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Production Of High Efficiency Insulators By Using Polymer Technology

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Abstract:-During the last decade, equipment connected to the electricity distribution network has evolved towards a widespread use of polymeric insulating aterials. Significant improvements have been gained with respect to porcelain-based insulators. On the technical side, sustained hydrophobicity, increased pollution resistance, lightweight, and resistance to vandalism, are some of the advantages. Moreover, on the economic side, increased reliability, along with ease of maintenance and storage, have all lead to relevant overall cost savings for the users, and to improved service quality and energy dependability for the final customers. The process, though, has not been extent of risks. The technology was rather new and the minimum requisites and quality criteria have not been fully understood until recently. It has been in the last five years that the need for specific testing and quality requirements have been definitely settled, based on more than 30 years of accumulated experience. This situation has facilitated market penetration of poorly designed, un-tested and under-performing equipment, which has in turn created uncertainties in users. This report is divided into three sections. The study has focused on those design tests that are specifically related to the polymeric nature of the isolating basis, and it was motivated by the large variability on quality and performance that has been detected in the market.

Keywords:insulator, Polymer, Heat,Voltage, String

INTRODUCTION

1.1 POLYMER VS. CERAMIC INSULATION

A number of reasons converge in the growing application of polymer-based materials as insulators in high voltage equipment. In essence, the extraordinary surface properties of certain polymers are very useful for its application as electric insulation in medium-to high pollution areas. A wise choice of polymer materials allows for significant performance improvements by significantly reducing the dry-band arcing phenomena, the surface leakage currents (in particular under heavy rain or pollution) and the flashover frequency and probability. Leakage current control is key physicochemical property of certain polymeric materials, when properly designed and prepared.

These same materials do also present an extraordinary resistance to harassing environmental conditions and to ageing degradation. The chemical structure of a polymeric material must be designed so that the molecular bonds are resistant to visible and UV light. Then, any properly designed insulating system manufactured with such a material can offer a service life in excess of 30 years, with excellent performance even under heavily polluted environments or other harassing conditions. This is a fact that has been already validated by experience in large-scale deployment of polymeric insulation systems in high voltage networks. At the microscopic level, the key points to be mastered and understood are the distinctive physicochemical properties at the polymers surfaces, and their stability under strong electromagnetic fields and/or aggressive environmental conditions (high temperatures, heavy pollution,…).

These surface properties of polymer materials can be summarized to be:

(1)Surface electronic structure;
(2) Surface reconstruction of engineered chemical bonds; and
(3) Adsorption energy and dynamics, defining dissociative vs molecular adsorption;

Diffusion barriers, and migration pathways through the surface associated with a number of chemical species, whose behavior on-surface determines the approppriatness of a specific material for the task at hand. These microscopic characteristics are those that endow the material with the required macroscopic functionality, such as the useful thermodynamic properties commonly known as high surface-tension, self-cleaning capabilities, and self regeneration.

2. INSULATORS

Definition

"Insulator is a device which does not allows the flow of current through it". In general, the insulators should have the following desirable properties.

i.High mechanical strength in order to withstand conductor load, wind load etc.
ii.High electrical resistance of insulator material in order to avoid leakage currents to earth.
iii.High relative permittivity of insulator material in order that dielectric strength is high.
iv.The insulator material should be non-porous, free from impurities and cracks otherwise them permittivity will be lowered.

(v) High ratio of puncture strength to flashover

The most commonly used material for insulators of overhead line is porcelain but glass, steatite and special composition materials are also used to a limited extent. Porcelain is produced by firing at a high temperature a mixture of kaolin, feldspar and quartz. It is stronger mechanically than glass, gives less trouble from leakage and is less effected by changes of temperature.

2.1 Types of Insulators

The successful operation of an overhead line depends to a considerable extent upon the proper selection of insulators.There are several types of insulators but the most commonly used are

1.Pin type insulators.
2.Suspension type insulators.
3.Strain insulator
4.Shackle insulator

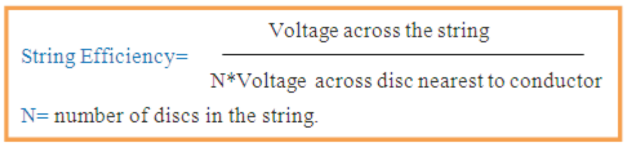
Causes of insulator failure.

Insulators are required to withstand both mechanical and electrical stresses.The latter type is pirmarily due to line voltage and may cause the breakdown of the insulator. The electrical break-down of the insulator can occur either by flash-over or puncture. In flash-over, an arc occurs between the line conductor and insulator pin (i.e., earth) and the discharge jumps across the air gaps, following shortest distance.

2.3 String Efficiency

As stated above, the voltage applied across the string of suspension insulators is not uniformly distributed across various units or discs. The disc nearest to the conductor has much higher potential than the other discs. This unequal potential distribution is undesirable and is usually expressed in terms of string efficiency.

The ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as string efficiency i.e.,



$$\text{String Efficiency} = \frac{\text{Voltage across the string}}{N^{*}\text{Voltage across disc nearest to conductor}}$$

N= number of discs in the string.

3. POLYMER INSULATORS

3.1 POLYMERS

SILICONE POLYMER

Silicone caulk can be used as a basic sealant against water and air penetration.Silicones are polymers that include silicon together with carbon, hydrogen, oxygen, and sometimes other elements. Some common forms include silicone oil, silicone grease, silicone rubber, silicone resin and silicone caulk.

3.1.3 Polymer properties

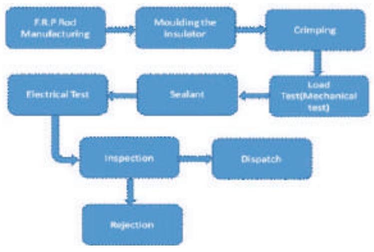
Polymer properties are broadly divided into several classes based on the scale at which the property is defined as well as upon its physical basis. The most basic property of a polymer is the identity of its constituent monomers. A second set of properties, known as microstructure, essentially describe the arrangement of these monomers within the polymer at the scale of a single chain. These basic structural properties play a major role in determining bulk physical properties of the polymer, which describe how the polymer behaves as a continuous macroscopic material. Chemical properties, at the nano-scale, describe how the chains interact through various physical forces. At the macro-scale, they describe how the bulk polymer interacts with other chemicals and solvents.

3.2 Comparison between Polymer and Porcelain Insulators

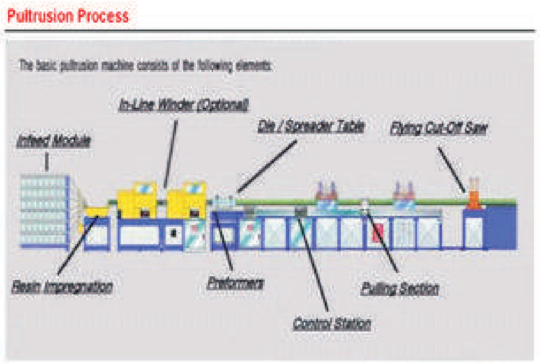
Polymer insulators present substantial advantages over ceramic or glass insulators: excellent and maintenance-free performance under heavily polluted environments, lightweight and ease of handling and installation, and anti-vandalic performance, to name but a few. It must be reminded that, under harassing environmental conditions, it is a common practice to cover ceramic insulators with silicone rubber coatings in order to reach acceptable performance, a practice that is costly, complex, and even dangerous, along with rather inefficient when compared with the logical solution to these performance problems: substitution of the underperforming insulators with modern polymer insulators.

3.4 Production of Polymer Insulator

Block Diagram



3.5 FRPROD MANUFACTURING



Fiber-reinforced plastic (FRP) (also fibre-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, basalt or aramid, although other fibres such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinylester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industries.

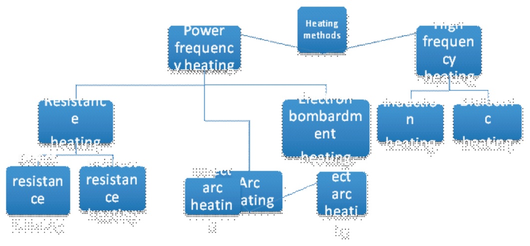
3.5.2 ELECTRIC HEATING

The process of heating using electrical energy is known as electrical heating.

Heating is required for both domestic and industrial purposes. The following are some of the applications of electrical heating:

Methods of Heating

The following are the different methods of electric heating



Direct resistance heating
Indirect resistance heating

Varying voltage using auto transformeror induction regulator

The temperature of the resistance furnace can be controlled by auto transformer by providing different taps on the auto transformer as shown in fig.1 or by varying the position of the rotor of an induction regulator as shown in fig.2 to get a variable voltage supply

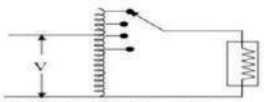


Fig.1 Auto transformer for temperature control of resistance furnace

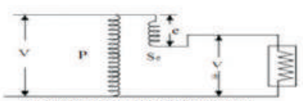


Fig.2 Equivalent circuit of induction regulator

Varying voltage by using series impedance
Varying voltage by using variable number of elements
Varying voltage by using series parallel or star delta arrangement
Varying voltage by periodically switching on or off electric supply

The temperature of a oven can also be controlled by periodically switching on or off electric supply particularly in case of small ovens. Here supply is given to the oven through a thermostat switch which switches on and switches off the supply at particular temperatures. The final temperature is proportional to the ratio of

$$\left(\frac{\text{time interval switch remains on}}{\text{total time interval of on off cycle}}\right)$$

The advantage of this method is that it is more efficient than series impedance method.

Design of heating element

The heating elements are normally made of wires of circular cross – section or rectangular conducting ribbons. Under steady state conditions, a heating element dissipates as much heat from its surface as it receives the power from the electric supply. If P is the power input and H is the heat dissipated by radiation, then under steady state conditions P = H. Heat radiated by a body, as per Stefan's law of radiation is given by

$$H = 5.67\,K\,e\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] W/m^2$$

Where T_1 and T_2 are absolute temperatures in Kelvin of hot and cold bodies respectively. e = emissivity whose values is unity for black body and 0.9 for heating elements. K = radiating efficiency whose values is unity for single element and may go down upto 0.5 for many elements. Both e and K are dimensionless.

$$Since\ P=\frac{V^2}{R}\quad therefore\ R=\frac{V^2}{P}$$

$$Also\ R=\rho\frac{L}{A}\quad or\ R=\frac{\rho L}{\pi/4d^2}$$

$$therefore\ P=\frac{\pi d^2V^2}{4\rho L}$$

$$or\ \frac{L}{d^2}=\frac{\pi}{4}\frac{V^2}{P\rho}\qquad(1)$$

If H is the heat dissipated by radiation per second per unit surface area of the wire then heat radiated per second = (πd) x L x H

Under steady state conditions P = (πd) x L x H

$$\text{Therefore}\ \frac{\pi d^2V^2}{4\rho L}=(\pi d)\times L\times H$$

$$or\ \frac{d}{L^2}=\frac{4\rho H}{V^2}\qquad(2)$$

From equation no. (1) and (2) we can find the values of L and d.

In case of ribbon type element if 'w' and 't' are the width and thickness of the ribbon respectively then

$$P=\frac{V^2}{R}=\frac{V^2}{\rho L/A}=\frac{V^2}{\rho L(w\times t)}=\frac{V^2wt}{\rho L}\qquad(3)$$

$$Or\ \frac{L}{wt}=\frac{V^2}{\rho P}\qquad(4)$$

Heat lost from ribbon surface = 2(w + t)LH Since in case of the ribbon type of element the thickness 't' is negligible in comparison with respect to width. Therefore heat lost from the ribbon surface is given by = 2wLH (5) From equation (3) and (5) we have

$$\frac{V^2wt}{\rho L}=2wLH\qquad(6)$$

$$Or\ \frac{t}{L^2}=\frac{2\rho H}{V^2}\qquad(7)$$

Diagrams for FRP

Mixing of Apex oil

Manufacture setup

Manufacture set for.R.PRod diameters and no. of glass rolls required

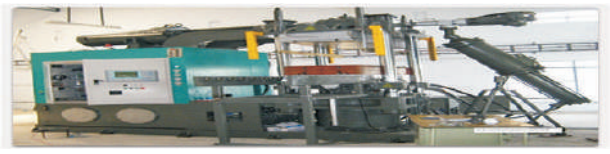
Cutting of FR.PAs per ISO-1998-2001

3.6 MOULDING

Product Description

We have five types of plastic machine for plastic molding, they are standard injection machine, synchronized injection machine, injection machine with variable pump, injection machine with servo motor, high speed injection molding machine, and it could satisfy all kinds of customer's requests.

Intr oduction:



Moulding Machine

1. Reliable plastic injection machine with servo motor, equiped with servo motor, closed loop control for pressure and flow Low noise, high precision. We design, manuafcture and supply our own brand of injection molding machine called "Longsheng" with clamping force ranged from 680kn to 16800kn, injection weight from 63G to 10000g, and can provide custom-builtmachine.

2. Inject all kinds of plastic parts, bottle preform, engineering plastic, UPVC, PVC, PE pipes fitting, pomponents for automotive, household, eletronics, telecommunication.

3.7 METAL FITTING AND CRIMPPING

After moudling the metals are fitted at the ends of FRP rod and this is crimpped with suitable force i.e 45KN for 33KV post insulators.

Crimpping helps the metal to hold fiber rod.

The type of metal fitting decides the type of insulators(pin, post, solid core etc)

CRIMPPING OF MACHINE

CRIMPPING OF INSULATOR

Table 2.

Kv of insulator	Force in KN
11	5
33	45
132	120

3.8 SEALANT

The product after assembling process, will be tested for mechanical load, routine tests and high voltage tests as per IEC standards

The final product after the above process & testing will be ultimately packed.

Now insulators will be ready for clearance to the end customers, the fixing of labels, batch number and date of manufacturing are all done.

The finish products are completely tested after obtaining the routine test reports, the stocks are released for sale.

3.9 Models of Polymer Insulators


Stay Arm Insulator


Line Post Insulators

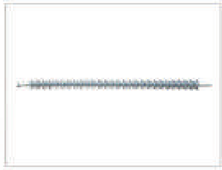

High-Voltage Insulator


Bracket Tube Insulator


Creeage Insulator


High Voltage Insulators


Power Insulators

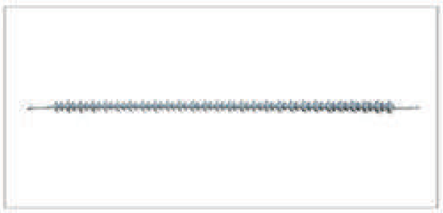

Power Insulators

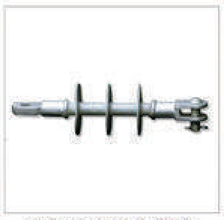

Power Insulators


Power Insulators


Pin Insulators


High Tension Insulator


Power Insulators


Power Insulators


Power Insulators

4. TESTS INVOLVED IN POLYMER INSULATORS

4.1 Classification of Tests

Based on the purpose of testing, the tests to be performed on polymer insulators are classified in four categories as follows:

1. Design Tests

Design tests are performed to verify the suitability of the manufacturer's design, materials, manufacturing process and technology. When an insulator is submitted to the design tests, the results shall be considered valid for all insulators of the same design that are represented by the tested one. The design tests are performed once. Design tests shall include the following tests:

4.2. Type Tests

Type tests verify the main characteristics of the insulators, which depend mainly on its shape and size. They shall be repeated when the design, type, or size of the insulators changes.

Three production line insulators of the relevant type shall meet the requirements. The following tests are recommended for this type of testing

i) Low-Frequency Dry Flashover Test
ii) Low-Frequency Wet Flashover Test
iii) Critical Impulse Flashover Test
iv) Radio Influence Test

4.5. Description and Procedure of Tests

Tests normally performed on an insulator by the manufacturer and the users are described below:

1 Water Penetration Test

Various materials absorb varying amounts of water that may affect the polymeric materials on different ways. Electrical properties change most noticeably with moisture absorption. In particular, the dielectric strength of materials varies greatly with absorbed water and materials that absorption. In particular, the dielectric strength of materials varies greatly with absorbed water, and materials varies greatly with absorbed water, and materials that absorb almost no water are favored for electrical insulation.

Mechanical properties are also deteriorated by moisture to some extent. Water penetration test is intended to determine the insulator resistance to moisture. Three samples of the insulator shall be kept immersed in boiling tap water, having 0.1% by weight of NaC1, for 100 hours. At the end of this period, the insulators shall remain in the vessel until the water cools to approximately 50°C. This temperature shall be maintained until the verification tests start. The verification tests consist of the sequence of tests described in 1.1 through 1.3 and shall be completed within 48 hours. These tests are described as followed:

a. Visual Examination

The housing shall be inspected visually. No cracks and no sign of dissolving or crumbling are permitted.

b. Steep Front Impulse Voltage Test

An impulse voltage with a front steepness of at least 1000 kV/ms shall be applied to each test section. Each test section shall be stressed with 25 impulses of positive and 25 impulses of negative polarity in accordance with ANSI standard and 10 impulses of positive and 10 impulses of negative polarity in accordance with CSA Standard. Each impulse shall cause an external flashover of the test section. No puncture shall occur.

c. Power Frequency Voltage Test

Each test specimen shall be individually subjected to 80% of its average flashover voltage as determined by averaging five flashover voltages on each of the three test specimens. The flashover voltage shall be corrected to standard conditions. The flashover voltage shall be reached within 1 minute by increasing the voltage linearly from zero. The voltage shall be maintained for 30 minutes. No puncture shall occur and the temperature of the shank measured immediately after the test shall not be more than 20°C above ambient.

d. Hardness Test

The hardness of two sheds of each insulator shall be measured in accordance with ASTM D2240. The hardness must not change from the pre-boiled specimen by more than 20%.

2 Aging and Accelerated Weathering Test

Outdoor weathering is a natural phenomenon which affects all materials to some extent. Outdoor weathering includes the effects of varying temperature, humidity, rain, wind, impurities in the atmosphere, and the heat and ultraviolet rays of the sun. Under such conditions, the surface of an insulating material may be permanently changed.

Physically by roughening and cracking and chemically by the loss of soluble components and by the reactions of the salts, acids, and other impurities deposited on the surface. Surfaces become hydrophilic and water penetrates more easily into the volume of the material. Three samples of the weathershed material shall be tested for 1000 hours by one of the following test methods, except that test without water is not permitted. Surface defects such as cracks and blisters are not permitted.

3. Dry Penetration Test

Three 10-mm long cross sections of the insulator shall be tested for porosity by performing a dye penetration test. The samples shall be placed upright on a layer of steel or glass balls in a 1% alcohol solution of fuchsin dye. The time taken for the dye to rise through the samples shall be longer than 15 minutes.

5. Power Arc Test

Three insulators having any one design of end fittings shall be tested for power are endurance while tensioned horizontally at 3000 lb. An arc shall be initiated across the insulator by means of a copper shorting fuse wire. The arc shall burn 15 to 30 cycles and its current magnitude is determined by ampere-time product (I X t) equal to a minimum of 150 kA cycles. Each insulator is only acceptable if there is no exposure of the core, no mechanical separation of the insulator, and no cracks in the housing.

6. Tracking and Erosion Test

The long -term performance of a polymer material used in electrical insulation design is directly related to the leakage current and the dry-band discharge that develop in service. Service experience has shown that the amplitude and frequency of dry-band discharges on electrical insulation are not dependent on design alone but also dependent on the surface properties of the polymer material used. For many years, tracking chamber methods had been proven to be very reliable in providing enough data on expected performance for a particular model insulator under severe contaminated conditions.

Tracking chambers can be classified in term of the process of wetting the sample into three groups namely salt-fog chambers, tracking wheel chambers and drizzle chambers. The tracking wheel test method imposes wet and dry cycles on a stressed surface of specimens in order to simulate the formation of dry-band arcing as it is experienced in service. It is designed to evaluate insulator shapes and/or materials for outdoor applications.

Surface degradation in outdoor applications of either erosion or tracking takes place only in association with arcing over dry bands, which developed during or immediately after precipitation. The surface damage, erosion, or carbonization results from the heat of the arc, and this damage accumulates until the surface between the electrodes can no longer sustain the applied voltage.

As this mechanism is the same as occurs in service, correlation with experience has been good. Three insulators shall be tested for resistance to tracking on a tracking wheel chamber. At the end of test, there shall be no significant signs of erosion and tracking. Each individual insulator shall not suffer more than two flashover provided no damage occurs to the surface of the insulator

7. Tensile Load Test

The element of time plays an important role in characterizing the mechanical properties on many polymer materials, particularly plastics and elastomers. Both plastics and elastomers share some of the features of a viscous fluid where stress is proportional to strain rate but independent of the strain itself, that is, they are viscoelastic. Thus, it becomes important to be concerned about how long the material must sustain load, how fast it is loaded, and how far it is compressed or elongated.

It is important to recognize that these factors should be of concern and that standard material test methods often have to be modified to reflect this concern. Three samples shall be subjected to a tensile load that shall be increased rapidly but smoothly from zero to 75% of specified mechanical load (SML) and then gradually be increased to the SML in a time between 30 and 90 seconds. If 100% of the SML is reached in less than 90 seconds.

The test is passed if on failure occurs. The load shall then be increased until the insulator fails. The historical failure loads shall justify the manufacturer's choice of SML

8. Torsional Load Test

Three insulators shall be tested to 50 Nm and release. The toraional load shall be applied to the test specimen through a torque member so constructed that the test specimen is not subjected to any cantilever stress. Failure of any one insulator after torsion to meet the dye penetration test shall constitute failure to meet the requirements of this recommendation.

9. Working Cantilever Load Test

Three insulators shall be tested. Gradually load the insulator to 1.1 times its working cantilever load rating at a temperature of 20° C + 10K and hold for 96 hours. The load shall be applied to the insulator as described in the definition of the cantilever load. After removal of the load; cut each insulator 90° to the axis of the core and about 50 mm from the base end fitting; cut the base end fitting longitudinally into two halves in the plane of the previously applied cantilever load. The test is regarded as passed if the threads of the base are reusable and each fiberglass rod has no delaminations, and no crack.

10. Thermal Mechanical Test

No non-ceramic material is completely resistant to heat. Time and temperature have their aging effects. Heat resistance is usually measured as change in tensile streng elongation and hardness. Low-temperature properties indicate a stiffening range and brittle point. With some materials crystallization occurs, at which time the material is brittle and will fracture easily

TEST SETUP

Three insulators shall be loaded at ambient temperature to at least 5% of the SML for 1-minute. During this time, the length of the insulators shall be measured.

This will be the reference length. The insulators shall then be submitted to thermal variation from -35°C to + 50°C (ANSI) and -50°C to + 50°C (CEA) while under a permanent mechanical load of 0.5 SML for 96 hours. The time at each temperature shall be at least 8 hours per cycle. At the end of thermal cycling, the insulators shall be allowed to reach ambient temperature and the length shall again be measured using the same load as for the reference length. The increase in each insulator's length shall be no more than 2mm. It is also required that, described in section 3.

11. Flammability Test

This test is intended to check the shed housing material for ignition and self-extinguishing properties. The test shall be performed according to IEC Publication 707, method FV. The test is passed if the test specimen belongs to category FVO of IEC Publication 707.

12. Low Frequency Dry Flashover Test

Three insulators shall be tested. The initial applied voltage may be quickly raised to approximately 75% of the expected average dry flashover voltage value. The continued rate of voltage increase shall be such that the time to flashover will be not less than 5 seconds nor more than 30 seconds after 75% of the flashover value is reached. The dry flashover voltage value of a test specimen shall be the arithmetical mean of not less than five individual flashover taken consecutively. Failure of the dry flashover value of any one of the three insulators to equal or exceed 95% of the rated dry flashover value shall constitute failure to meet the requirements.

13. Low Frequency Wet Flashover Test

Three insulators shall be tested and voltage application at not less than 1 minute after the final adjustment of the spray, the applied voltage may be raised quickly to approximately 75% of the expected average wet flashover voltage value.

TEST SETUP

The continued rate of voltage increase shall be such that the time to flashover will be not less than 5 seconds nor more than 30 seconds after 75% of the wet flashover voltage value is reached. The wet flashover voltage value of a test specimen shall be the arithmetical mean of not less than five individual flashover taken consecutively. Failure of the flashover value of any one of the three insulators to equal or exceed 90% of the rated wet flashover value shall constitute failure to meet the requirements.

14. Critical Impulse Flashover Test

Three insulators shall be tested under dry