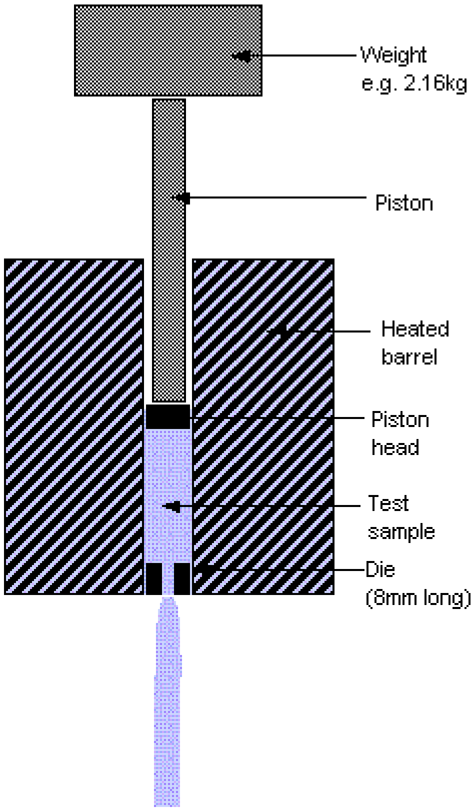
MELT FLOW INDEX (MFI)

The melt flow index (MFI) is a measure of the ease of flow of the melt of a thermoplastic polymer. It is defined as the mass of polymer, in grams, flowing in ten minutes through a capillary of a specific diameter and length by a pressure applied via prescribed alternative gravimetric weights for alternative prescribed temperatures. Polymer processors usually correlate the value of MFI with the polymer grade that they have to choose for different processes, and most often this value is not accompanied by the units, because it is taken for granted to be g/10min. Similarly, the test load conditions of MFI measurement is normally expressed in kilograms rather than any other units. The method is described in the similar standards ASTM D1238 and ISO 1133.

Melt flow rate is an indirect measure of molecular weight, with high melt flow rate corresponding to low molecular weight. At the same time, melt flow rate is a measure of the ability of the material's melt to flow under pressure. Melt flow rate is inversely proportional to viscosity of the melt at the conditions of the test, though it should be borne in mind that the viscosity for any such material depends on the applied force. Ratios between two melt flow rate values for one material at different gravimetric weights are often used as a measure for the broadness of the molecular weight distribution.



Die—The outside of the steel die shall be such diameterthat it will fall freely to the bottom of the 9.5504 ± 0.0076 mmdiameter hole in the cylinder. The die shall have asmooth straight bore 2.0955 ± 0.0051 mm in diameter andshall be 8.000 ± 0.025 mm in length.

Melt flow rate is very commonly used for polyolefins, polyethylene being measured at 190 °C and polypropylene at 230 °C. The plastics engineer should choose a material with a melt index high enough that the molten polymer can be easily formed into the article intended, but low enough that the mechanical strength of the final article will be sufficient for its use.

ISO standard 1133-1 governs the procedure for measurement of the melt flow rate.[5] The procedure for determining MFI is as follows:

1. A small amount of the polymer sample (around 4 to 5 grams) is taken in the specially designed MFI apparatus. A die with an opening of typically around 2 mm diameter is inserted into the apparatus.
2. The material is packed properly inside the barrel to avoid formation of air pockets.
3. A piston is introduced which acts as the medium that causes extrusion of the molten polymer.
4. The sample is preheated for a specified amount of time: 5 min at 190 °C for polyethylene and 6 min at 230 °C for polypropylene.
5. After the preheating a specified weight is introduced onto the piston. Examples of standard weights are 2.16 kg, 5 kg, etc.
6. The weight exerts a force on the molten polymer and it immediately starts flowing through the die.
7. A sample of the melt is taken after the desired period of time and is weighed accurately.
8. MFI is expressed in grams of polymer per 10 minutes of duration of the test.

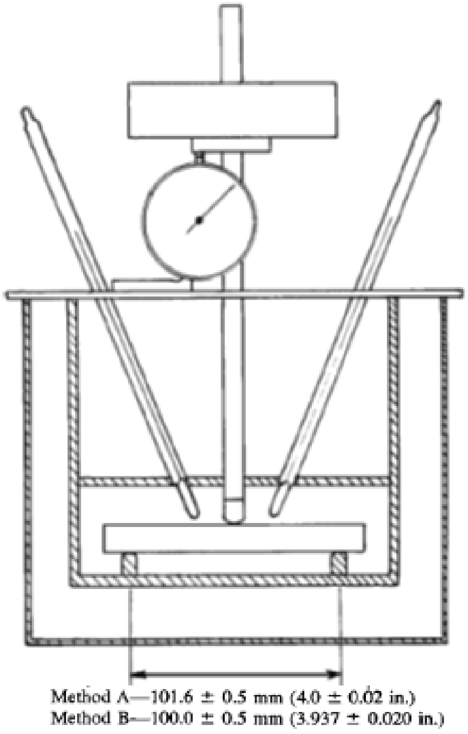
HEAT DISTORTION TEMPERATURE

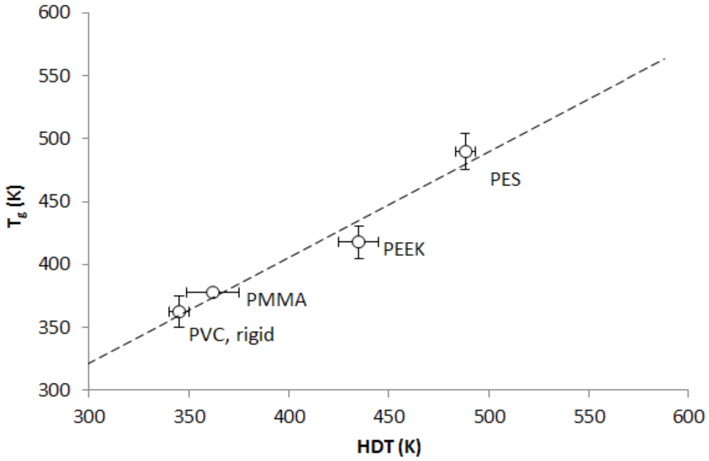
The heat distortion (or heat defelction) temperature (HDT) is an important property of polymers. It gives an indication at what temperature materials start to "soften" when exposed to a fixed load at elevated temperatures. As per ASTM D 648, a bar of rectangular cross section is tested in theedgewise position as a simple beam with the load applied at itscenter to give maximum fiber stresses of 0.455 MPa (66 psi) or1.82 MPa (264 psi). The specimen is immersed underload in a heat-transfer medium provided with a means ofraising the temperature at 2 ± 0.2°C/min. The temperature ofthe medium is measured when the test bar has deflected 0.25mm (0.010 in.). This temperature is recorded as the deflectiontemperature under flexural load of the test specimen.

Calculate the testing force and the mass that must be added to achieve the desired stress as follows:

$$F= 2Sbd^2/3L$$

F = load, N
S = fiber stress in the specimen (0.455 MPa or 1.82 MPa),
b = width of specimen, mm,
d = depth of specimen, mm,
L = distance between supports, (101.6 mm—Method A, or 100 mm—Method B)



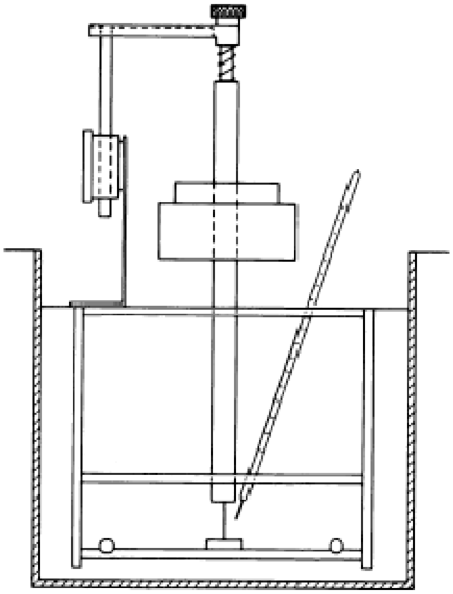


The heat deflection temperature of amorphous materials is related to the glass transition temperature (amorphous materials) or melting temperature (crystalline materials). The HDT, is a useful indicator of the temperature limit above which the material cannot be used for structural applications. It is often reported on the TDS of commercial grades of plastics. However, HDT and T_g (or T_m) cannot be used Interchangeable. The Tg describes the temperature at which vitrification or glassification begins, i.e when "freezing" of the movements of chain segments (kinetic units) takes place, whereas the HDT is a macroscopic measure of the "stiffness" of a material when the temperature increases. For unfilled systems, the two properties are often closely related (see Figure below). However, fillers, and reinforcements will greatly change the HDT since reinforcements make the material stiffer whereas the T_g is not noticeably affected by these ingredients since it describes the softening of the polymeric portion. Infact, the HDT of filled and unfilled plastics can vary a lot, depending on the filler / fiber content and type. Both properties are equally affected by plasticizers.

For structural applications, the HDT is often a better measure for the temperature application limit than the T_g (or T_m). Sometimes, manufacturers and suppliers of polymeric materials confuse these two properties. However, these properties are not interchangeable.

VICAT SOFTENING POINT (VSP)

Vicat softening temperature or **Vicat** hardness is the determination of the **softening point** for materials that have no definite melting **point**, such as plastics. It is taken as the temperature at which the specimen is penetrated to a depth of 1 mm by a flat-ended needle with a 1 mm^2circular or square cross-section.



Summary of Test Method

A flat-ended needle loaded with a specified mass isplaced in direct contact with a test specimen. The mass appliedcan be one of two accepted loads, as follows:

Loading 1—10 ± 0.2 N
Loading 2—50 ± 1.0 N

The specimen and needle are heated at either of two permissiblerates, as follows:

Rate A—50 ± 5°C/h
Rate B—120 ± 10°C/h

The temperature at which the needle has penetrated to a depthof 1 ± 0.01 mm is recorded as the Vicat softening temperature.

ELECTRICAL PROPERTIES

DIELECTRIC STRENGTH (ASTM D 149, IEC 243-1)

The dielectric strength of an insulating material is defined as the maximum voltage required to produce a dielectric breakdown. Dielectric strength is expressed in volts per unit of thickness such as V/miL. All insulators allow a small amount of current to leak through or around themselves. Only a perfect insulator, if there is such an insulator in existence, can be completely free from small current leakage. The small leakage generates heat, providing an easier access to more current. The process slowly accelerates with time and the amount of voltage applied until a failure in terms of dielectric breakdown, or what is known as puncture, occurs. Obviously, dielectric strength, which indicates electrical strength of a material as an insulator, is a very important characteristic of an insulating material. The higher the dielectric strength, the better the quality of an insulator. Table 4-1 lists some typical dielectric strength values of common plastics materials. Three basic procedures have been developed to determine dielectric strength of an insulator. Figure 4-1 illustrates the basic setup for a dielectric strength test. A variable transformer and a pair of electrodes are normally employed. Specimens of any desirable thickness prepared from the material to be tested are used. Specimen thickness of 1/16 in. is fairly common.

The first procedure is known as the short-time method. In this method, the voltage is increased from zero to breakdown at uniform rate. The rate of rise is generally 100, 500, 1000, or 3000 V/sec until the failure occurs. The failure is made evident by actual rupture or decomposition of the specimen. Sometimes a circuit breaker or other similar device is employed to signal the voltage breakdown. This is not considered a positive indication of voltage breakdown because other factors such as flashover, leakage current, corona current, or equipment magnetizing current can influence such indicating devices.

The second method is known as the slow rate-of-rise method. The step-by-step test method requires applying initial voltage equal to 50 percent of the breakdown voltage, as determined by the short-time test, and then increasing the voltage in equal increments and holding for specified time periods until the specimen breaks down. In almost all cases, the dielectric strength values obtained by the step-by-step method corresponds better with actual use conditions. However, the service failures are generally at voltage below the rated dielectric strength because of the time factor involved (2). The dielectric strength of an insulating material is calculated as follows:

$$\text{Dielectric strength (V/mil)} = \frac{\text{Breakdown voltage (V)}}{\text{Thickness (mil)}}$$

Dielectric Constant (Permittivity)

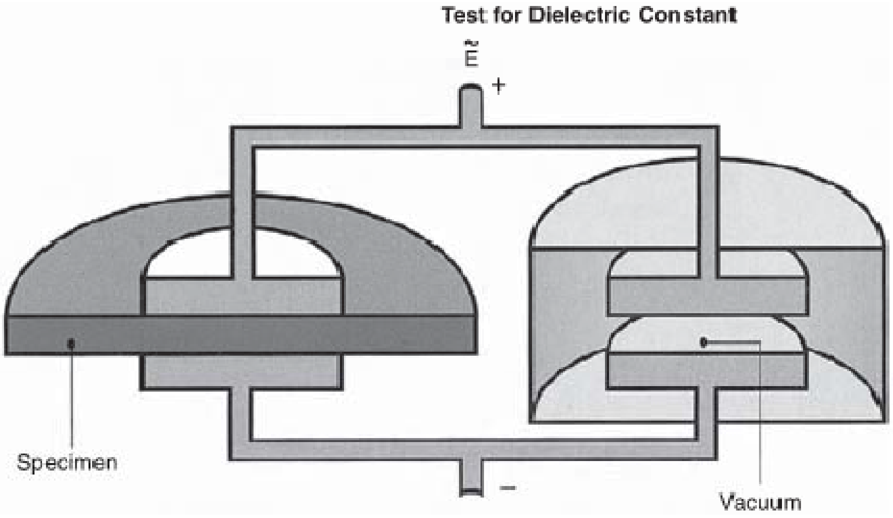
The dielectric constant of an insulating material is defined as the ratio of the charge stored in an insulating material placed between two metallic plates to the charge that can be stored when the insulating material is replaced by air (or vacuum). Defined another way, the dielectric constant is the ratio of the capacitance by two metallic plates with an insulator placed between them and the capacitance of the same plates with a vacuum between them.

$$\text{Dielectric constant} = \frac{\text{Capacitance, Material as dielectric}}{\text{Capacitance, Air (or Vacuum) as dielectric}}$$

Simply stated, the dielectric constant indicates the ability of an insulator to store electrical energy. In many applications, insulating materials are required to perform as capacitors. Such applications are best served by plastic materials having a high dielectric constant. Materials with a high dielectric constant have also helped in reducing the physical size of the capacitors. Furthermore, the thinner the insulating material, the higher the capacitance. Because of this fact, plastic foils are extensively used in applications requiring high capacitance.

One of the main functions of an insulator is to insulate the current-carrying conductors from each other and from the ground. If the insulator is used strictly for this purpose, it is desirable to have the capacitance of the insulating material as small as possible.

For these applications, one is looking for materials with very low dielectric constant. Table 4-2 lists typical dielectric constant values of various plastics. The dielectric constant of air (or vacuum) is 1 at all frequencies. The dielectric constant of plastics varies from 2 to 20.



Dielectric constant is the ratio of the system capacitance with the plastic specimen as the dielectric to the capacitance with a vacuum as the dielectric.

The dielectric constant test is fairly simple. The test specimen is placed between the two electrodes, as shown in Figure 4-2, and the capacitance is measured. Next, the test specimen is replaced by air and the capacitance value is again measured. The dielectric constant value is determined from the ratio of the two measurements. Dielectric constant values are affected by factors such as frequency, voltage, temperature, and humidity.

Dissipation Factor

In all electrical applications, it is desirable to keep the electrical losses to a minimum. Electrical losses indicate the inefficiency of an insulator. The dissipation factor is a measure of such electrical inefficiency of the insulating material. The dissipation factor indicates the amount of energy dissipated by the insulating material when the voltage is applied to the circuit (6). The dissipation factor is defined as the ratio of the conductance of a capacitor in which the material is the dielectric to its susceptance or the ratio of its parallel reactance to its parallel resistance. Most plastics have a relatively lower dissipation factor at room temperature. However, at high temperatures, the dissipation factor is quite high, resulting in greater overall ineffciency in the electrical system. The loss factor which is the product of dielectric constant and the dissipation factor, is a frequently used term, which relates to the total loss of power occurring in insulating materials.

OPTICAL PROPERTIES

REFRACTIVE INDEX (ASTM D 542, ISO 489)

Refractive index is a fundamental property of transparent materials. Refractive index values are very important to a design engineer involved in designing lenses for cameras, microscopes, and other optical equipment. The refractive index, also known as the index of refraction, is defined as the ratio of the velocity of light in a vacuum (or air) to its velocity in a transparent medium. The Abbé refractometer is the refractometer most widely used to determine the index of refraction

LUMINOUS TRANSMITTANCE AND HAZE

Luminous transmittance is defined as the ratio of transmitted light to the incident light. The value is generally reported in percentage of light transmitted. Polymethyl methacrylate, for example, transmits 92 percent of the normal incident light. There is about 4 percent reflection at each polymer–air interface for normal incident light.

Haze is the cloudy appearance of an otherwise transparent specimen caused by light scattered from within the specimen or from its surface.

Haze is defined as the percentage of transmitted light which in passing through a specimen deviates from the incident beam by forward scattering. It is generally accepted that if the amount of transmitted light is deviated more than 2.5° from the incident beam, the light flux is considered to be haze. Haze is normally caused by surface imperfections, density changes, or inclusions that produce light scattering. Haze is also reported in percentage.

Light transmittance and haze are extremely important from a practical viewpoint. For example, a window glazing material must have high light transmittance characteristics and must be free from haze. In contrast, the housing material for the light fixture must have maximum diffusion and minimum transparency to conceal the bright light source. The housing material must also have high light transmittance

COLOUR

In order to see any object, the object must be illuminated with an illuminant.The type of illuminant, angle of illumination, and angle of viewing all affect theappearance of the object. Therefore, in measuring color, one must consider spectralenergy distribution and intensity of the illuminant as it affects the appearance ofthe object. To standardize the variations among the illuminants, the InternationalCommission on Illuminants, known as CIE (Commission Internationale del'Eclairage) has established standard illuminants. For example, illuminant A representsan incandescent light; illuminant B, noon sunlight; illuminant C, overcastsky daylight. One other factor that must be considered in color measurement is thevariations in the color observer. CIE has also established a standard observer. ACIE standard observer is a numerical description of the response to color of thenormal human eye (11). CIE spectral tristimulus values are derived by using theCIE standard source, CIE standard observer, and object.

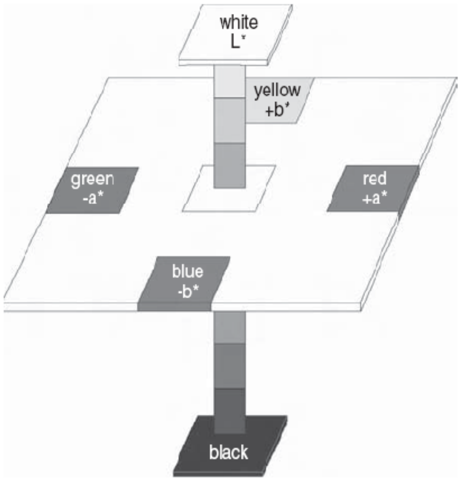


Figure 6-10. L, a, b color space.

From the above discussion, it is clear that given a CIE standard source, object,and spectral tristimulus values, one can easily measure color. The instrumentdeveloped for such color measurement is called a tristimulus colorimeter. A tristimuluscolorimeter measures color in terms of three primary colors: red, greenand blue, or more properly stated, in terms of three tristimulus values. Many differentcolor scales have been developed to describe the color numerically in termsof lightness and hue. One of the most widely accepted systems is known as the L,a, b tristimulus system. Figure 6-10 illustrates L, a, b color space. The coordinateL is in the vertical direction and corresponds to lightness. A perfect white has anL value of 100 and a perfect black a zero. The variables a_L and b_L identify the hueand the chroma of the material. A plus value of aL indicates redness and a minusvalue greenness. For example, a school bus yellow with the following valuesdescribes a color: L = 70.3; a_L = 30.3; b_L = 23.7. This color can be described incommon terms as fairly light, as indicated by a high L value, and yellowish red, asindicated by a_L and b_L values