis of the testing machine and the central axis of a properly mounted specimen coincide.

5.3.2 The clamping or holding device may be designed for manual or automatic mounting of specimens.

5.3.3 The required clamping force can be obtained with the clamping or holding devices by any suitable mechanism; for example, screw, cam action, pneumatic, or toggle.

5.3.4 Clamping surfaces in contact with a test specimen shall be of any suitable material and configuration which provides the required restraint, preclude slippage, and minimize specimen failure in the clamped areas. Clamp liners may be used, provided the above conditions are met.

5.3.5 When the flat-faced type clamp proves unsatisfactory because of slippage or excessive breakage in the clamp, snubbing type devices (capstan, drum, split-drum, etc.) may be used.

5.4 *Calibrating Devices*—Calibrating weights or other calibrating devices conforming to Practice E 74 are required for verification of calibration. Calipers, a steel rule that can be read to 0.25 mm (0.01 in.), or a suitable cathetometer, and a stop watch are required for verification of recorded elongation, and crosshead and chart speed.

6. Machine Operational Design

6.1 The use of motor-driven machines is preferred over manually driven machines because of improved control of testing.

6.2 Testing machines of the CRT-type shall not be used for measuring forces below fifty times their resolution. For example, if the minimum force that can be read is 0.5 cN (0.5 gf), the testing machine may not be used for materials which test at 25.0 cN (25 gf) or less.

6.2.1 Choose the full scale force such that the expected maximum force falls within:

6.2.1.1 10 to 90% full scale for the CRE-type testing machines,

6.2.1.2 15 to 85% full scale for the CRT-type testing machines,

6.2.1.3 15 to 85% full scale for the CRL-type testing machines,

6.3 Machines shall operate at a uniform rate of pulling

[5] Two styles of standard break fabrics obtained from Testfabrics, Inc., P.O. Drawer O, Middlesex, NJ 08846 have been found satisfactory for this purpose. See also A1.3 of this specification.

clamp (CRE), and (CRT), or loading (CRL) as specified in 6.4, 6.5, and 6.6.

6.3.1 Machines may be built for operating at various rates of operation or at a single constant rate.

6.3.2 When machines are intended for operation at a specified or required average time to break as specified in individual standards (for example, 20 s to break as in Test Method D 2256 and Test Methods D 1682) then their rate of operation must be adjustable. The adjustment may be continuous or in steps not exceeding 125:100. Machines with a continuously adjustable rate of operation shall be equipped with a device indicating the rate of operation.

6.3.3 The machine rate of operation shall be within the tolerances prescribed in the individual standards.

6.4 *CRE-Type*:

6.4.1 Machines shall be designed for operation at such uniform rates of pulling clamp as are specified in individual standards.

6.4.2 The force-measuring system, including the recording mechanism, shall have a full-scale pen response time less than 2 s in either direction. In addition, the response time for pen deflections of less than full scale shall be proportional to the fraction of full-scale time represented by those deflections within a tolerance of ±10% of the nominal full-scale response time.

NOTE 1—The response time of the recording mechanism is the limiting factor affecting the choice of a rate for testing. The rate chosen shall give the maximum slope of the recorded curve which does not exceed one half of the slope of the maximum pen speed. See Fig. 1.

6.5 *CRT-Type*—Machines shall be designed for operation of the pulling clamp at a uniform rate as specified in individual standards.

6.6 *CRL-Type*—Machines shall be designed to apply forces at a uniform rate, or at a uniform rate of loading per unit of specimen linear density, as specified in individual standards.

6.7 Machines may be built for either manual or automatic mounting of the specimen into the clamp or holding devices.

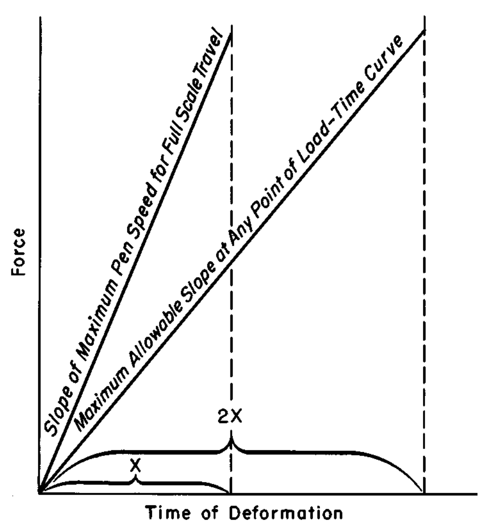


FIG. 1 Limitations on Response Speed of Recorder Pen

7. Tolerance on Indicated Force, Recorded Elongation, Nominal Gage Length, and Speed of Moving Clamp

7.1 On instruments where the capacity of the force measuring mechanism (load cell) is used for digital analysis without regard to the full scale force displayed on the recorder, the maximum allowable error in force indication shall be ±0.5 % of the reading for CRE-type machines and ±1.0 % for CRT- and CRL-type machines (see Section 8).

7.2 The maximum allowable error in recorded grip displacement shall be ±1% of the recorded values for CRE-type machines and± 2.5 mm (0.5 in.) for CRT- and CRL-type machines (see Section 9 for CRE-type machines and Section 10 for CRT- and CRL-type machines).

7.3 The maximum allowable variation in nominal gage length on repeated return of the clamps to their starting position shall be less than 0.25 mm (0.01 in.).

7.4 The maximum allowable variation of crosshead speed of the CRE-type tester or moving clamp of the CRT-type tester from the required testing speed shall be less than 4%.

7.5 The maximum allowable variation of the loading rate for the CRL-type of tester from the required rate shall be less than 5%.

8. Verification of Indicated Force

8.1 This section provides a general procedure for the verification of the force calibration of tensile testing machines for textiles. No attempt is made to give detailed instructions applicable to any particular case. The verification should be performed or supervised by a qualified person competent to exercise scientific judgment in matters not covered herein. Detailed instructions are given in Annex A1 covering verification of one variety of testing machine of the CRL-type.

8.2 Verify tensile testing machines as directed in the applicable procedure and at the suggested time intervals listed in Practices E 4, except as otherwise provided in the following paragraphs.

8.3 Verify the machine in the condition under which it is used, with all attachments and recording mechanisms in operation if they are to be used in actual testing; but with any pawls or other detent device in the force-measuring mechanism rendered inoperative. Following the application of each test force, eliminate the effect of friction by gently oscillating the force-measuring mechanism or by tapping the machine to ensure that the applied force is in equilibrium with the force registered by the measuring mechanism.

8.4 Examine the measuring, indicating, and recording mechanisms for friction or slack. Estimate, in terms of the units in which the machine is calibrated, the magnitude of such factors and, if excessive, reduce the error at the source to conform to the tolerance as stated in 7.1.

8.5 If other than vertical test forces must be applied, suitable apparatus must be devised subject to the general requirements for accuracy of calibration devices prescribed in Practice E 74. If cords and pulleys are used, any errors due to axle friction, pulley eccentricities, cord friction, and uncertainty of cord center line shall be within the required limits of Practice E 74. If an elastic calibration device is used, take due account of possible variations in its readings resulting from its inclined or horizontal position.

9. Verification of Recorded Clamp Displacement of CRE-Type Machines

9.1 This procedure is applicable to machines with synchronous drives between the crosshead and the chart, and to machines with independent crosshead and independent chart drives.

9.2 Bring the clamps to their normal position for the start of the test. Measure the distance between the clamps from nip to nip to the nearest 0.25 mm (0.01 in.). Designate this distance as the nominal gage length.

9.3 Set the speed of the crosshead and the speed of the chart drive (when the chart is equipped with an independent drive) at the actual speeds to be used in testing.

9.4 Adjust the chart with the pen resting exactly on a division line. Mark this line as zero. Without a specimen in the machine, start the crosshead and the chart simultaneously and permit them to run until the clamp separation has increased some convenient amount, such as nominal gage length plus 200 or 500 mm (8 or 20 in.). Stop the machine and the recorder simultaneously.

9.5 Measure the distance between the clamps as directed in 9.2 and designate this distance as "total clamp separation." Count the chart divisions traversed by the recorder pen. The percent elongation per chart division may then be calculated using Eq 2:

$$E = 100 \times ((T - G)/(C \times G)) \tag{2}$$

where:

E = percent elongation per chart division,
T = total clamp separation,
G = nominal gage length,
C = chart divisions traversed, and
100 = ratio to percent conversion constant.

NOTE 2—The speeds of both the crosshead and the chart drive of most CRE-type machines are easily altered either by changing gear ratios or by continuous speed change devices. It is of particular importance, therefore, that careful attention be given to the exact ratio of chart divisions traversed by the pen in the elongation direction to unit distance traveled by the crosshead.

NOTE 3—The deflection of the weighing clamp with respect to the weighing head in CRE-type testing machines shall not exceed 0.13 mm (0.005 in.) for forces within the rated capacity of the machine. The deflection may be measured with a cathetometer or other similar equipment having a precision of 0.03 mm (0.001 in.). Testing at short gage lengths of high modulus materials may require corrections or stiffer measuring systems.

10. Verification of Recorded Elongation for CRT- and CRL-Type Machines

10.1 Bring the clamps of the testing machine to their normal positions for the start of a test. Place a chart in the holder and adjust its position with the pen at the zero force and zero elongation points. (On machines having a specific location for the chart as determined by supports, adjust the pen to record zero force and zero elongation.) Measure the distance between the inner edges of the clamping surfaces of the clamps to the nearest 0.25 mm (0.01 in.). Designate this distance as the nominal gage length. The distance can be measured conveniently by means of a pair of calipers and a steel rule graduated to 0.25 mm (0.01 in.). A cathetometer of equal precision may be used.

10.2 Operate the machine without a specimen to register increasing clamp separation at zero force. If the chart is properly positioned in the holder, the pen line drawn will be superimposed on the axis of the chart showing zero force and variable elongation. Adjust the chart to obtain this condition, if necessary.

10.2.1 If the pen is set slightly to one side of the zero force axis, any deviation of the pen line from parallelism with the ruled line can be detected more readily.

10.2.2 For inclined plane testing machines, set the plane in the starting position and traverse the carriage by hand to ascertain parallelism of pen line and zero force axis on the chart.

10.3 Operate the machine as directed in 10.2 until the pen indicates a known separation; for example, 25 mm (1.0 in.). Measure the distance between the clamps to the nearest 0.25 mm (0.01 in.) as directed in 10.1. This distance should equal the nominal gage length, plus the separation recorded on the chart.

10.3.1 For inclined plane testing machines, with the plane in the starting position, traverse the carriage by hand until the pen indicates a known or specified separation; for example, 25 mm (1.0 in.). Block the carriage to prevent any movement of the pen, and measure the actual distance between clamps.

10.4 Repeat this operation as directed in 10.3 with greater separations; for example, 50 and 75 mm (2.0 and 3.0 in.).

10.5 Any discrepancy between the recorded separation and the actual increase in distance between the clamps is an error in the recorded elongation and may be caused by one or more factors, such as faulty spacing of chart elongation graduations, faulty pen mechanism, or error in the multiplying lever train. Other causes of error in indicated elongation are discussed in Annex A2.

10.6 To establish the presence of other errors in the recorded elongation, place a chart in the testing machine and adjust it as directed in 10.1. Clamp a suitable specimen, such as a steel strip having negligible elongation under the forces used, in both clamps. Operate the machine to draw a line on the chart. This line should be superimposed on the chart axis indicating variable force and zero elongation. Deviation of the pen line from the printed axis on the chart indicates an error in recorded elongation due to the geometry of the testing machine, to the use of an incorrect chart, or to slippage in the clamps.

10.6.1 The base line indicating zero elongation and increasing force is not necessarily a straight line. On pendulum type testing machines, it is frequently somewhat curved at higher forces. On many testing machines, it forms an angle other than 90° with the base line indicating zero force and increasing elongation. The angle depends upon the design of the machine.

11. Verification of Nominal Gage Length

11.1 Determine the accuracy of the pulling clamp return by first establishing the nominal gage length as directed in 10.1. With no specimen in place, operate the machine (at actual testing rates) through start-and-return cycles, measuring the distance between clamps as directed in 10.1 after each return.

Variations in the gage length shall not exceed ±0.25 mm (0.01 in.) at any testing rate.

12. Keywords

12.1 elongation; tension (tensile) properties/tests; testing machines

ANNEXES

(Mandatory Information)

A1. FORCE CALIBRATION OF CRL-TYPE MACHINES, INCLINED PLANE TYPE

A1.1 Calibrate the force of CRL-type machines which employ or use the inclined plane principle as follows:

A1.1.1 The apparatus required includes: (*1*) a balance or scale, (*2*) calibration weights which cover twice the normal capacity range of the tester and are accurate to 0.1%, and (*3*) a steel measuring tape.

A1.1.2 Weigh the carriage plus accessory weights, jaws, pen holder, pen, and any other item which travels with the carriage. When different capacities are secured by the use of supplementary weights, weigh these separately.

A1.1.3 Determine the maximum angle of inclination from the dimensions of the plane and the vertical displacement during operation as directed below.

A1.1.3.1 Insert a chart in its holder. Move the carriage and draw a penline. If the penline does not coincide with the base line of the chart when the plane is in the horizontal position, make appropriate adjustments.

A1.1.3.2 With the carriage in its normal starting position (horizontal), measure to the nearest 1.0 mm (0.03 in.) the distance, *A*, from the center of the fulcrum to some point, *X*, at the right end of the track or plane. Measure the vertical distance, *B*, of point *X* from some reference line such as the base or floor.

A1.1.3.3 Start the machine and lower the plane, allowing the pen to come to rest on the uppermost horizontal chart line. Measure the vertical distance, *C*, of the selected point from the reference. Then $B - C$ equals the vertical distance traveled by the plane. Calculate the sine of the angle of inclination using Eq A1.1:

$$\text{Sine of angle of inclination} = (B - C)/A \tag{A1.1}$$

A1.1.4 The effective force (disregarding friction) applied by the carriage (plus supplementary weights) is the total weight multiplied by the sine of the angle of inclination.

A1.2 Determine the friction of the carriage as follows:

A1.2.1 The apparatus required includes: (*1*) a pulley, 20 mm (0.78 in.) in width, 76 mm (3.0 in.) in diameter, of flat periphery with fine groove in center, and mounted with ball bearings on a shaft designed to fit the tester in place of the left-hand fixed clamp support (Note A1.1), (*2*) metric or pound calibration weights covering the capacity of the tester, accurate to 0.1% (Note A1.2), (*3*) a small bucket with handle having a mass of approximately 20 g and a capacity of approximately 200 mL, (*4*) quantity of lead shot, and (*5*) line to attach calibration weights to the carriage for which the linkage must be flexible and substantially nonextensible (Note A1.3).

NOTE A1.1—The friction of the pulley over which the weights are suspended must be determined and a suitable correction made. This can be done conveniently by plotting pulley friction against bearing force at three points in the loading force of the machine. To determine pulley friction, attach weights of equal mass to both ends of a linkage suspended over the pulley. To one side, add lead shot until the added mass moves the weight slowly downward. Weigh the amount of shot required. This is the pulley friction corresponding to the bearing force on the pulley. The bearing force is equal to the sum of the mass of the suspended weight (including the load shot) plus the mass of the pulley and linkage. In a similar manner, determine the pulley friction at bearing forces covering the range used in the calibration of the inclined plane tester. Plot the friction against the bearing force.

NOTE A1.2—The calibration forces should cover the capacity of the tester; thus, if the capacity is 250 N, forces giving a force of 50, 100, 150, 200, and 250 N are required for chart settings of 20, 40, 60, 80, and 100 % of full-scale width, respectively; or if the capacity is 50 lbf, weights of 10, 20, 30, 40, and 50 lbf are required for chart settings of 20, 40, 60, 80, and 100 % of the full-scale width.

NOTE A1.3—The cord should be low in mass and the mass/mm (mass/in.) known. A stretched or low elongation cord is suggested as a suitable material.

A1.2.2 Place a chart in its holder and roll the carriage along in a horizontal position at zero force. The base line drawn by the pen should correspond exactly with the base line on the chart. Adjust the chart, if necessary, to obtain this condition.

A1.2.3 Remove the left-hand clamp and mount the pulley. Fasten the linkage to the carriage clamp and pass the linkage over the pulley. Load the carriage to cover the range for which calibration is required. Attach the appropriate calibration weight to the linkage to correspond to the angle of inclination, α, for which the carriage friction is to be determined.

A1.2.4 Start the plane in motion. Allow the plane to move until the pen is 50 mm (2.0 in.) above the base line, and stop the plane.

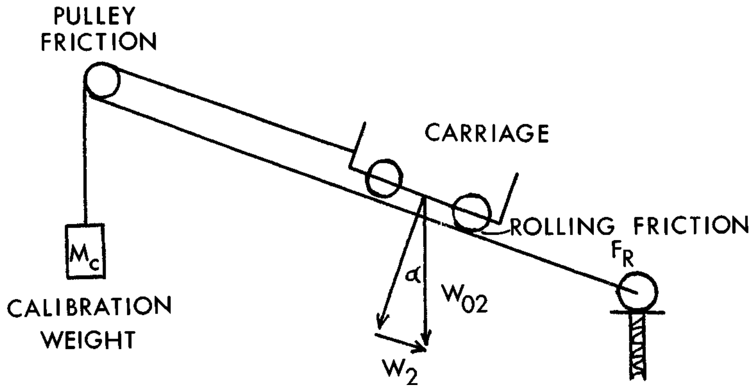
A1.2.5 With the calibration weight in equilibrium with the carriage, place the bucket on the carriage. Add sufficient shot to the bucket until the carriage, when started, moves slowly down the plane. Remove, and weigh the bucket and shot.

A1.2.5.1 The applicable forces are shown schematically in Fig. A1.1 and may be calculated using the following equations Eq A1.2-A1.4:

$$W_2 = W_{o2} \sin \alpha \tag{A1.2}$$

$$F_r = W_2 - F_p \tag{A1.3}$$

$$W_d = W_2 + M_c \tag{A1.4}$$



W_2	=	force applied to specimen, g,
W_{02}	=	force due to mass of carriage and bucket, g,
F_r	=	friction within pulley, g,
Wd	=	resultant force applied to specimen, g,
α	=	the angle of inclination, o,
M_c	=	mass of calibration weight, g.

FIG. A1.1 Schematic of Applicable Forces

where:

W_2	=	force applied to specimen, gf (lbf),
W_{o2}	=	force due to mass of carriage and bucket, gf (lbf),
F_r	=	rolling friction of carriage, gf (lbf),
F_p	=	friction within pulley, gf (lbf),
W_d	=	resultant force applied to specimen, gf (lbf),
α	=	the angle of inclination, °, and
M_c	=	mass of calibration weight, g (lb).

A1.2.6 Determine the bearing force for each angle of inclination checked using Eq A1.5, as follows:

$$L_d = 2M_c \cos 1/2(90° - \alpha) \quad \text{(A1.5)}$$

where:

α	=	angle of inclination of plane, and
M_c	=	mass of calibration weight.

A1.2.7 Determine the pulley friction corresponding to the above bearing forces from the previously prepared graph (see Note A1.1). Designate this value as P_{fd}.

A1.2.8 The rolling friction of the carriage plus the recording mechanism equals $W_2 - P_{f\,d}$. Use the average of five observations as the friction.

A1.2.9 The calculated carriage friction can be checked by adding the bucket and shot to the calibration weight and operating the carriage up-plane, assuming that the friction of the pulley and carriage is the same in both directions. If the value obtained in the up-plane tests does not equal the value obtained in the down-plane tests, overhaul the bearings.

NOTE A1.4—It is assumed that this procedure produces an equilibrium condition in which the mass of the calibration weight is balanced by the effective mass of the carriage but the latter will not move because of the friction in the pulley and in the carriage. If equilibrium is not obtained, check the mass of the calibration weight and the carriage. Adjust the angle of inclination, if necessary, to secure equilibrium. Locate the carriage at a position on the plane for which the mass of the linkage between the pulley and the carriage times the sine of the angle equals the mass of the linkage between the pulley and the calibration weight.

A1.2.10 Make determinations at angles of inclination covering the full range of plane movement.

A1.2.11 If the error between the indicated and effective force as determined by this procedure changes in proportion to the increase in the angle, it is probable that the plane is not making the proper angle. An adjustment of the carriage mass may be made to overcome this error.

A1.2.12 A variable friction for different angles of inclination indicates that the track or carriage bearings are in poor mechanical condition. If this trouble cannot be remedied, a variable correction will have to be applied to the observed results.

A1.3 *Checking with Standard Wire*—Once the calibration of the instrument has been verified, determine the breaking strength of soft-drawn bare copper wire samples. Use these samples to check the level of calibration at frequent intervals.

A2. CAUSES OF ERROR IN RECORDING ELONGATION

A2.1 Failure of the tensile testing machine to record the proper elongation may be due to one or more of the causes given in A2.1.1-A2.1.5. Note that not all of these possibilities will apply to a particular type of machine.

A2.1.1 *Faulty Ruling of Charts*—The rulings on the charts should be at right angles, or at the proper angle. The lines indicating a designated elongation may not be straight lines.

A2.1.2 *Faulty Cutting of Chart Sheets*—The opposite edges of the chart sheet should be parallel and the sides should be at right angles to the top and bottom. The edges should be cut through a line printed outside the ruled area as a guide for this purpose. The presence of a cut line can be detected at the edge of a properly cut chart sheet.

A2.1.3 *Failure of the Chart, Pen, and Clamp to Start*

Moving at the Same Time—Poor coordination of movement is indicated by a changing error in the recorded elongation when calculated on a percentage basis.

A2.1.4 *Improper Traverse Movement of the Pen*—Improper traverse of the pen can be caused by a compacted cable or by a stretched cable on testing machines using this type of mechanism. It can also be caused by an error in the ratio of the circumference of two pulleys mounted on the same shaft.

A2.1.5 *Improper Magnification of Chart or Pen Movement*—Magnification of the movement of the chart, where this is obtained by means of a movable pulley, will be in error if the diameter of the cable varies.