EXHIBIT D

(Part 5 of 5)

(tertiary) creep has an accelerating creep rate and terminates by failure of material at time for rupture. See also stress-relaxation.

Creep limit. Alternate term for creep strength.

Creep rate. Time rate of deformation of a material subject to stress at a constant temperature. It is the slope of the creep vs time diagram obtained in a creep test. Units usually are in/in/hr or % of elongation/hr. Minimum creep rate is the slope of the portion of the creep vs time diagram corresponding to secondary creep.

Creep recovery. Rate of decrease in deformation that occurs when load is removed after prolonged application in a creep test. Constant temperatures is maintained to eliminate effects of thermal expansion, and measurements are taken from time load is zero to eliminate elastic effects.

Creep rupture strength. Stress required to cause fracture in a creep test within a specified time. Alternate term is stress rupture strength.

Creep strength. Maximum stress required to cause a specified amount of creep in a specified time. Also used to describe maximum stress that can be generated in a material at constant temperature under which creep rate decreases with time. An alternate term is creep limit.

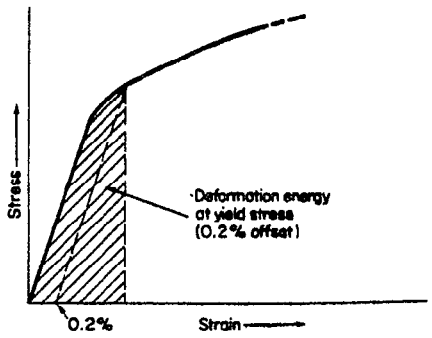
Creep test. Method for determining creep or stress relaxation behavior. To determine creep properties, material is subjected to prolonged constant tension or compression loading at constant temperature. Deformation is recorded at specified time intervals and a creep vs time diagram is plotted. Slope of curve at any point is creep rate. If failure occurs, it terminates test and time for rupture is recorded. If specimen does not fracture within test period, creep recovery may be measured. To determine stress relaxation of material, specimen is deformed a given amount and decrease in stress over prolonged period of exposure at constant temperature is recorded. Standard creep testing procedures are detailed in ASTM E-139, ASTM E-150 (metals under rapid heating). ASTM D-674 (plastics) and ASTM D-2294 (adhesives).

Crush resistance. Load required to produce fracture in a glass sphere subjected to crush loading. (ASTM D-313).

Crushing load. Maximum compressive force applied during a compression or crushing test. For materials that do not shatter, crushing load is defined as the force required to produce a specified type of failure.

Crushing strength. Compressive load required to cause a crack to form in a sintered metal powder bearing (ASTM B-202). Cold crushing strength of refractory bricks and shapes is the gross compressive stress required to cause fracture. (ASTM C-133).

Deformation energy. Energy required to deform a material a specified amount. It is the area under the stress-strain diagram up to a specified strain.



Deformation under load. Measure of the ability of rigid plastics to withstand permanent deformation and the ability of nonrigid plastics to return to original shape after deformation. Standard test methods for determining both types of deformation under load are given in ASTM D-621. For rigid plastics, deformation (which can be flow or flow and shrinkage) is reported as % change in height of specimen after 24 hr under a specified load. For nonrigid plastics, results are reported as % change in height after 3 hr under load and recovery in the 1 1/2 hr period following removal of the load. Recovery is % increase in height calculated on basis of original height.

Delamination strength. Measure of the node-to-node bond strength of honeycomb core materials. It is equal to the tensile load applied to a honeycomb panel at fracture divided by its width times thickness (ASTM C-363).

Dry strength. Strength of an adhesive joint determined immediately after drying or after a period of conditioning in a specified atmosphere. (ASTM D-1114).

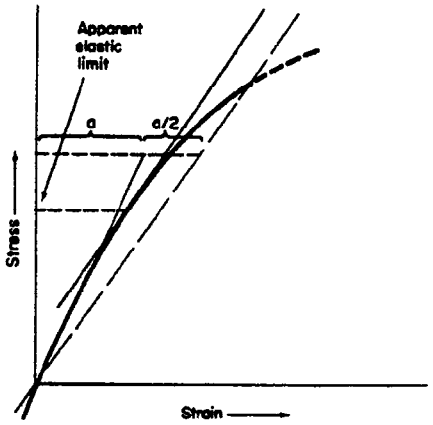
Ductility. Extent to which a material can sustain plastic deformation without rupture. Elongation and reduction of area are common indices of ductility.

Eccentricity of loading. Distance between the actual line of action of compressive or tensile loads and the line of action that would produce a uniform stress over the cross section of the specimen.

Edge tearing strength. Measure of the resistance of paper to tearing when folded over a V-notch beam and loaded in a tensile testing machine (ASTM D-827). Results are reported in lb or kg. (See Tear Resistance.)

Elastic limit. Greatest stress than can be applied to a material without causing permanent deformation. For metals and other materials that have a significant straight line portion in their stress/strain diagram, elastic limit is approximately equal to proportional limit. For materials that do not exhibit a significant proporational limit, elastic limit is an arbitrary approximation (the apparent elastic limit).

Elastic limit, apparent. Arbitrary approximation of the elastic limit of materials that do not have a significant straight line portion on a stress/strain diagram. It is equal to the stress at which the rate of strain is 50% greater than at zero stress. It is the stress at the point of tangency between the stress-strain curve and the line having a slope, with respect to the stress axis, 50% greater than the slope of the curve at the origin.



Elasticity. Ability of a material to return to its original shape when load causing deformation is removed.

Elongation. Measure of the ductility of a material determined in a tension test. It is the increase in gage length (measured after rupture) divided by original gage length. Higher elongation indicates higher ductility. Elongation cannot be

used to predict behavior of materials subjected to sudden or repeated loading.

Embrittlement. Reduction in ductility due to physical or chemical changes.

Engineering stress. Load applied to a specimen in a tension or compression test divided by a cross-sectional area of the specimen. The change in cross-sectional area that occurs with increases and decreases in applied load, is disregarded in computing engineering stress. it is also called conventional stress.

Extensometer. Instrument for measuring changes in linear dimensions. Also called a strain gage.

Fiber stress. Stress through a point in a part in which stress distribution is not uniform. For example, the stress in a beam under bending load varies from compression to tension across the beam. It is more meaningful in determining the properties of the beam material to consider the maximum stress generated in the outer fibers of the beam. Similarly, stress in a beam under twist loading is a maximum in the material furthest from the axis of twist.

Flex resistance. Ability of foam rubber to sustain repeated compressive loads without damage to cell structure. (ASTM D-1055).

Flexural modulus of elasticity. Alternate term for modulus in bending.

Flexural strength. Maximum fiber stress developed in a specimen just before it cracks or breaks in a flexure test. Flexural yield strength is reported instead of flexural strength for materials that do not crack in the flexure test. An alternate term is modulus of rupture.

Flexure test. Method for measuring behavior of materials subjected to simple beam loading. It is also called a transverse beam test with some materials. Specimen is supported on two knife edges as a simple beam and load is applied at its midpoint. Maximum fiber stress and maximum strain are calculated for increments of load. Results are plotted in a stress-strain diagram, and maximum fiber stress at failure is flexural strength. Flexural yield strength is reported for materials that do not crack. Standard test procedures are given in ASTM D-790 (plastics), ASTM C-328 and ASTM C-369 (fired whiteware). ASTM D-797 (elastomers), ASTM A-438 (cast iron) and ASTM D-158 (glass).

Flow stress. Stress required to cause plastic deformation.

Fracture stress. True stress generated in a material at fracture.

Hooke's law. Stress is directly proportional to strain. Hooke's law assumes perfectly elastic behavior. It does not take into account plastic or dynamic loss properties.

Kink test. Method for determining ductility of metal wire. A short section of wire is looped and drawn in tension to produce a kink. Relative ductility is indicated by the occurence or non-occurence of failure and extent to which kink may be opened up without failure.

Knot strength. Tenacity of a fiber in which an overhand knot is tied. Knot strength is a measure of a fiber's sensitivity to compressive and shear stresses.

Load-deflection diagram. Plot of load vs corresponding deflection.

Maximum fiber stress. Maximum tensile or compressive stress in a homogeneous flexure or torsion test

specimen. For a specimen loaded as a simple beam at its midpoint, maximum fiber stress occurs at mid-span and may be calculated by the formula (for rectangular specimens).

$$S = \frac{3PL}{2bd^2}$$

where S is maximum fiber stress; P, load; L, span; b, width of the beam; and d, depth of the beam. For a circular cross section member loaded in torsion, maximum fiber stress may be calculated by the following formula:

$$S = \frac{Tr}{J}$$

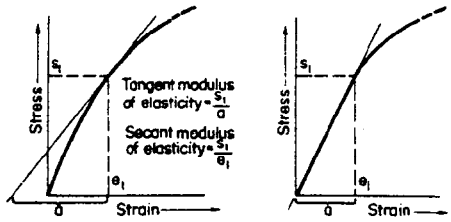
where T is twisting moment; r, original outer radius and J, polar moment of inertia of original cross section.

Mean stress. Algebraic difference between maximum and minimum stress in one cycle of fluctuating loading, as in a fatigue test. Tensile stress is considered positive and compressive stress negative.

Modulus. Alternate term for modulus of elasticity, often used in connection with rubber.

Modulus in bending. Ratio of maximum fiber stress to maximum strain, within elastic limit of stress-strain diagram obtained in flexure test. Alternate term is flexural modulus of elasticity.

Modulus of elasticity. Rate of change of strain as a function of stress. The slope of the straight line portion of a stress-strain diagram. Tangent modulus of elasticity is the slope of the stress-strain diagram at any point. Secant modulus of elasticity is stress divided by strain at any given value



of stress or strain. It also is called stress-strain ratio. Tangent and secant modulus of elasticity are equal up to the proportional limit of a material.

Depending on the type of loading represented by the stress-strain diagram, modulus of elasticity may be reported as: compressive modulus of elasticity (or modulus of elasticity in compression); flexural modulus of elasticity (or modulus of elasticity in flexure); shear modulus of elasticity (or modulus of elasticity in shear); tensile modulus of elasticity (or modulus of elasticity in tension); or torsional modulus of elasticity (or modulus of elasticity in torsion). Modulus of elasticity may be determined by dynamic testing, where it can be derived from complex modulus.

Modulus used alone generally refers to tensile modulus of elasticity. Shear modulus is almost always equal to torsional modulus and both are called modulus of rigidity. Moduli of elasticity in tension and compression are approximately equal and are known as Young's modulus. Modulus of rigidity is related to Young's modulus by the equation:

$$E = 2G(1 + r)$$

where E is Young's modulus (psi), G is modulus of rigidity (psi) and r is Poisson's ratio. Modulus of elasticity also is called elastic modulus and coefficient of elasticity.

Modulus of rigidity. Rate of change of strain as a function of

stress in a specimen subjected to shear or torsion loading. It is the modulus of elasticity determined in a torsion test. Alternate terms are modulus of elasticity in torsion and modulus of elasticity in shear.

Apparent modulus of rigidity is a measure of the stiffness of plastics measured in a torsion test (ASTM D-1043). It is "apparent" because the specimen may be deflected past its proportional limit and the value calculated may not represent the true modulus of elasticity within the elastic limit of the material.

Modulus of rupture. Ultimate strength determined in a flexure or torsion test. In a flexure test, modulus of rupture in bending is the maximum fiber stress at failure. In a torsion test, modulus of rupture in torsion is the maximum shear stress in the extreme fiber of a circular member at failure. Alternate terms are flexural strength and torsional strength.

Modulus of strain hardening. Alternate term for rate of strain hardening.

Monotron hardness. Measure of indentation hardness. It is the load (kg) required to press a specified ball indentor to a specified depth. Indentors consist of 1 mm diamond (M-2), 1/16 in. tungsten carbide (M-3), and 2.5 mm tungsten carbide (M-4). Standard depth of indentation is 0.045 mm, but for hard materials depth of indentation may be limited to 0.015 mm, in which case the load is multiplied by 3.

Necking. Localized reduction of cross-sectional area of a specimen under tensile load. It is disregarded in calculating engineering stress but is taken into account in determining true stress.

Nominal stress. Stress calculated on the basis of the net cross section of a specimen without taking into account the effect of geometric discontinuities such as holes, grooves, fillets, etc.

Offset yield strength. Arbitrary approximation of elastic limit. It is the stress that corresponds to the point of intersection of a stress-strain diagram and a line parallel to the straight line portion of the diagram. Offset refers to the distance between the origin of the stress-strain diagram, and the point of intersection of the parallel line and the 0 stress axis. Offset is expressed in terms of strain (often 0.2%).

Operating stress. Stress imposed on a part in service.

Overstressing. Application of high fluctuating loads at the beginning of a fatigue test and lower loads toward the end. It is a means for speeding up a fatigue test.

Peel resistance. Torque required to separate an adhesive and adherend in the climbing drum peel test. (ASTM D-1781). It is a measure of bond strength.

Peel strength. Measure of the strength of an adhesive bond. It is the average load per unit width of bond line required to part bonded materials where the angle of separation is 180 degreees and separation rate is 6 in/min. (ASTM D-903).

Plastic deformation. Deformation that remains after the load causing it is removed. It is the permanent part of the deformation beyond the elastic limit of a material. It also is called plastic strain and plastic flow.

Plasticity. Tendency of a material to remain deformed, after reduction of the deforming stress, to a

value equal to or less than its yield strength.

Plasticity number. Index of the compressibility of rubber at elevated temperatures. Equal to 100 times the height of a standard specimen, after a 3 to 10 minute compression by a 5 kg load (ASTM D-926).

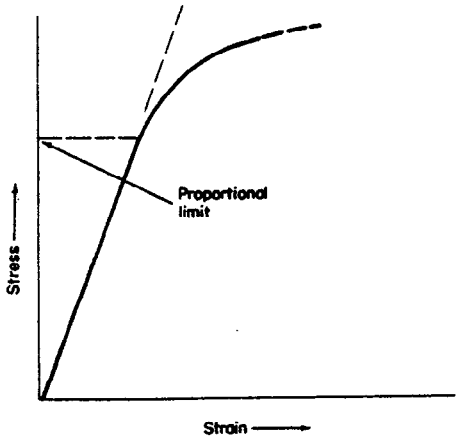
Poisson's ratio. Ratio of lateral strain to axial strain in an axial loaded specimen. It is the constant that relates modulus of rigidity to Young's modulus in the equation:

$$E = 2G(r+1)$$

where E is Young's modulus; G, modulus of rigidity; and r, Poisson's ratio. The formula is valid only within the elastic limit of a material. A method for determining Poisson's ratio is given in ASTM E-1321.

Proof stress. Stress that will cause a specified permanent deformation.

Proportional limit. Highest stress at which stress is directly proportional to strain. It is the highest stress at which the curve in a stress-strain diagram is a straight



line. Proportional limit is equal to elastic limit for many metals.

Rate of strain hardening. Rate of change of true stress as a function of true strain in a material undergoing plastic deformation. An alternate term is modulus of strain hardening.

Recovery. Index of a material's ability to recover from deformation in the compressibility and recovery test (ASTM F-36), the deformation under load test (ASTM D-621) and the plastometer test (ASTM D-926). In the compressibility and recovery test, it usually is reported with compressibility and given as %. It is calculated by dividing the difference between recovered thickness and thickness under load, by the difference between original thickness and thickness under load. In the deformation under load test, it indicates the extent to which a non-rigid plastic recovers from prolonged compressive deformation at an elevated temperature. It is given as %, and is calculated by dividing the difference between height recovered 1 $^1/_2$ hr after load is removed and height after three hr of loading, by the change in height under load. In the plastometer test, it indicates the extent to which an elastomer recovers from compressive loading at an elevated temperature. It is equal to plasticity number minus recovered height. See also Rockwell recovery.

Recovery test. Method for measuring compressibility and recovery of gasket and seal materials (ASTM F-36).

Reduction of area. Measure of the ductility of metals obtained in a tension test. It is the difference between original cross-sectional area of a specimen and the area of its smallest cross section after testing. It is usually expressed as % decrease in original cross section. The smallest cross section can be measured at or after fracture. For metals, it usually is

measured after fracture and for plastics and elastomers, it is measured at fracture.

Relative modulus. Ratio of the modulus of a rubber at a given temperature to its modulus at 73 F. It is determined in the Gehman torsional test.

Relaxation. Rate of reduction of stress in a material due to creep. An alternate term is stress relaxation.

Residual elongation. Measure of ductility of plastics. It is the elongation of a plastic specimen measured 1 minute after rupture in a tension test.

Rupture resistance. Indication of ability of rubber to withstand tensile loading. it is the load required to rupture a rubber specimen under conditions set out in ASTM D-530.

Rupture strength. Nominal stress developed in a material at rupture. It is not necessarily equal to ultimate strength. And, since necking is not taken into account in determining rupture strength, it seldom indicates true stress at rupture.

Secant modulus of elasticity. Ratio of stress to strain at any point on curve in a stress-strain diagram. It is the slope of a line from the origin to any point on a stress-strain curve.

Shear modulus of elasticity. Tangent or secant modulus of elasticity of a material subjected to shear loading. Alternate terms are modulus of rigidity and modulus of elasticity in shear. Also, shear modulus of elasticity usually is equal to torsional modulus of elasticity. A method for determining shear modulus of elasticity of structural materials by means of a twisting test is given in ASTM E-143. A method for determining shear modulus of structural adhesives is given in ASTM E-229.

Shear strength. Maximum shear stress that can be sustained by a material before rupture. It is the ultimate strength of a material subjected to shear loading. It can be determined in a torsion test where it is equal to torsional strength. The shear strength of a plastic is the maximum load required to shear a specimen in such a manner that the redulting pieces are completely clear of each other. It is reported in psi based on the area of the sheared edge (ASTM D-732). The shear strength of a structural adhesive is the maximum shear stress in the adhesive prior to failure under torsional loading (ASTM E-229). Methods for determining shear strength of timber are given in ASTM D-143 and ASTM D-198.

Splitting resistance. Measure of the ability to felt to withstand tearing. It is the load required to rupture a slit felt specimen by gripping lips of the cut in jaws and pulling them apart (ASTM D-461). An alternate term is tear resistance.

Springback. Degree to which a material returns to its original shape after deformation. In plastics and elastomers, it is also called recovery.

Stiffness. Measure of resistance of plastics to bending. It includes both plastic and elastic behavior, so it is an apparent value of elastic modulus rather than a true value (ASTM D-747).

Strain. Change per unit length in a linear dimension of a part or specimen, usually expressed in %. Strain, as used with most mechanical tests, is based on original length of the specimen.

True or natural strain is based on instantaneous length, and is equal to: $\ln l/l_0$, where l is instantaneous length and l_0 is original length of the specimen. Shear strain is the change in angle between two lines originally at right angles.

Strain energy. Measure of energy absorption characteristics of a material under load up to fracture. It is equal to the area under the stress-strain diagram, and is a measure of the toughness of a material.

Strain hardening exponent. Measure of increase in hardness and strength caused by plastic deformation. It is related to true stress and true strain by the equation:

$$\sigma = \sigma_0 \delta^n$$

where σ is true stress, σ_0 is true stress at unit strain, δ is true strain and n is strain hardening exponent.

Strain point. Temperature at which internal stress in glass is substantially relieved in about 1 hour. (ASTM C-336).

Strain rate. Time rate of elongation.

Strain relaxation. Alternate term for creep of rubber.

Strength reduction ratio. Alternate term for fatigue notch factor.

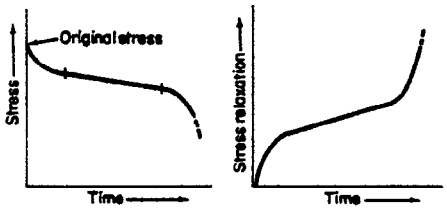
Stress. Load on a specimen divided by the area through which it acts. As used with most mechanical tests, stress is based on original cross-sectional area without taking into account changes in area due to applied load. This sometimes is called conventional or engineering stress. True stress is equal to the load divided by the instantaneous cross-sectional area through which it acts.

Stress amplitude. One-half the range of fluctuating stress developed in a specimen in a fatigue test. Stress amplitude often is used to construct an S-N diagram.

Stress concentration factor. Ratio of the greatest stress in the area of a notch or other stress raiser to the corresponding nominal stress. It is a theoretical indication of the effect of stress concentrators on mechanical behavior. Stress concentration factor usually is higher than the empirical fatigue notch factor or strength reduction ratio, because it does not take into account stress relief due to local plastic deformation.

Stress ratio. Ratio of minimum stress to maximum stress in one cyle of loading in a fatigue test. Tensile stresses are considered positive and compressive stresses negative.

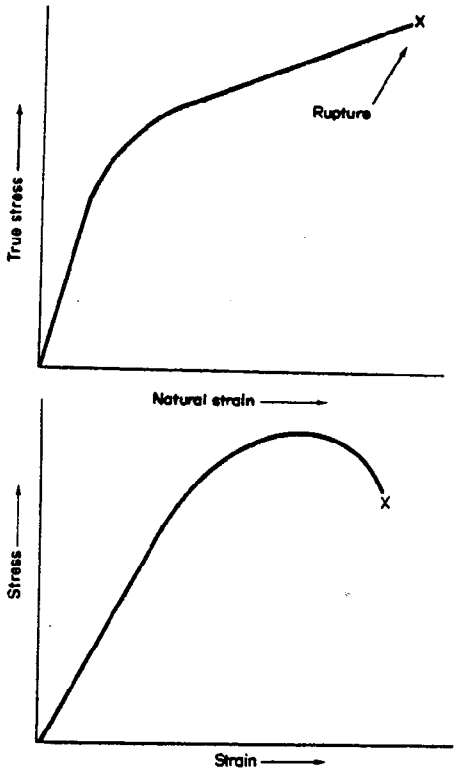
Stress relaxation. Decrease in stress in a material subjected to



prolonged constant strain at a constant temperature. Stress relaxation behavior is determined in a creep test. Data often is presented in the form of a stress vs time plot. Stress relaxation rate is the slope of the curve at any point.

Stress rupture strength. Alternate term for creep strength.

Stress-strain diagram. Graph of stress as a function of strain. It can be constructed from data ob-



tained in any mechanical test where load is applied to a material, and continuous measurements of stress and strain are made simultaneously. It is constructed for compression, tension and torsion tests.

Stress-strain ratio. Stress divided by strain at any load or deflection. Below the elastic limit of a material, it is equal to tangent modulus of elasticity. An alternate term is the secant modulus of elasticity.

Stripping strength. Alternate term for peel strength.

Tangent modulus of elasticity. The instantaneous rate of change of stress as a function of strain. It is the slope at any point on a stress-strain diagram.

Tear length. Measure of the drawability of sheet metal. Two small parallel slots are cut in the edge of the sheet to form a tab which is gripped and torn from the sheet. The variation in length of tabs torn in different directions is an indication of crystal orientation in the sheet. (Tabs torn in the direction of orientation are longer). The degree of orientation is an indication of difficulty to be expected in drawing the sheet to uniform shapes.

Tear resistance. Measure of the ability of sheet or film materials to resist tearing. For paper, it is the force required to tear a single ply of paper after the tear has been started (ASTM D-689).

Three standard methods are available for determining tear resistance of plastic films: ASTM D-1004 details a method for determining tear resistance at low rates of loading; a test in ASTM D-1922 measures the force required to propagate a precut slit across a sheet specimen; and, ASTM D-1038 gives a method for determining tear propagation resistance that is recommended for specification acceptance testing only.

Tear resistance of rubber is the force required to tear a 1 in. thick specimen under the conditions outlined in ASTM D-624. Tear resistance of textiles is the force required to propagate a single-rip tongue-type tear (starting from a cut) by means of a falling pendulum apparatus (ASTM D-1424).

Tearing strength. Tensile force required to rupture a pre-slit woven fabric specimen under the conditions outlined in ASTM D-2261 and ASTM D-2262. Edge tearing strength of paper is the force required to tear a specimen folded over a V-notch and loaded in a tensile test machine (ASTM D-827).

Tenacity. Force required to break a yarn or filament, expressed in grams per denier. It is equal to breaking strength divided by denier.

Tensile modulus of elasticity. Tangent or secant modulus of elasticity of a material subjected to tensile loading. Alternate terms are Young's modulus and modulus of elasticity in tension. It can be measured in a tension test or in a dynamic test, where it is related to resonant frequency of a cylindrical rod by the equation:

$$E = \frac{4\pi^2 l^2 \rho f^2}{k^2 j^4}$$

where E is modulus of elasticity; l, length of the rod; ρ, density; f, resonant frequency; k, radius of gyration of the rod about an axis normal to the rod axis and plane of motion (d/4 for cylindrical rods); and j, a constant dependent on the mode of vibration. Tensile modulus of elasticity is approximately equal to compressive modulus of elasticity within the proportional limit. An alternate term is Young's modulus.

Tensile strength. Ultimate strength of a material subjected to tensile loading. It is the maximum stress developed in a material in a tension test.

Tension impact test. Method for determining energy required to fracture a specimen under shock tensile loading (ASTM D-1822).

Tension set Extent to which vulcanized rubber is permanently deformed after being stretched a specified amount for a short time. It is expressed as a % of the original length or distance between gage marks (ASTM D-412).

Tension test. Method for determining behavior of materials under axial stretch loading. Data from test is used to determine elastic limit, elongation, modulus of elasticity, proportional limit, reduction in area, tensile strength, yield point, yield strength and other tensile properties. Tension tests at elevated temperatures provide creep data.

Procedures for tension tests of metals are given in ASTM E-8.

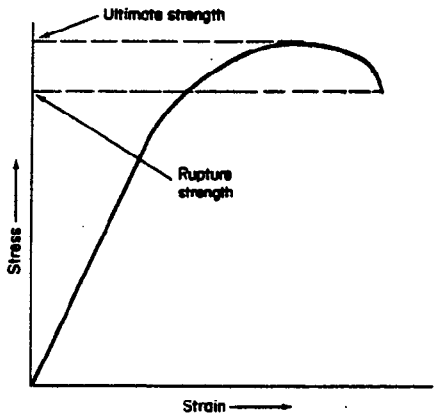
Time for rupture. Time required to rupture specimen under constant stress and temperature in a creep test.

True strain. Instantaneous % of change in length of specimen in mechanical test. It is equal to the natural logarithm of the ratio of length at any instant to original length.

True stress. Applied load divided by actual area of the cross section through which load operates. It takes into account the change in cross section that occurs with changing load.

Ultimate elongation. Alternate term for elongation of material at rupture under tensile loading.

Ultimate strength. Highest engineering stress developed in material



before rupture. Normally, changes in area due to changing load and necking are disregarded in determining ultimate strength.

Wet strength. Breaking strength of paper saturated with water. Also, the strength of an adhesive bond after immersion in water.

Yield point. Stress at which strain increases without accompanying increase in stress. Only a few materials (notably steel) have a yield point, and generally only under tension loading.

Yield point elongation. Strain at yield point of a material. It is an indication of ductility.

Yield strength. Indication of maximum stress that can be developed in a material without causing plastic deformation. It is the stress at which a material exhibits a specified permanent deformation and is a practical approximation of elastic limit.

Offset yield strength is determined from a stress-strain diagram. It is the stress corresponding to the intersection of the stress-strain curve, and a line parallel to its straight line portion offset by a specified strain. Offset is usually specified as 0.2%, i.e., the intersection of the offset line and the 0-stress axis is at 0.2% strain.

Yield strength elongation. Strain corresponding to yield strength of material. It is an indication of ductility.

Yield value. Stress in an adhesive joint at which a marked increase in deformation occurs without an increase in load.

Young's modulus. Alternate term for modulus of elasticity in tension or compression.

APPENDIX C

GRIPS AND FIXTURES

Instron has specimen grips available in a variety of types and sizes for testing any material. For application with the Model 4201 and 4202 instruments, these grips range in capacity from loads in a fraction of a gram to the full 5 kN (1125 lb) and 10 kN (2250 lb) capacities of these systems.

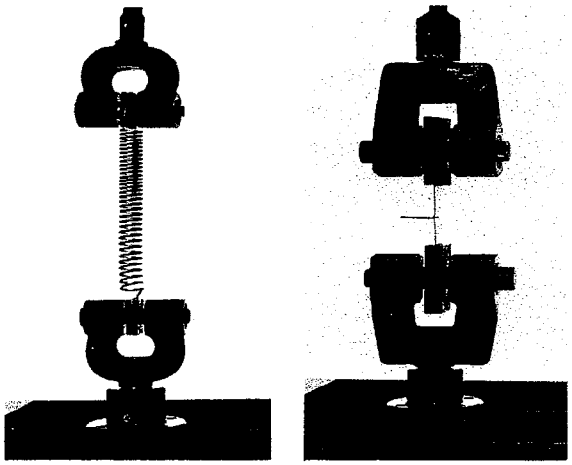
The grips and fixtures described in this section are typical of the types immediately available for use with a 4200 series system. Fixtures for conducting special types of tests or for fulfilling conditions required by specifications and standards are also available. Contact your regional Instron Sales and Service Center for more information.

Screw Action Grips

The screw action grips (Figure C-1) are mechanical types which are available in three maximum capacities: 5 kg; 200 lb (100 kg); and 1000 lb (500 kg). This type of grip, which is normally used for testing flat specimens, can be equipped with a wide selection of interchangeable grip faces in various sizes and in a choice of surfaces.

On this type of grip, one face is adjustable to compensate for specimen thickness. In this manner, the line of tensile force can be made to coincide with the centerline of the grips. The other face clamps against the specimen when it is tightened with a T-handle wrench that is provided with the grips.

A resilient nylon compression washer in the clamping mechanism of these grips provides a "follow-up" action to compensate for any pressure decay in the specimen during a test. The interchangeable faces are mounted on hardened steel pins in such a manner that one face is free to swivel on a horizontal axis and the other on a vertical axis. This action allows for self-alignment to compensate for variations in specimen thickness. The gripping efficiency of this design results in a minimum of pressure required to hold the specimen, thereby minimizing specimen breakage at the grip faces.



200 lb (100 kg) Capacity | 1000 lb (500 kg) Capacity

Figure C-1. Screw Action Grips

Grip Faces

The choice of the best gripping surface is determined largely by practical experience with the materials to be tested. The surfaces available for the faces of the screw action grips are smooth ground, rubber-coated or serrated. Line contact and special coated are also available.

Generally, the smooth ground surface offers high gripping efficiency with most flat materials. The

rubber-coated surface is of value with materials that tend to be weakened by pinching at the edge of the grip face, such as monofilaments, wire, certain plastics and paper. The serrated surface is recommended for stiff materials which require the greatest gripping strength, such as rigid plastics and sheet metal. The line contact faces, which have a round rod attached to a horizontal groove in one clamping face, are used for elastomeric materials such as thin films.

Wedge Action Grips

The Instron wedge action grips (Figure C-2) for use with the 4201 or 4202 instruments are rated at 5,000 lb (2500 kg). These grips have a high-capacity, wedge-type action along with several other unique features. For example, the grips are tightened without altering the vertical position of the faces, making it possible to preselect the exact point at which the specimen will be held. This is done by moving the grip frames instead of the faces during the tightening procedure.

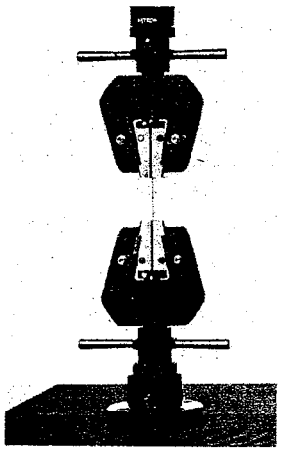
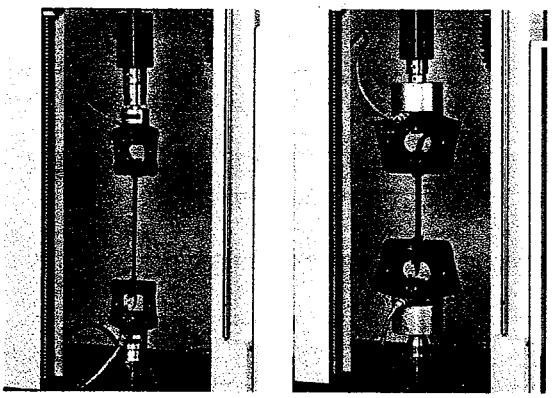


Figure C-2. Wedge Action Grips

The high mechanical advantage of the wedge-action design applies a strong grip on hard-to-hold specimens without a compressive force, which would tend to cause buckling. Also, these grips eliminate recoil when a specimen breaks, but allow easy release after a test. The grip faces are easily changed to accommodate flat or round specimens of different sizes.

Pneumatic Action Grips

The pneumatic action grips (Figure C-3) are available in three maximum capacities: 500 g; 10 lb (5kg); and 200 lb (100 kg). This type of grip clamps onto the specimen by lever arms which are actuated by compressed air cylinders built into the grip bodies. The mechanical advantage of this design provides a high gripping force with standard air pressure. This can be increased to accommodate materials which are often difficult to hold in other types of grips.



10 lb (5 kg) Capacity 200 lb (100 kg) Capacity

Figure C-3. Pneumatic Action Grips

A constant gripping force is maintained on the specimen by the pneumatic design, which also automatically compensates for decay of gripping force due to creep of the specimen in the grip. Another advantage of this design is the ability to control gripping force by adjusting the air pressure. This makes it possible to optimize grip-

ping force and minimize specimen breaks at the grip faces.

The pneumatic grips use the interchangeable faces described in the paragraph entitled, Grip Faces. These are mounted on hardened steel pins, with one face swiveling on a horizontal axis and the other on a vertical axis. This allows for self-alignment to compensate for variations in specimen thickness.

The grips are closed or released by a self-contained toggle lever. However, an optional pneumatic foot switch (Figure C-4) is available.

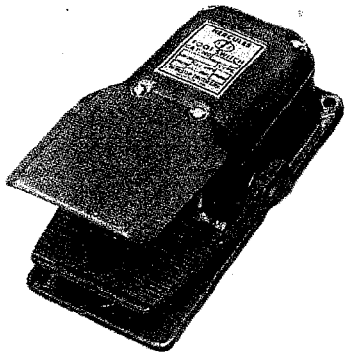


Figure C-4. Pneumatic Foot Switch (Optional)

Portable Air Compressor

A portable air compressor (Figure C-5) for use with pneumatic grips is available from Instron.

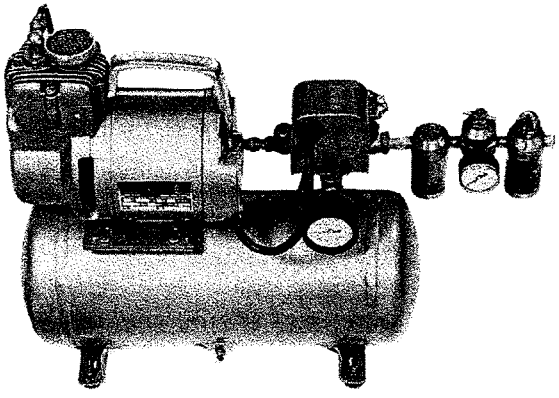


Figure C-5. Portable Air Compressor (Optional)

This compressor is easy to use and ideal for applications where other industrial air sources do not exist. It provides continuous, low-noise level operation at pressures up to 70 psig. The unit operates from standard 120 VAC and weighs only 36 lb.

Pneumatic-Hydraulic Grips

These type of grips have the same advantages as the pneumatic grips described previously, but have the maximum capacity of 1000 lb (500 kg). A hydraulic booster package is used to permit operation of these high capacity grips at an air pressure of only 60 lb. At that level, the hydraulic booster develops 1700 psi at the grip piston, or 3000 lbf at the grip faces. For operator protection, the high pressure hydraulic system cannot be energized until both upper and lower grips have been closed initially through a spring force of fifteen pounds applied at a foot switch.

Pneumatic Cord and Yarn Grips

The pneumatic cord and yarn grips (Fig. C-6) are available in maximum capacities of 2000 g, 150 lb (68 kg) and 350 lb (160 kg). These grips are designed to minimize problems associated with the testing of cord and fiber materials, where the gripping area of the specimen is small in relation to its strength. Standard gripping techniques for these materials usually result in unwanted specimen breakage at the grips. The cord and yarn grip design overcomes the holding problem by distributing the gripping stress and by providing an extremely high, pneumatically-cushioned gripping force. This eliminates slippage without pinching off the specimen.

The pneumatic operation of these grips permits the adjustment of air pressure to grip cords of almost any

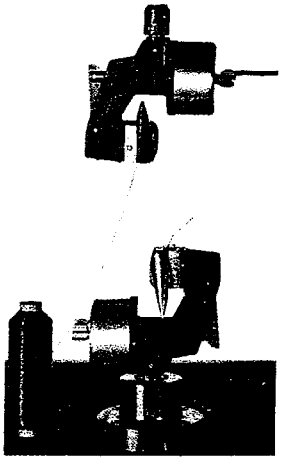


Figure C-6. Pneumatic Cord and Yarn Grips

strength and finish to the full capacity of the grips. The pneumatic action compensates for decay in holding force due to specimen creep. This action also allows for rapid opening and closing of the faces to greatly increase the speed of routine testing.

These grips use a pneumatically actuated moveable face which acts upon a contoured fixed gripping face. The fixed face serves as a capstan and provides support for the specimen. Hence, the transition from the free stressed length of the specimen to the rigidly clamped area is gradual rather than abrupt. Polished guide horns are used on the grips to ease loading. The sample is placed over the tip of the horns and is guided to the proper gripping position on the contoured clamp.

Operation of the cord and yarn grips is by a footswitch (Figure C-4), or some types use a pretension control which automatically closes the lower grip when the correct pretension is applied.

Fiber Clamps

The fiber clamps (Figure C-7) are designed for testing single fibers and very fine wire using a 500 gram capacity tension cell. The clamp faces are mounted on steel pins so that one face is free to swivel on a horizontal axis and the other on a vertical axis. This action allows a self alignment to compensate for variations in specimen thickness. The gripping pressure is applied against the specimen through a spring and wedge mechanism, which is operated by a knurled nut at the base of each clamp. This method of gripping requires a minimum of pressure to hold the specimen, thus minimizing the chance of breaks occurring at the clamp faces.

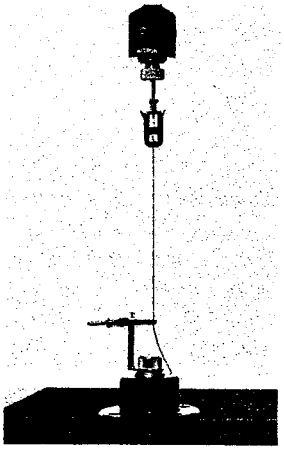
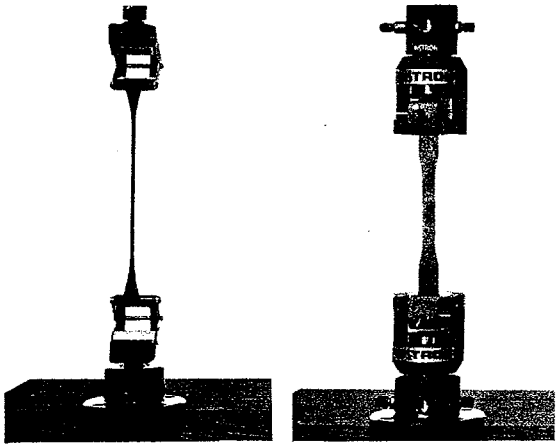


Figure C-7. Fiber Clamps

Elastomeric Grips

The elastomeric grips (Figure C-8) have a maximum capacity of 200 lb (100 kg). These grips provide excellent testing accuracy of elastomeric materials due to positive non-slip gripping. The upper grip is counterbalanced so that the specimen will be aligned, hence eliminating the introduction of non-axial forces. The snubbing type gripping action increases the holding force as the load increases. Hard rubber covered snubbing rollers are available for testing of thin films. Specimen insertion is very easy and spring pressure of the rolling bracket holds the specimen until loading is applied.

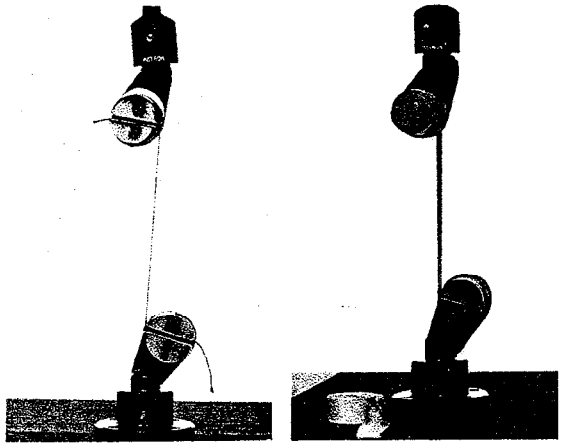


Self-tightening Eccentric Rollers

Figure C-8. Elastomeric Grips

Cord Capstan Grips

The cord capstan grips (Figure C-9) were designed for the testing of up to $^{1}/_{8}$-inch twisted or braided cord, and have a maximum capacity of 500 lb (250 kg). These grips have a right-hand, round groove which allows the specimen to beloaded from the outside and wound into the centerline on the upper grip. On the lower grip, the specimen is wound before final gripping between the split halves of the capstan.



Cord Capstan Webbing Capstan

Figure C-9. Capstan Grips

The grooved capstans allow two full turns of the specimen to be wound. This distributes the load of heavier cords over a larger area and minimizes stress concentration at the bite. Smooth capstan surfaces can be provided instead of the grooves surfaces to accommodate narrow tapes and belting.

Flexure Jig

The flexure jig (Figure C-10) allows the flexure testing of a specimen through single point loading in a tension test mode. The specimen is horizontally supported at each end of an adjustable 2, 4, 6 or 8-inch span by a yoke suspended from the weigh beam coupling. A second, interlocking yoke, connected to the base grip adapter, applies the flexing force to the top of the specimen at the center of the span. Bearings attached to one yoke are guided by slots in the other yoke to ensure that the force bears exactly on the center of the specimen. The jig is made of stainless steel and accommodates specimens up to 1-inch wide and $^{7}/_{8}$-inch thick.

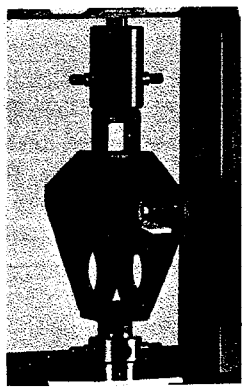


Figure C-10. Flexure Jig

Flexure Fixture

The Instron flexure fixtures (Figure C-11) include anvils and all the adaptive hardware necessary to perform a variety of tests, including: flexural modulus, flexural strength, flexural yield strength

and maximum bending deflection. The accessories are standard and are easily installed. The fixtures may be specified for center or fourth point loading. The span of the fourth point and reaction points may be varied, and precise indexing is possible due to the scales included with the fixtures. Interchangeable anvils on both load and reaction fixtures permit the bearing radius to be varied. During a test, crosshead displacement provides an accurate measurement of mid-span deflection for single=point loading. A deflectometer is used to provide precise measurement during double-point loading.

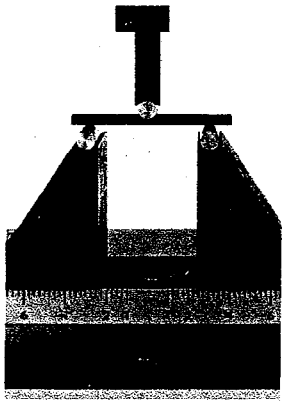


Figure C-11. Flexure Test Fixture 3-Point

O-Ring Test Fixture

The Instron O-Ring test fixture (Figure C-12) meets the testing requirements of ASTM specification D1414-65T. It consists of an upper frame which attaches to the weigh beam coupling, and a lower frame which connects to the base grip adapter. Both frames contain bearing-mounted rollers which are available in 1/8, 1/4 or 1/2-inch diameters. The lower roller is rotated in synchronism to the motion of the moving crosshead by a sprocket and chain. The specimen O-Ring, which is placed over the two rollers, turns one revolution of the rotating roller for each 6 inches of crosshead motion. This minimizes stresses in the O-Ring during tests.

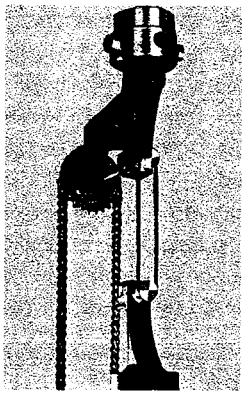


Figure C-12. O-Ring Test Fixture

Environmental Chambers

Instron environmental chambers (Figure C-13) provide a precisely controlled thermal environment for materials testing programs. Standard chambers are convection heated with ranges to 600° C (1100° F) with optional cooling by either CO_2 or N_2. A full complement of pullrods and high temperature grips are readily available.

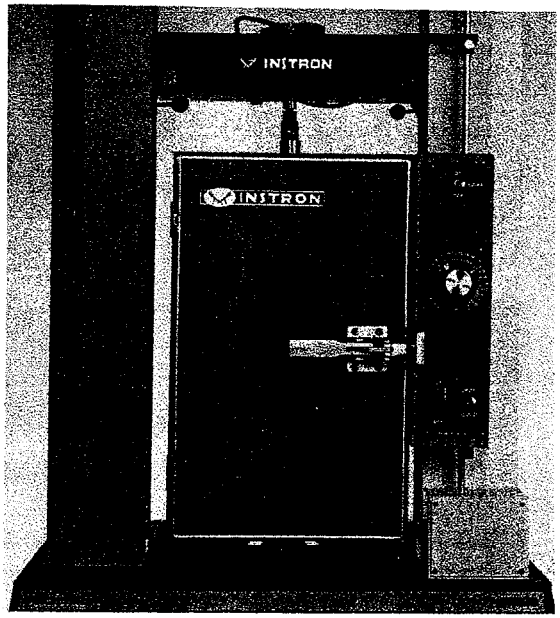


Figure C-13. Environmental Chamber

Additional Fixtures

Figures C-14 through C-18 illustrate some of the additional fixturing available from Instron. These devices are designed for the user to obtain maximum performance from an Instron testing system for a wide variety of applications. For assistance in other specialized testing methods, contact the nearest Instron Sales and Service Center where technically trained personnel are always available to evaluate and develop testing techniques.

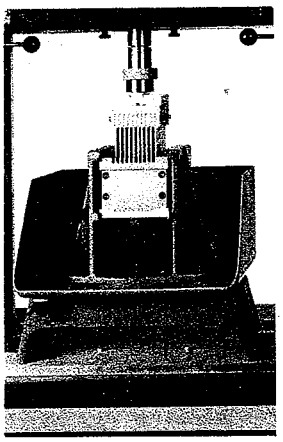
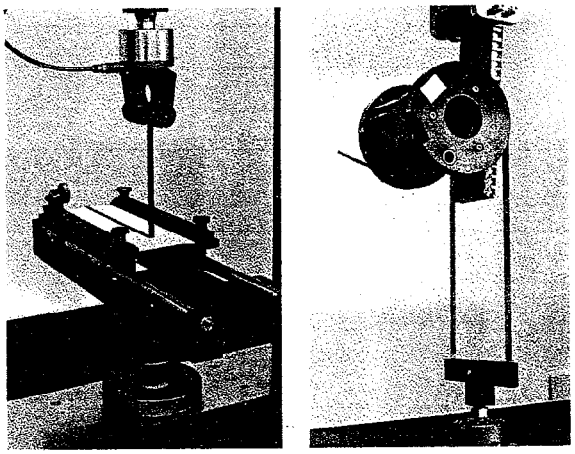


Figure C-14. Food Testing Fixtures



90° Constant Angle Climbing Drum

Figure C-15. Peel Testing Fixtures

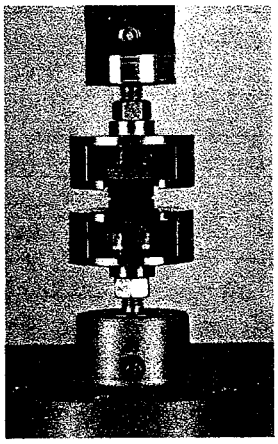


Figure C-16. Adhesive Bond Test Grip

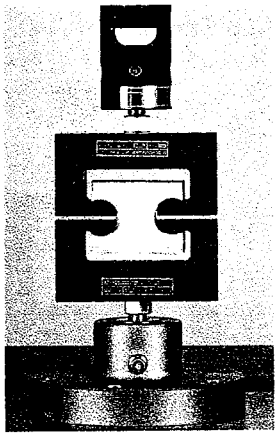


Figure C-17. Wood Tensile Fixture

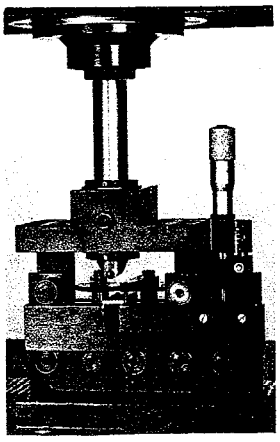


Figure C-18. Short Beam Shear Fixture for Flat Specimens

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