(3) INSULATOR TESTING SPECIFICATION FOR INSULATORS HAVING AN OPERATING VOLTAGE EXCEEDING 25,000 VOLTS

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Introductory:

This specification gives the conditions of tests and inspections which are found best to secure reliable high-tension line insulators for use under the ordinary conditions of power transmission work. It is expected to serve as a skeleton or model specification and may be supplemented by such additional matters as may be appropriate for any particular case.

GENERAL SPECIFICATION COVERING ALL TYPES

1. (a) This specification is intended to cover the inspection and testing as to design, quality and manufacture, of porcelain insulators, cat.No....., of Company.

(b) The operating voltage is.....

2. *Drawings:*

A dimensioned drawing shall be furnished showing the complete insulator and, if the insulators are built up or composed of a string of elements, showing also each element.

3. *Inspection:*

The maker will give to the purchaser or his representative such access to his works at all times during working hours as is reasonable and necessary to determine the suitability of material to be supplied, and shall furnish all necessary apparatus, labor, etc., in making the tests herein called for without cost to the purchaser.

All insulators are subject to final inspection, test and acceptance at maker's pottery.

The inspection or waiving of inspection will not relieve the maker from obligation to furnish material in accordance with this specification.

4. *Design:*

All insulators shall be designed to fail by flash-over and not by puncture.

Insulators shall be of robust construction and design so as not to be easily injured in handling.

The ultimate criterion of the merit of an insulator is its performance in service and the best practical measure thereof is its behavior under definite tests. However, as no practicable tests actually reproduce service conditions, for example in the matter of high-frequency voltage, criticism on theoretical grounds is valuable, and, other things being equal, preference should be given to the insulators most closely conforming to theoretically best designs.

METAL PARTS

5. *Corrosion:*

All metal parts shall be of non-corrodible material or shall be galvanized in accordance with the specifications for galvanizing prescribed by the joint committee of the National Electric Light Association in its specification for overhead crossings of power lines above telephone and other low-voltage lines.

6. *Factor of Safety:*

Metal parts shall have a factor of safety of at least three over the maximum strain that they may receive in service, except that with pins for pin type insulators the factor may be reduced to two where a higher factor is impracticable.

PORCELAIN

7. *Quality:*

All porcelain parts shall be made dense and homogeneous as is best adapted to high-tension insulator requirements, free from injurious cracks and flaws or other defects that would render them unfit for use in insulators. The burning of all porcelain sections shall be done so as to insure thorough vitrification. The surface shall be smooth and uniform and moisture-proof.

8. *Glazing:*

The glazing shall be and of a reasonable uniform shade, smooth, hard and continuous over all surfaces except those to be in contact with the cement. It shall be unaffected by weather, ozone, nitric acid, nitric oxides, alkali dust, or sudden changes in temperature over the atmosphere range.

9. *Absorption:*

The requirement for imperviousness shall be as follows:

The sample for test must not have a glazed surface, and the volume must be in the neighborhood of 2 cu. in. (30 cu. cm.). It must be dried at 120 deg. cent. until weight is constant, and then immersed in water for 48 hours. The temperature of the water to be between 20 and 40 deg. cent. It is then removed from bath, surface water rubbed off with a cloth, and weighed. It must not have absorbed water to the extent of more than one-tenth of one per cent of its original weight.

CEMENT

10. *Assembling:*

All cemented joints between insulator parts shall be carefully made, using for this purpose the best grade of neat Portland cement, thoroughly mixed. The assembly shall be so done that no hollows or voids will be left between the cemented surfaces and all superfluous cement must be cleaned off of the insulator before crating.

ELECTRICAL TESTING

11. *Wave Form:*

The wave form of the generator shall be true sine curve within the limits specified for generators by the Standardization Rules of the American Institute of Electrical Engineers.

12. *Control of Voltage:*

The voltage shall be controlled in a way not to distort the wave form. It is preferred that it be controlled by a regulator consisting of a shunt resistance connected directly across the low-voltage side of the transformer, and a series resistance in the supply. The shunt resistance must always by-pass at least five (5) times the exciting current of the transformer. The principal control is effected by the series resistance. The method is often spoken of as a potentiometer method.

For routine tests other methods of variation of potential may be used, provided such routine test apparatus has been calibrated by an approved method for the actual parts or groups of

parts to be subjected to the routine test. Such calibration shall be made on the maximum number of pieces to be used in the routine test.

13. *Measurement of Voltage:*

The method of measuring the voltage on the test circuit shall be that method recommended by the American Institute of Electrical Engineers, covering such cases.

For routine work, instead of taking spark gap readings for every test, the maker may calibrate his equipment by the approved method of voltage measurement, thus securing a curve between primary voltage and secondary spark gap readings, which curve may be used to determine the secondary voltage. Such calibration shall be made on the routine test apparatus with the maximum number of parts to be actually used in the routine test.

14. *Kilowatt-Ampere Capacity of Testing Apparatus:*

The kilowatt-ampere capacity of the testing apparatus is important, for the leading current taken by the insulators tends to distort the test voltage. The maximum current taken from the test apparatus should not be so great as to distort the voltage wave sufficiently to cause a condenser to take more than times the current¹ it would take on a true sine voltage,² and the current taken from the test apparatus shall in no case exceed full rated load.

15. *Surrounding Conditions During Tests:*

With insulators intended for lines not exceeding 75,000 volts no object other than leads and support should approach nearer than 6 ft. (1.8 m.) to the insulator. For insulators intended for lines of higher voltages the conditions for the "design test" of complete insulators should be made as nearly as practicable the same as the conditions of actual service as regards the grounding of one side of the insulator and the arrangement and distance of grounded objects. A conductor of 6 ft. (1.8 m.) or more in length, extending equally on both sides of the clamp, should be used to represent the transmission wire.

Routine tests not being on completed insulators do not require these precautions, but in each case the method of making routine

1. See paper by C. M. Davis, A.I.E.E. PROC., February, 1913, page 237.

2. This may be determined by the formula $I = n V C$, where I is amperes, V is volts, n is cycles per second and C is capacity in microfarads.

tests shall be calibrated when the surroundings are different from those here prescribed.

16. *Frequency:*

Tests should be made at the frequency at which the insulator is to be used. Where special agreement is made tests must be made at 60 cycles on insulators intended for use on higher and lower frequencies. No error of a serious magnitude will be expected within the range of 25 to 133 cycles.

17. *What Constitutes a Breakdown:*

An insulator is said to "fail" under a voltage test whenever a puncture occurs in any part of the insulator or when a discharge of any sort passes from one terminal to the other, since such a discharge would be followed by an arc on a power line.

Local breakdown, either corona or local sparks, is an important symptom of weakness, and indicates possible bad performance under other conditions. The weight to be given local breakdown, however, is a matter of judgment and is best considered in the light of simultaneous competitive tests.

18. *Rain Tests:*

Water should be sprayed on the insulator at a uniform rate averaging 1 in. (2.5 cm.) depth in 5 minutes, and should be reasonably uniformly distributed over the whole insulator. The rate of precipitation shall be measured by collection of water in a pan at the location of the insulator, the insulator being removed. A satisfactory spray in the form of a fine mist can be obtained by some forms of atomizers where pressure is available.

The spray shall strike the insulator at an angle of approximately 45 deg.

The water used shall have a high specific resistance, not less than ohms per cu. in. (..... ohms per cu. cm.). Pure water may often be obtained from condensed steam or melted ice, or rain.

When insulators are to be used in localities subjected to salt spray or alkali mists special tests should be made.

Oil Tests:

Tests on a certain percentage of each 1000 insulators, not exceeding $\frac{1}{4}$ of one per cent should be made to determine the ability of the insulator to resist puncture. This test is best made by submerging the insulator in oil.

Suspension insulators should be completely assembled with the standard fittings with which they are to be used in service.

With pin type insulators there should be attached to the head of the insulator, wires representing the tie and line wires, and a metal pin should be placed in proper manner in the pin hole.

The test voltage should then be applied to the fittings in each case. The puncture value obtained under these conditions should not be less than 135 per cent of the dry flash-over voltage.

In making the test, apply to the insulator a voltage 30 to 40 per cent below the dry flash-over value for 30 seconds, then raise the voltage by steps, until puncture occurs, at a rate of about 1000 volts per second.

PIN TYPE INSULATORS

19. *Inspection:*

All parts should be inspected before assembling.

20. *Electrical Tests Before Assembling:*

All parts of the insulator before being assembled will be tested for three minutes at the voltages given in the following table. Should any part be punctured in the last minute of test, the test will then be continued until no puncture occurs in one full minute of test. These tests are to be conducted by inverting the parts in pans of water and placing water inside the several pieces, the potential then being applied to the two bodies of water.

TEST OF VOLTAGES ON PARTS

Head.....	volts
Second Shell.....	"
Third shell.....	"
Center.....	"

21. *Final Electrical Tests:*

All complete assembled insulators shall be tested electrically at 10 per cent below the flash-over voltage for three minutes. This test is to be applied in the same manner as the tests for parts described for Routine Tests, §§12, 13 and 15.

22. *Design Tests—Mechanical:*

The following design test shall be made on enough complete insulators, not exceeding $\frac{1}{4}$ of one per cent, to determine the behavior of the design and the uniformity of the product.

The insulators covered by these specifications must be capable of withstanding without signs of distress a pull of lb. (..... kg.) applied at the tie-wire groove in a direction at 90 deg. with the axis of the insulator and pin. For the purpose of making this test, the insulator shall be mounted on the pin to be

used in service. In case of failure the question as to whether the insulator or the pin is at fault shall be determined by testing again with a solid steel pin turned from a piece of round steel of such dimensions that this piece of steel acting as a pin for the insulator will not bend under the above-mentioned load.

23. Design Tests—Electrical:

The following design tests shall be made in enough complete insulators, not exceeding $\frac{1}{4}$ of one per cent, to determine the performance of the type. The insulator shall stand without failure:

A *dry arc-over* test of not less than three times potential between line wires applied for one minute.

A *wet arc-over* test of $2\frac{1}{4}$ times the potential between line wires for one minute.

SUSPENSION TYPE INSULATORS

24. Inspection:

All parts shall be inspected before assembling.

25. Electrical Tests Before Assembling:

The unassembled porcelain disks shall be given a regular routine electrical test at a voltage 10 per cent below flash-over potential for five minutes. If puncture occurs in the fifth minute, the tests must be continued until no puncture occurs in one full minute of test.

26. Mechanical Test:

After approximately ten days setting of the cement, all units shall be given the regular routine mechanical test of lb. (..... kg.), with tension applied in line with the axis of the insulator.

27. Final Electrical Tests:

All disks shall be tested at a voltage 10 per cent less than flash-over for two minutes. If puncture occurs during the last minute the test must be continued until no puncture occurs in one full minute of test. This test shall be made after the mechanical test above prescribed, §26.

28. Design Tests—Electrical:

The following design tests shall be made on enough complete assembled insulators, not exceeding $\frac{1}{4}$ of one per cent, to determine the performance of the type. The insulator shall stand without failure.

A *dry arc-over* test of the complete insulator, consisting of units, of volts, applied for one minute.

A *wet arc-over* test of each insulator, of volts.

It is preferable that the arc-over of the complete insulator shall be over the insulator as a whole and shall not be over the individual elements.

There is no advantage in a dry flash-over strength greatly exceeding the wet flash-over strength and there is the disadvantage of the greater danger of puncture. The wet flash-over voltage should not be less than twice the voltage between line wires.

29. *Design Tests—Mechanical:*

At the option of the purchaser or his engineer, one-tenth of one per cent of the whole number of assembled parts forming one element may be mechanically tested to destruction. Where practicable such units as are rejected for other causes shall be used in making this test.

APPENDIX

The following tests are recommended as desirable where appropriate. They are not incorporated in the above tests as experience with them is not yet sufficiently broad.

30. *Uniformity Test:*

Twenty-two single disks or elements taken at random from stock which have passed factory test, shall each in turn be placed in oil, potential not exceeding 30 to 40 per cent of arc-over voltage shall be applied, and gradually increased at about the rate of 1000 volts per second until puncture shall occur. Any twenty of these values of puncture voltage shall then be selected by the maker. The difference between the maximum and minimum puncture voltage must not be more than 20 per cent of the average voltage. This test should be repeated with one or more additional groups of 22 disks, not exceeding in the aggregate $\frac{1}{4}$ of one per cent of the total, enough to determine the uniformity of the product.

31. *Impulse Test:*

Twenty-two units shall be selected at random. Each of these disks, or preferably several disks in series, shall be connected in turn to the impulse circuit shown in Fig. 1. The gap *A* shall be set at three or preferably four times the arc-over voltage of a single unit. The voltage shall be increased until gap *A* arcs over, when the circuit shall be immediately opened by breaker. This

shall comprise a "stroke." strokes shall be applied to each unit or string of units or until puncture occurs. Preference shall be given to the insulator showing the greatest uniformity and the highest average puncture voltage. Referring to Fig. 1, page 1646, the shunt condenser capacity shall be..... microfarads, and the inductance millihenrys.

NOTE: The above test will show, in a general way, the probable effect of surges, lightning, etc., on the life of the insulator, as well as uniformity of the porcelain. The number of strokes, and voltage, to puncture, will depend upon wave front of impulse, or frequency, etc. This cannot now be definitely specified, as the phenomena have not yet been sufficiently investigated. A test as above, however, is very important in competitive tests.

32. *Rain Tests—Position of Insulator:*

With pin insulators, where more convenient, instead of inclining the spray at 45 deg. with the insulator, the latter being vertical,—the spray may be made vertical and the insulator inclined at 45 deg.