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ELECTRICAL PROPERTIES

- Introduction
- Dielectric strength
- Dielectric constant
- Dissipation and power factor
- Volume and surface resistivity
- Arc resistance
- Comparative tracking index
- Static & Antistatic charges
- Conductive polymers

INTRODUCTION

The unbeatable combination of such characteristics as ease of fabrication, low cost, light weight, and excellent insulation properties have made plastics one of the most desirable materials for electrical applications. The majority of applications involving plastics are insulation related, plastics can be made to conduct electricity by simply modifying the base material with proper additives such as carbon black.

The advent of new high-performance engineering materials has made it possible that plastics can now be used in extreme temperatures, chemicals, moisture, and stresses.

GENERAL CONCEPT ABOUT INSULATING MATERIALS

- Insulating materials are those which provides high resistance to electrical current flow.
- The majority of insulators are organic in nature, having covalent linkages.
- The primary function of plastics in electrical application has been that of insulator.
- The specific choice of an insulation material is usually determined by its application.
- Now a days plastic materials like PP, PE,PVC, epoxy, PC, Floro polymers are a few amongst the long life of polymers which have wide range of applications in this industries as insulators due to their good mechanical properties and easy fabrication.
- Typical electrical application of plastics material includes; plastic coated wires, terminal connectors, industrial and household plugs. Switches and printed circuit boards.

REQUIREMENT OF AN INSULATOR

- High insulation resistance
- Good Resistance to environmental factors
- Good arc resistance
- Mechanically strong.
- High dielectric strength.

DIELECTRIC STRENGTH

Definition :

- The dielectric strength of an insulating material is defined as the maximum voltage required to produce a dielectric breakdown.
- The dielectric strength of an insulating material is the voltage gradient at which electric failure or breakdown occurs as continuous arc.
- Dielectric strength is expressed in voltage per unit of thickness such as V/mm.

DIELECTRIC STRENGTH

SIGNIFICANCE

This test is an indication of the electrical strength of a material as an insulator. The dielectric strength of an electrical insulating material is a property of interest for any application where an electrical field will be present. In many cases the dielectric strength of a material will be the determining factor in the design of the apparatus in which it is to be used.

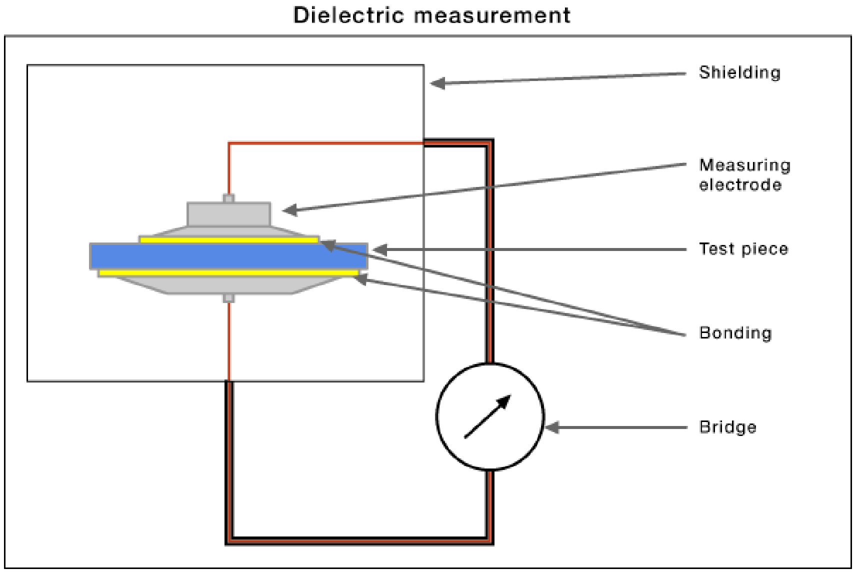
TEST METHODS : ASTM D-149 / IEC 243 –1 / BS 2782 / BS 6564

SAMPLE DETAILS & CONDITIONING

The recommended specimen type for this test is a 100 mm plaque or larger. Any specimen thickness can be used, however the most common thickness is between 0.8 or 3.2 mm

The test sample is Conditioned in standard laboratory atmosphere is 23 ± 2°C ,50± 5 % RH.

DIELECTRIC STRENGTH



EQUIPMENT DETAILS:

The instrument used for this test consists of the following :

- Voltage source
- Voltage measurement device (Bridge)
- Electrodes
- Test Chamber (Shielding)

DIELECTRIC STRENGTH

TEST PROCEDURE:

- It is insured that the main supply to the equipment is turned off.
- The test chamber is opened . The Specimen is placed in the form of sheets or plates having parallel plane surfaces and are of a size sufficient to prevent flashing over , after conditioning ,between heavy cylindrical brass electrodes, which carry electrical current during the test.
- The main supply to the equipment is switch on .The voltmeter must show zero reading.
- The voltage is raised by regulator slowly till the flashover occurs.
- The voltage at flashover is noted which is the breakdown voltage

DIELECTRIC STRENGTH

OBSERVATION, CALCULATION & RESULT :

For each sample the thickness is measured & the breakdown voltage is noted. The breakdown voltage divided by the thickness gives the value of Di electric strength.

The Dielectric value is expressed in Volt/mm.

DIELECTRIC STRENGTH

FACTORS INFLUENCING:

- Specimen thickness
- Temperature
- Humidity
- Electrodes
- Time
- Mechanical Stress
- Processing

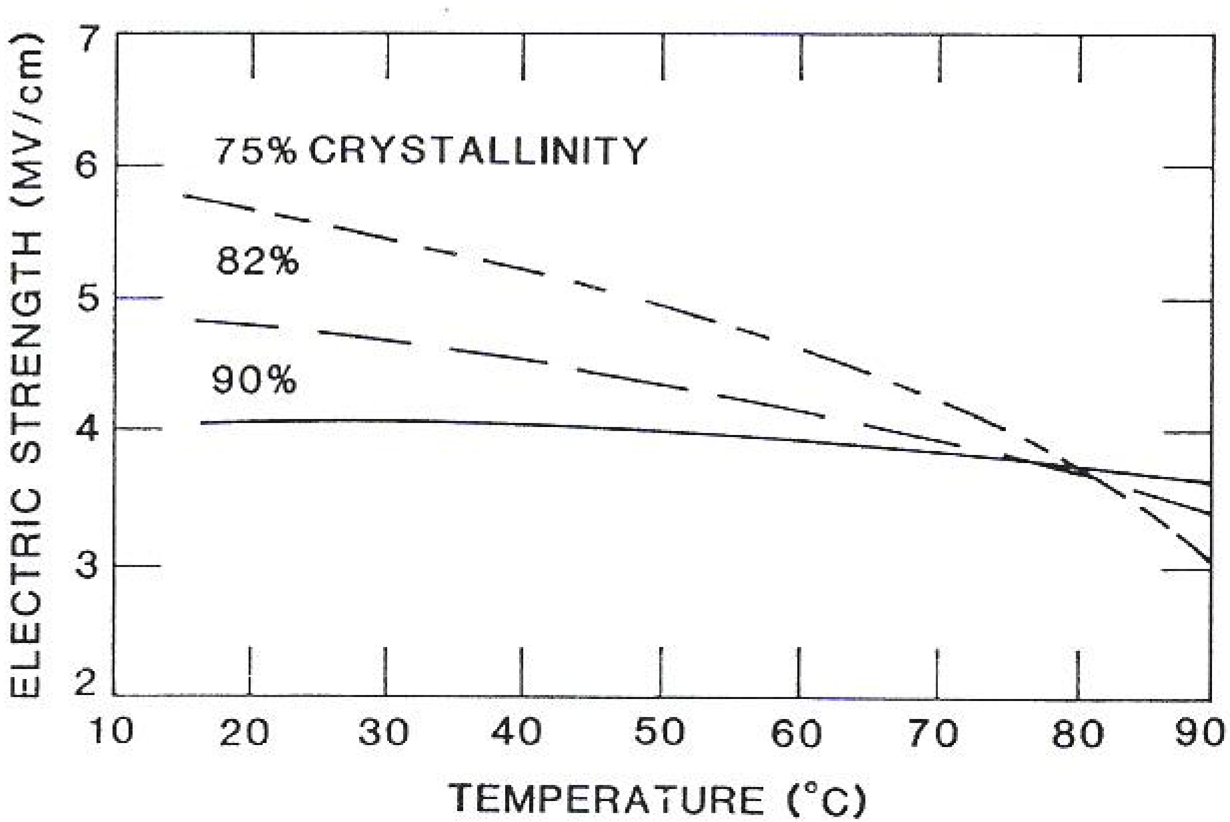
DIELECTRIC STRENGTH

SAFETY PRECAUTIONS :

- As the equipment works on high voltage an independent earthing system must be provided to the equipment.
- The test chamber must not be opened when test is in progress.
- Insulating gloves must be used while using equipment.
- Equipment must be installed with proper over load and voltage protection system.
- Appropriate exhaust system must be available.

DIELECTRIC STRENGTH

CASE STUDY : Effect of crystallinity & temperature on Dielectric strength



DIELECTRIC STRENGTH OF SOME PLASTICS

Plastics	Dielectric strength (V/mil)
Rigid PVC	800 - 1400
Thermoplastic Polyester	600 - 750
Polypropylene	650
High Impact Polystyrene	650
Nylons	350 - 560
GP Polystyrene	500
Acetals (Delrin)	500
PTFE (Teflon)	500
Polyethylene (PE)	480
Polycarbonate	450
ABS	415
Phenolics	240 - 340

DIELECTRIC CONSTANT (PERMITIVITY)

DEFINITION :

- 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.

- Dielectric constant is used to determine the ability of an insulator to store electrical energy.

DIELECTRIC CONSTANT (PERMITIVITY)

SIGNIFICANCE

When a material is to be use in electric application where high capacitance is needed, a higher dielectric constant is required.

TEST METHODS

ASTM D-150/ IEC 250

SAMPLE DETAILS & CONDITIONING

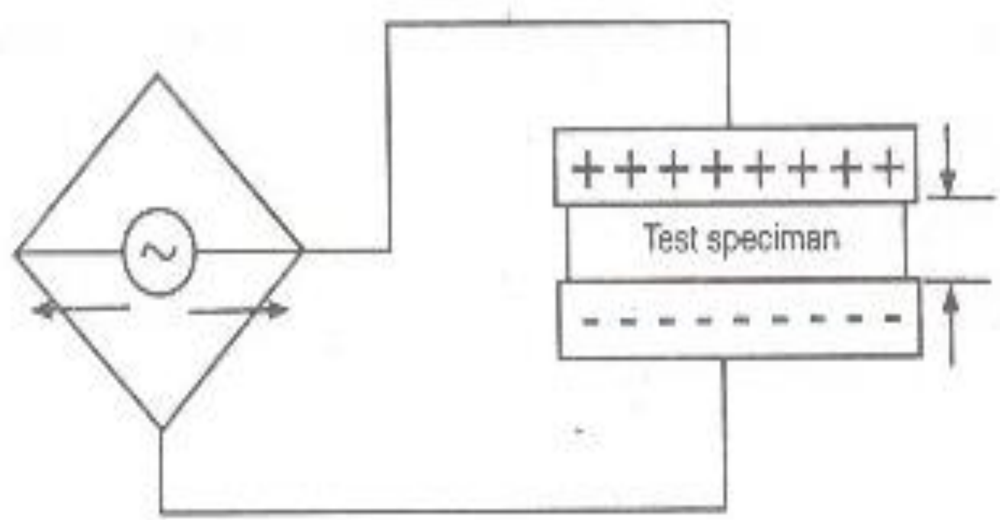
It must be larger than 50 mm circular electrodes used for the measurement.

The specimen allowed to remain the standard laboratory conditions of 23± 2°C and 50 ± 2% RH for a period of at least 16 hours immediately prior to test.

DIELECTRIC CONSTANT (PERMITIVITY)

EQUIPMENT / INSTRUMENT DETAILS:

The equipment for measurement of dielectric constant is nothing but is an equipment used to measure the capacitance.



Electrode configuration and test circuit for measurement of dielectric constant

DIELECTRIC CONSTANT (PERMITIVITY)

TEST PROCEDURE :

- Methods for measurement of capacitance can be done by three methods:

  1. Null method

  2. Resonance method

  3. Deflection method

- The test specimen is placed between the two electrodes and the capacitance is measured. Next, the test specimen is replaced by air and the capacitance value is again measured.

DIELECTRIC CONSTANT (PERMITIVITY)

OBSERVATION , CALCULATION & RESULT :

1. The Capacitance , material as dielectric (C_1) is noted.
2. The Capacitance, air or vacuum as dielectric (C_2) is noted
3. Dielectric Constant is calculated by formula (C_1/C_2)

DIELECTRIC CONSTANT (PERMITIVITY)

FACTORS INFLUENCING:

- Frequency
- Voltage
- Temperature
- Humidity
- Water Immersion
- Weathering
- Deterioration

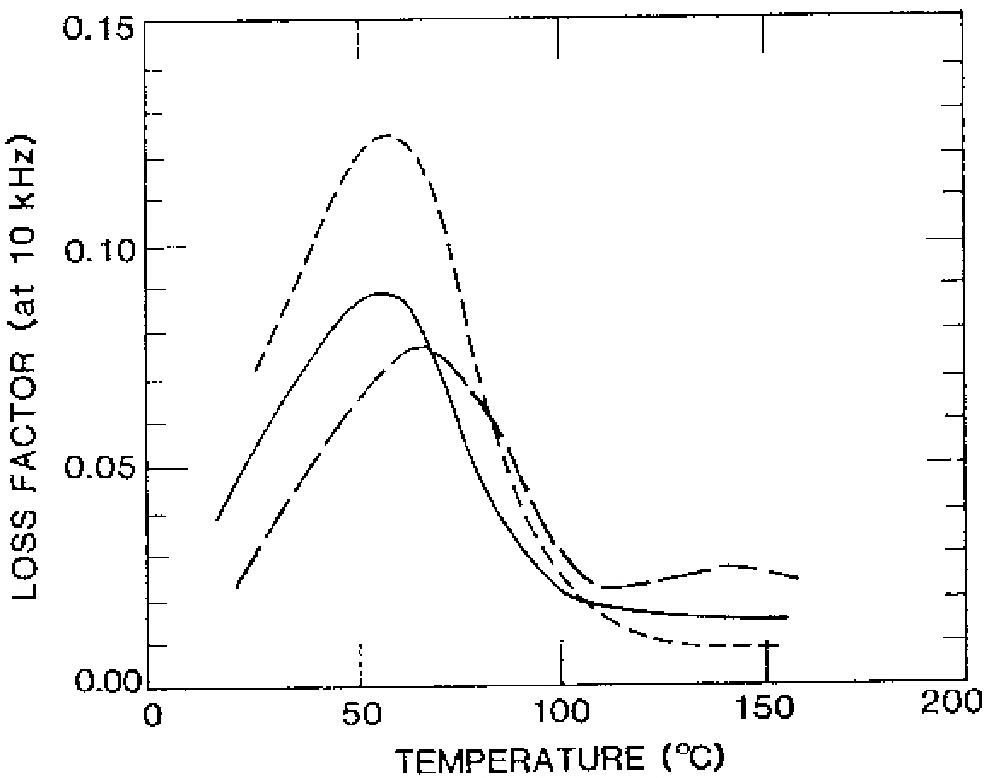
DIELECTRIC CONSTANT (PERMITIVITY)

SAFETY PRECAUTIONS:

- The test apparatus & all associated equipment electrically connected to it must be solidly grounded.
- When using the solid electrodes, the air gap between electrodes must be avoided, which may affect the result.
- The plate spacing must be adjusted accurately to a value suitable to the specimen to be tested. For low loss materials in particular the plate spacing and the specimen thickness should be such that the specimen will occupy not less than about 80 % of the electrode gap.
- Insulating gloves must be used while using equipment.
- Equipment must be installed with proper over load and voltage protection system.

DIELECTRIC CONSTANT (PERMITIVITY)

CASE STUDY : Effect of temperature on Dielectric constant (loss factor)



DIELECTRIC CONSTANT OF SOME PLASTICS

PLASTICS	DIELECTRIC CONSTANT
Melamines	5.2 – 7.9
Phenolics	4.0 – 7.0
Nylon 30% Gf	3.5 – 5.4
Epoxies	4.3 – 5.1
High impact polystyrene	2.0 -4.0
Nylon	3.5 – 3.8
Acetals	3.7
Polycarbonate 30% GF	3.48
Polysulfone 30% GF	3.4
Thermoplastic Polyester	3.2
ABS	3.2

DISSIPATION FACTOR & POWER FACTOR

DEFINITION :

DISSIPATION FACTOR:

The measure of power loss dissipated as heat due to the build-up and collapse of the dielectric field within the insulation in an A.C. circuit, especially at high frequencies, is termed as dissipation factor. It is often known as tan δ or loss tangent.

POWER FACTOR :

Power factor is the ratio of power loss in watts dissipated in the material to the product of the r.m.s voltage applied and the r.m.s current passing through the material. It is equal the cosine of the phase angle i.e cos θ.

DISSIPATION FACTOR & POWER FACTOR

SIGNIFICANCE

- In case of electrical insulation & as capacitor dielectric , the dissipation factor (ac loss) must be small in order to reduce the heating of the material and to minimise its effect on the rest of the network.
- The dissipation factor is a measure of the electrical energy lost as heat in the material serving as the dielectric substance of capacitors where the electric field is applied perpendicular to the plane of application.

TEST METHODS : ASTM D 1531 / ASTM D 1673

EQUIPMENT DETAILS & TEST PROCEDURE

For determination of dissipation factor & power factor the value of parallel capacitance and equivalent parallel resistance has to be measured. These values can be measured in same way as explained for measurement of capacitor in dielectric test.

DISSIPATION FACTOR & POWER FACTOR

OBSERVATION, CALCULATION & RESULT :

1. The Parallel Capacitance (Cp) is noted.

2. The Equivalent Parallel resistance (Rp) is noted

3. Dissipation factor is calculated by following formula D=1/w.Cp.Rp

DISSIPATION FACTOR OF SOME PLASTICS

PLASTICS	DISSIPATION FACTOR (AT 1MHZ)
Low density polyethylene	> 0.0005
High density polyethylene	> 0.0005
Acetal	0.0048
Polypropylene (isotactic)	0.0005-0.0018
PVC (unplasticized)	0.006-0.019
ABS	0.007-0.015
Polycarbonate	0.01
Polmethylmethacrylate	0.02-0.03
Polyethyleneteraphthalate	0.0208

SURFACE & VOLUME RESISTIVITY

DEFINITION :

SURFACE RESISTIVITY :

- It is defined as the ability of material to resist the leakage along the surface of the insulator.
- The surface resistivity is a measure of the resistance of the material to a surface flow of current.

VOLUME RESISTIVITY :

- It is defined as the ratio of the potential gradient parallel to the current in the material to the current density.
- The volume resistivity is a measure of the resistance of the material in terms of its volume.

SURFACE & VOLUME RESISTIVITY

SIGNIFICANCE

The insulating material should have resistance as high as possible with good mechanical, chemical and heat resisting properties .

TEST METHODS :

ASTM D-257 / ASTM D 2305 / BS 2782 / BS 3815/ ISO 1325

SAMPLE DETAILS & CONDITIONING :

The specimen will be a sheet of material, 1 to 3 mm thick, at least 10 mm large than the diameter of the unguarded electrode.

The test sample is Conditioned at 23± 2°C and a relative humidity of 50 ±5% for 24 hours.

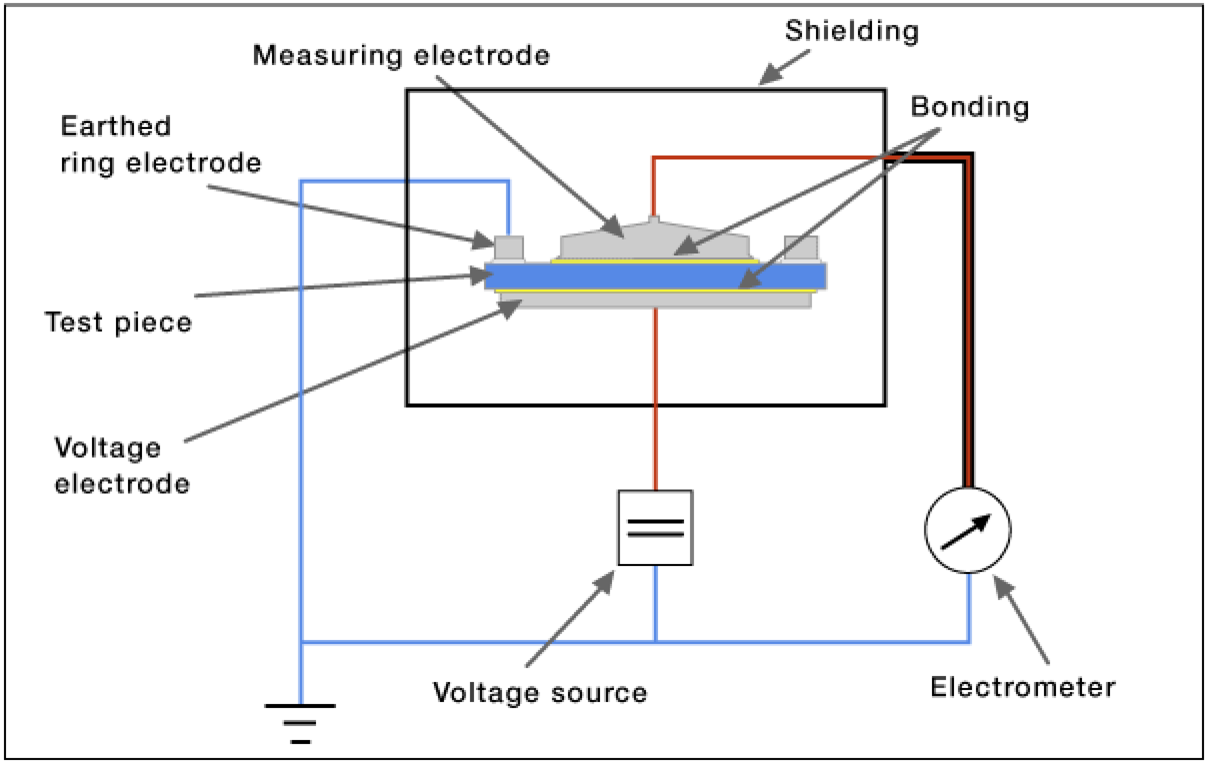
SURFACE & VOLUME RESISTIVITY

EQUIPMENT DETAILS:

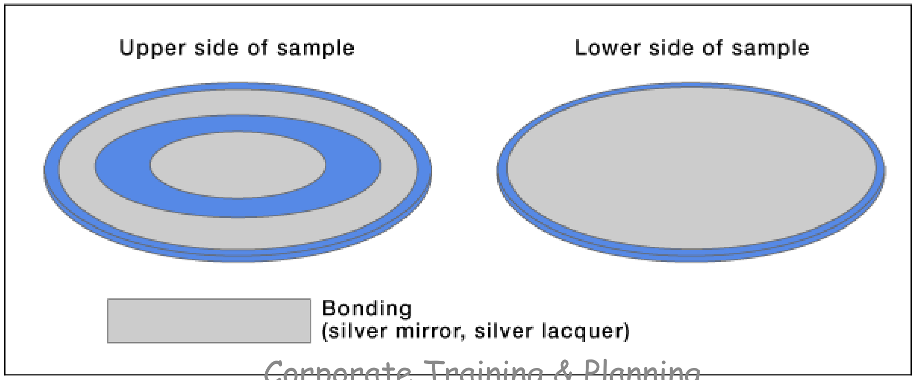
For most material the volume resistivity will be greater than 109 Ω cm and the measured resistivity using the electrodes will be about 109 Ω. Measurement in this range will require the use of an "**Megaohmmeter**" drawing "Bias" current less than 10-12 A.

SURFACE & VOLUME RESISTIVITY

Volume resistivity

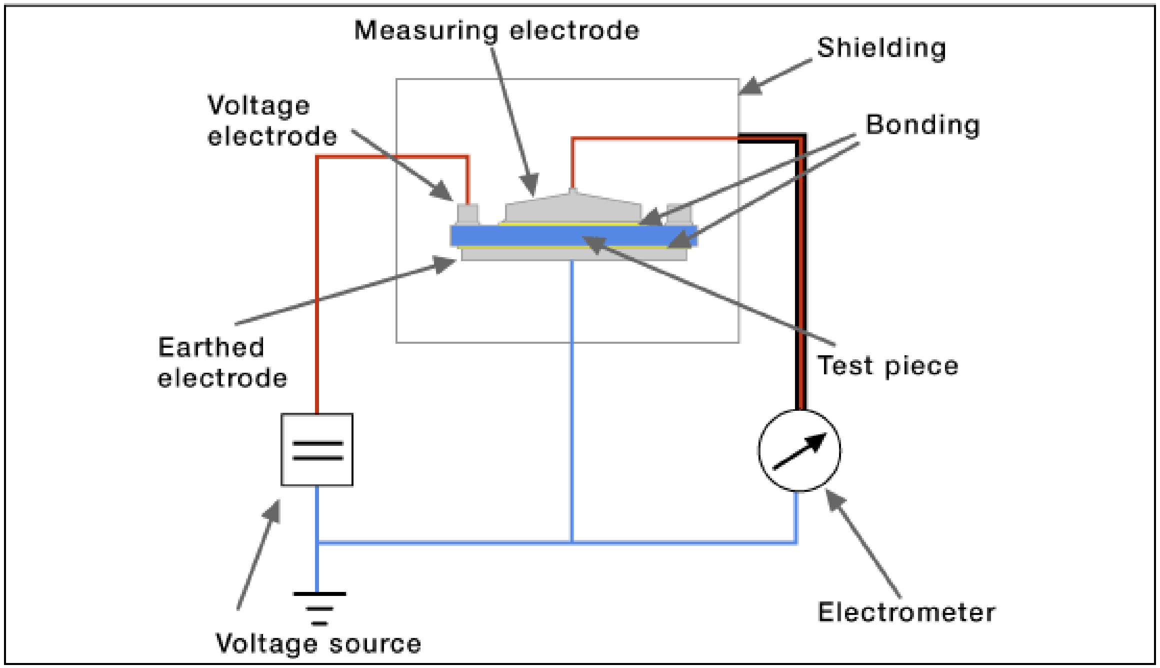


Volume resistivity

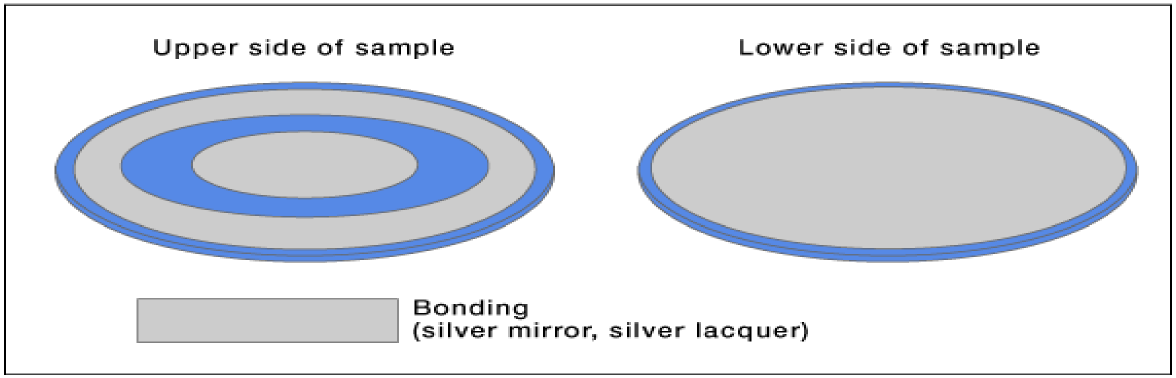


SURFACE & VOLUME RESISTIVITY

Surface resistivity



Surface resistivity



SURFACE & VOLUME RESISTIVITY

TEST PROCEDURE:

- The specimen is prepared in accordance with the particular test procedure being employed and is then conditioned as necessary.
- Any necessary intimate electrodes and contacting medium are applied. It the intimate electrodes are applied by vacuum metallizing, the specimen is conditioned after application.
- The specimen is mounted in the specimen holder/electrode assembly and connections made to the measuring instrument.
- Test potential is applied via the 'charging' position of the instrument switch for atleast about 10% of the specified electrification time (usually about 5 seconds).
- The instrument connection switch is moved to the "read" position and the range switch set to an appropriate level at least 10 seconds before reading the resistance at the specified electrification time. The time of electrification is usually 1 min. 7 the applied voltage is 500$\pm$5 Volt. The indicated resistance will not usually be constant but will steadily increase, at a rate dependent on the test material.
- If necessary, the capacity of the specimen/electrode assembly is measured.

SURFACE & VOLUME RESISTIVITY

OBSERVATION , CALCULATION & RESULT

VOLUME RESISTIVITY

1.The Volume Resistance (Rv) is noted from the meter.
2. The Area of electrode (A) is calculated.
3. The thickness of the specimen (t) is measured.
4. Volume Resistivity is calculated by following formula $\rho_v = R_v A/t$

SURFACE RESISTIVITY

1. The Surface Resistance (Rs) is noted from the meter.
2. The parameter of guard electrode (p) is calculated.
3. The gap between the electrodes (g) is measured.
4. Volume Resistivity is calculated by following formula $\rho_s = R_s p/g$

SURFACE & VOLUME RESISTIVITY

FACTORS INFLUENCING:

- A small amount of impurities in a polymer can considerably change its electrical resistance.
- Prolong uses of an insulator may cause degradation and adversely affect the insulation resistance following the chemical charge which take place in the polymer.
- The resistivity of the polymer is also affected by the type and amount of additive used.
- The nature and geometry of electrodes.
- Magnitude and time of applied voltage.
- Test conditions i.e. temperature & humidity.
- Molding defects in the test specimen.
- Moisture content in the test specimen.

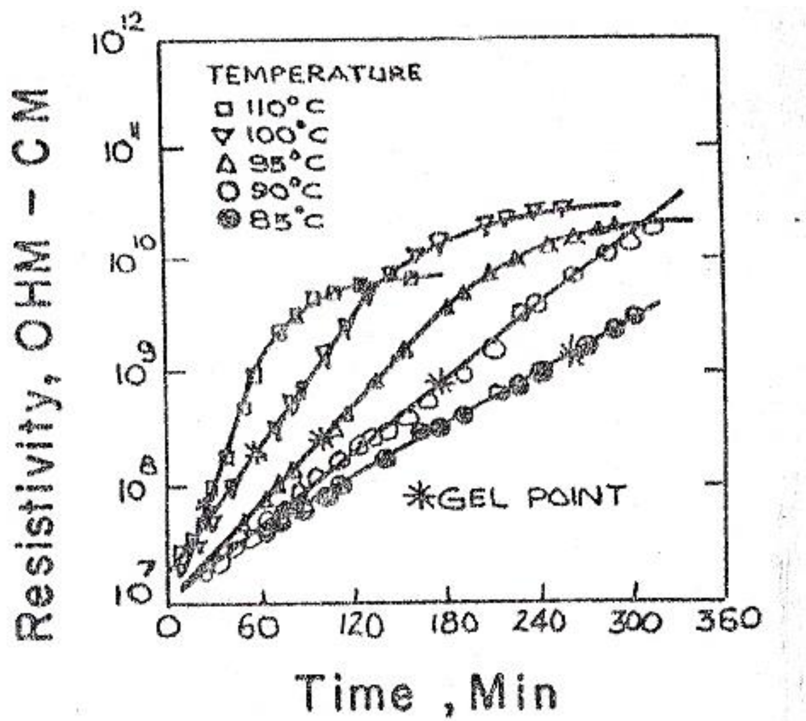
SURFACE & VOLUME RESISTIVITY

SAFETY PRECAUTIONS:

- The Test apparatus and all associated equipment electrically connected to it must be solidly grounded.
- The electrodes must be handled carefully to avoid damage etc
- Insulating gloves must be used while using equipment.
- The surfaces of the specimen must be smooth & perfectly clean for getting the accurate Value.
- While using the digital meters, it must be kept in switched on condition for some time before starting the test to stabilize the reading.
- The equipment must not be frequently turned-on and turned-off.

SURFACE & VOLUME RESISTIVITY

CASE STUDY : Effect of temperature on Resistivity



VOLUME RESISTIVITY OF SOME PLASTICS

PLASTICS	VOLUME RESISTIVITY (Ω-CM)
Urea Formaldehyde	10^{12} - 10^{13}
Acrylics	10^{14}
Epoxy	10^{14}
Polystyrene	10^{16}
SAN	10^{16}
ABS	$5x\ 10^{16}$
Polycarbonate	$2x\ 10^{16}$
Flexible PVC	10^{11} – 10^{15}
Nylon 6,6	10^{14} – 10^{15}
Rigid PVC	10^{15}
Polyethylene	10^{16}
Polypropylene	10^{16}
Thermoplastic Polyester	$3x10^{16}$
PTFE	10^{18}

ARC RESISTANCE

DEFINITION

Arc resistance is defined as the ability of the plastic material to resist the action of a high voltage electrical arc, and is usually stated in terms of time require to form material electrically conductive.

SIGNIFICANCE

It is used for differentiation among silmilar materials with respect to their resistance to the action of high voltage low current to the surface of the insulation. By this action a conductive path is made due to thermal & chemical decomposition and erosion.

ARC RESISTANCE

TEST METHODS : ASTM D 495

SAMPLE DETAILS & CONDITIONING

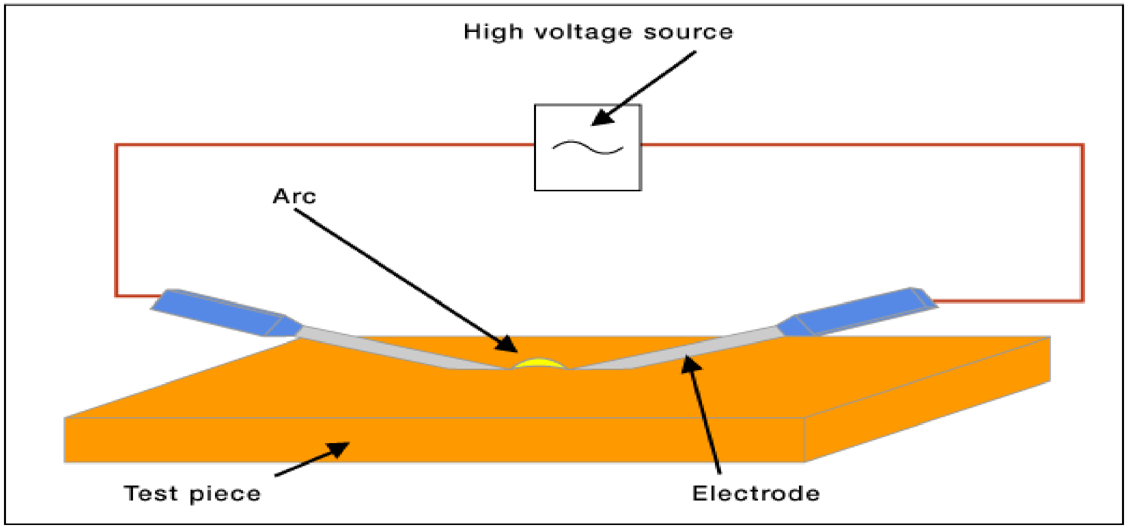
- A flat surface sample with minimum 1 mm thickness is used. When testing molded parts, the arc is applied to a location deemed most significant
- The specimen is warmed in a 50°C oven for about 30 minutes.

ARC RESISTANCE

EQUIPMENT DETAILS: The instrument used for this test consists of the following

- Voltage generation and control device
- Autotransformer
- Voltmeter & Mill ammeter
- Interrupter
- Timer
- Electrodes
- Electrode assembly

Arc resistance



ARC RESISTANCE

TEST PROCEDURE:

- It is insured that the main supply to the equipment is turned off.
- The test chamber is opened. The specimen is placed in the electrode assembly and the spacing between the electrodes is checked which are generally separated by 6.35 mm and placed in vertical position at an angle of 35° from the horizontal plane of specimen surface.
- The main supply to the equipment is switched on .
- The equipment is calibrated so as to apply open circuit voltage of 12.5 KV and current is adjusted to 10 mA. Once arc is maintained at this test condition timer is turned on.
- Initially arc severity is maintained with current of 10mA for 1 min. At the end of each 1 min. the arc severity is increased stepwise.
- The time for the formation of conductive path (failure) is recorded.

ARC RESISTANCE

OBSERVATION, CALCULATION & RESULT :

- The failure is characterized by carbonization of the surface, tracking, localized heating to incandescence or burning.
- The total time to failure is recorded.
- Arc resistance is measured in seconds to failure.

ARC RESISTANCE

SAFETY PRECAUTIONS:

- The test apparatus & all associated equipment electrically connected to it must be solidly grounded.
- The electrodes must be cleaned in regular intervals.
- Insulating gloves must be used while using equipment.
- The test chamber must not be opened when test is in progress.

ARC RESISTANCE OF SOME PLASTICS

PLASTICS	ARC RESISTANCE (SEC)
Low density polyethylene	135-160
Medium/ High density polyethylene	200-235
Polypropylene (Isotactic)	136-185
Nylon6 and 6,6	140
Polystyrene	60-100
Polycarbonate	10-120
Acrylonitrile –butadiene-styrene (ABS)	50-85
Poly (vinyl chloride) (unplasticized)	60-80
Styrene Acrylonitrile	100-150
Polytetraflouroethylene	>200
Poly (methyl methacrylate)	No track
Acetal (Polyoxymethylene)	129

COMPARATIVE TRACKING INDEX

DEFINITION

Comparative tracking index is defined for electrical insulating materials as the numerical value of that voltage which will cause failure by tracking when the number of drops of contaminant required to cause failure is equal to 50.

SIGNIFICANCE

Electrical equipment may fail as a result of electrical tracking of insulating material that is exposed to various contaminating environments & surface conditions .

COMPARATIVE TRACKING INDEX

TEST METHODS : ASTM D 5288

SAMPLE DETAILS

Typical test specimens can be 50 mm or 100 mm diameter disks or any similar shape.

Minimum thickness shall be 2.5 mm

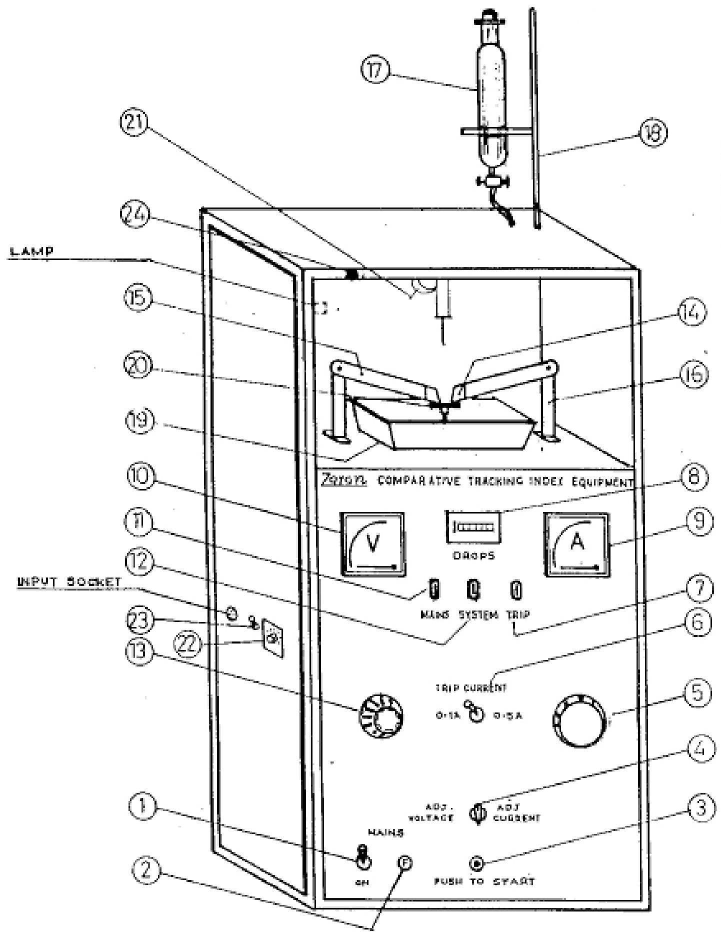
COMPARATIVE TRACKING INDEX

EQUIPMENT DETAILS:

The equipment for Comparative tracking index consists of following :

- Variable power source.
- Voltmeter
- Ammeter
- Current Limiting Resistor
- Shorting switch: Single –pole single – throw
- Over-current Relay
- Platinum Electrode
- Dropping apparatus

COMPARATIVE TRACKING INDEX



1. Main switch
2. Fuse
3. Push button
4. Function selector
5. Current control knob
6. Tripping circuit selector
7. Trip pilot lamp
8. Drops counter
9. Ammeter
10. Voltmeter
11. Mains pilot lamp
12. System pilot lamp
13. Voltage control knob
14. Electrode
15. Electrode arm
16. Pillars
17. Burette
18. Burette stand
19. Tray
20. Adjustable platform
21. Pump
22. Timer knob
23. Lamp switch
24. Door switch

COMPARATIVE TRACKING INDEX

TEST PROCEDURE:

- It is insured that Main supply to the equipment is off.
- The dropping assembly is filled with solution and set the counter at 0.
- The test specimen is placed on the supporting platform so that the electrodes can be placed on the specimen.
- The electrodes are positioned in such a fashion, so that the chisel edges contact the specimen at a 60° angle between electrodes and so that the chisel faces are parallel in the vertical plane and are separated by 4 ± 0.2 mm.
- The power to equipment is turned ON.

COMPARATIVE TRACKING INDEX

- The power source is set to the desired voltage level.
- The drop interval is regulated so that the time interval between two consecutive drops must be 30 ± 5 seconds.
- The reading of no. of drops is recorded at different voltage levels such that at least two levels produce failures in less than 50 drops and two levels greater than 50 drops
- A test may be repeated on a given specimen provided the electrode gap is positioned a minimum of 25 mm from any area affected by a previous test or from any edge.
- Test voltage should be limited to 600V or less. Testing at higher voltages will generate electric discharges above the surface of the specimen, which will produce erroneous results.

COMPARATIVE TRACKING INDEX

OBSERVATION, CALCULATION & RESULT :

- The reading of voltage & no. of drops are noted.
- A graph is plotted between the number of drops of electrolyte at breakdown versus voltage. On the curve the voltage which corresponds to 50 drops is noted. This voltage is the comparative track Index (CTI)
- The CTI is expressed in volts.

COMPARATIVE TRACKING INDEX

SAFETY PRECAUTIONS:

- The test apparatus and all associated equipment electrically connected to it must be solidly grounded.
- The electrodes must be cleaned on regular intervals.
- Insulating gloves must be worn while operating the equipment
- The test chamber must not be opened while test is in progress
- The concentration of electrolyte must be checked in regular intervals

COMPARATIVE TRACKING INDEX

STATIC CHARGES AND ANTISTATIC CHARGES

- Static electricity can be simply stated as an excess or deficiency of electrons on a surface. In cases where insulating material is separated from another insulator (or from a conductor), the electrostatic charges generated may become unbalanced which can leave an excess or deficit of electrons on the insulating material.

- Static charges occurs when two nonconductive bodies rub or slide together or separate from one another. It is often referred to as the tribo electric effect. One of the material will result in a positive electrical charge on its surface and the other a negative charge.

- A number of factors influence the polarity and size of the charge. They are cleanliness, pressure of contact, surface area and speed of rubbing or separating.

CONDUCTING POLYMERS

INTRODUCTION

Conducting plastics materials are those plastics which are capable of carrying the current through itself. Generally thermoplastics can be used as conductive plastics. Modification of thermoplastics by the addition of a conductive material to the resin matrix results in a product or compound having conductive properties.

CONDUCTING POLYMERS

ADVANTAGES OF CONDUCTIVE PLASTICS OVER METAL CONDUCTORS:

- Conductive plastics are more cost effective than metals in some applications requiring electrical conductivity. The economics of the injection moulding process is one reason for this advantage.

- Another advantage is the design capability of combining several metal fabrication steps into a single moulding step with plastics.

- In addition, conductive plastics offer significant performance and design advantages over metals.

- Conductive plastics have superior impact resistance and non corrosiveness over metals

CONDUCTING POLYMERS

TYPES OF CONDUCTIVE PLASTICS :

I. The first is one which is filled with conductive filler particles, such as carbon black or metal powders. Such plastics generally have resistivities from about 107 Ωcm down to about 10-2 Ωcm. In this range they are relatively insensitive to temperature, humidity and voltage, but if they are flexible they are sensistive to strain history.

II. The second type of conductive polymers contains additives known as antistatic agents, which are organic molecules that diffuse to the surface and either dissociate to give mobile ions or are hydrophilic and collect a film of moisture on the surface. These are sometimes highly sensitive to humidity and temperature but little is known about their sensitivity to voltage and they are insensitive to strain.

CONDUCTING POLYMERS

ADVANTAGES OF USING THERMOPLASTICS AS A CONDUCTIVE PLASTICS :

- Light weight
- Cost effectiveness
- Appearance
- Convenient processing and finishing

CONDUCTING POLYMERS

CONDUCTIVE ADDITIVES :

- Suppliers of conductive thermoplastics products uses a number of conductive additives. The examples of these conductive additives are as under:

Reinforced type	Additive type
PAN carbon fibre	Carbon black powder
Pitch carbon fibre	Aluminium flakes
Nickel coated carbon fibre	Metal powders
Stainless steel fibres	Organic-antistatic
Aluminium fibres	Metal coated glass beads
Metallized glass fibres	Metal coated mica

THANK YOU