DISCUSSION ON "THE TESTING OF HIGH-VOLTAGE LINE INSULATORS." ATLANTIC CITY, N. J., JUNE 30, 1908

Percy H. Thomas: The testing of a high-voltage insulator by application of voltage from a spark-gap or other high-frequency discharge has an extremely important bearing on the type of insulator. A four-part insulator or a three-part insulator, in fact any large insulator, has its resisting power made up of a number of elements all practically in series. The possibility of the concentration of potential on certain parts of these insulators is well recognized. This condition is recognized as greatly reducing the breakdown voltage of an arrester. The feature I wish to bring out is that with very high frequencies this concentration effect is enormously multiplied. I believe that a careful study of this matter will result in some modification of insulator design.

I ask Mr. Skinner if it is worth considering that there will be a difference in local heating, according to the frequency of the test current; for example, a 133-cycle test might show local heating which would not show on a 25-cycle test. Any local heating in a specific insulator is a very important item, as it indicates an inside weakness.

Ralph D. Mershon: Mr. Skinner's paper interests me not so much because it suggests specifications for an insulator but because it recommends certain definite methods of test. There is one recommendation especially with which I heartily concur; that is, make rain tests by using, in all cases, a vertical spray and placing the insulator at a specified angle, instead of endeavoring to imitate rain conditions as regards the angle of precipitation.

Rain conditions are indefinite and variable, so that any assumptions made in regard to them must necessarily cover only one of many conditions. The best that can be done is to assume a maximum rate of uniform precipitation at a definite angle. We know, with a fair degree of accuracy, the maximum rate which will not be exceeded in practice. The angle of precipitation may, however, vary from approximately zero degrees with the horizontal, to 90 degrees. It is usual to assume 45 degrees as a fair compromise. But having made these assumptions, which can not represent all actual conditions, we are unable accurately and conveniently to produce them. It is extremely difficult to get a water spray to fall at any definite angle, other than 90 degrees with the horizontal, and with uniform precipitation. The result is that flash-over tests made by different observers with different testing equipments, or even at different times by the same observer with the same equipment, are often most discordant.

It seems to me it would be much better to adopt a method of test which, whether it does or does not appear to represent very closely actual conditions, will serve as a criterion and

will offer some chance of reproduction, approximately at least, at different times and with different observers. This will be accomplished if the spray be kept vertical and the insulator inclined, for there is a great deal better chance in that case of obtaining a uniform spray at a definite angle with respect to the insulator.

The present method of testing insulators for flash-over conditions under precipitation is very unsatisfactory, so far as repetition is concerned. I have lately made some experiments on a new type of insulator under what was supposed to be a precipitation of one inch in five minutes at an angle of 45° . About a week afterwards another observer made similar tests under as nearly as possible similar conditions, and obtained the same results. About three weeks afterwards the same man endeavored to repeat the results and could not get anywhere near the figures which had been obtained in the first place for flash-over under rain conditions. I have had similar experiences repeatedly and, as the result, have usually, when desiring to compare two insulators as regards flash-over, endeavored to test them together, either simultaneously or by keeping the spray the same and alternately substituting one insulator for the other. The latter is probably the safer method, as more likely resulting in the same precipitation in both cases.

I am disappointed that Mr. Skinner has not gone more fully into the question of the kind of spray nozzle for producing a uniform precipitation. It is difficult to get a nozzle which will give uniform distribution and do so continuously. It would be of great value if Mr. Skinner could tell us where or how to obtain a nozzle which would fulfil the requirements.

The rate of precipitation usually assumed is about one inch in five minutes. The maximum rate of precipitation of which the United States Weather Bureau has any record is less than eight-tenths of an inch in five minutes. Something more than the maximum observed rate is desirable, and it would seem, therefore, that one inch in five minutes would be amply sufficient. I would suggest that this figure, or its equivalent, two-tenths of an inch in one minute, be adopted, instead of the range of precipitation which Mr. Skinner has suggested.

I agree with Mr. Thomas that frequency will, in all probability, have a considerable effect on the flash-over voltage of the insulator; if this is shown to be the case, the insulator should be tested at the frequency for which it is designed. The flash-over voltage will also probably depend a good deal upon the method of voltage control in making the test. The discordant results obtained with different testing equipments are, no doubt, due in part to the fact that the voltage is usually controlled by means of a rheostat in series with the testing transformer. This method of control will, under some conditions, materially modify the wave-form. If the voltage be varied by varying the field of the generator, there is a much better chance for concordant results.

Clayton H. Sharp: In reference to the production of a proper spray or precipitation for use in the testing of insulators, I am having constructed at present an apparatus which has been suggested by an arrangement in use, I believe, in the German Reichsanstalt. This arrangement consists of a large cylindrical vessel, which has a considerable number of little tubes running out from the bottom of it, equally spaced in centers of one and one-half inch squares. The top is closed and has a micrometer valve by which the admission of air can be controlled. On the side there is an ordinary gauge glass to show the level of the water and the rate of precipitation. These tubes will have cotton wicking stuffed into them of proper thickness, and a tail of fine wire, to enable the drops to fall off. With an arrangement of that kind, I hope to get a uniform dropping of the water; in other words, an imitation of a rain-storm, which can be regulated by changing the admission of air by the valve, and in which the rate of precipitation can be measured on the gauge glass at the side. By setting up a fan at one side the effect of a hard wind may be obtained. I do not know that such an apparatus has ever been used, at any rate in this country; if it has I would like to know what the results of experience with a device of that kind have been. It seems to me that such a device has a great advantage, coming nearer to an actual rainstorm than any ordinary spraying arrangement. It gives separate drops of water, and that is what we want.

E. M. Hewlett: Regarding the rain test on insulators, some folks like heavy rain, some like a flood, and some are satisfied with a mist. I do not believe you can satisfy everybody. It looks as though possibly a steam test might give a better average condition; there will not be so many conditions to balance up. You can get quite a film of moisture on the surface with the steam test, and can duplicate it more readily than the rain test, making better average tests. The rain test is of value in determining insulator design.

Chas. P. Steinmetz: There is one test which I do not find mentioned in Mr. Skinner's paper, and that is the test of the insulator after being submerged in water for a considerable period, a week or ten days, or more. A porcelain insulator may well stand all the tests outlined here, and may fail in service after a few weeks or months, by absorption of moisture through hair cracks in the glaze, due to incomplete vitrification or to porosity of the material. Porcelain is by no means an ideal material for an insulator. It is a heterogeneous mass, more or less completely vitrified in its interior, and covered with a glaze. If the vitrification is perfect, it is just as good and uniform as glass, but if the vitrification is not perfect, as long as the glaze keeps the moisture out it will stand, but as soon as by temperature variation of the air the glaze begins to acquire hair cracks, moisture soaks in and the insulation strength goes down. Glass would be preferable except that it is mechanically

weak, and is hygroscopic, and so covers itself with a film of moisture. I am not entirely satisfied with such a test as immersion in water, but I bring it to your attention. Perhaps some one else might suggest a better way of testing a small percentage of insulators for absorption of moisture and decrease of disruptive strength resulting therefrom by long-continued exposure to water and atmospheric conditions.

I also raise the question whether it is advisable, as proposed in the paper, to allow any tests of less than twice the rated voltage. Here tests are proposed of one and one-quarter and one and one-half times the rated voltage. Now, you know that in our standardization rules, no voltage test is permitted on any apparatus of less than twice the rated voltage. That is the minimum test permitted. Here we have recommended tests under undesirable, but still actually existing conditions, of one and one-quarter times the rated voltage. The margin is rather small, probably too small. Many of us feel that at the present time the insulator is the weakest link in the long-distance transmission system. The occasional use, for instance, of 60,000-volt insulators on 40,000-volt systems also shows that the engineers feel that the extra high-voltage insulator is really not quite as good, does not have the same margin of safety, as other apparatus. It would be much more consistent if we insisted in testing the insulators to ascertain that they have the same margin of disruptive strength as all other apparatus is supposed to have, instead of so moderating the tests as to allow the insulators to be rated at a voltage to which they are not entitled on the basis of the margin of safety standard for all other parts of the system.

In regard to specifying the number of insulators tested on one trial, etc., my understanding is that the paper proposed additional matter to the rules of our Standardization Committee, so in this connection our standardization rules—which specify how many insulators you can test from one transformer, that is, how large the capacity current can be compared to the transformer capacity—would apply. All those features that are specified by our standardization rules are implied, and the paper merely brings forward additional matter.

C. E. Skinner: I am a little surprised that nothing has been said in the discussion in regard to the dew test. I do not know whether this test has been used to any great extent or not, but those who have used it claim that it is far more satisfactory than any rain test, and also more severe, and it is one that ought to be relatively easy to repeat.

In regard to the number of insulators which may be tested on a given size transformer, I would say that Dr. Steinmetz has already covered the point. You will note that the paragraphs on voltage control, capacity of testing transformers, etc., are practically copied from the standardization rules. They are partly repeated here, in order to make the specification complete.

In regard to the question of placing the insulator vertically, and having an angular spray, I agree entirely with Mr. Mershon; no method has yet been brought to my attention which could be controlled with sufficient accuracy to allow repetition. This specification is intended to be a performance specification, and to have a performance specification you must be able to repeat your tests. The best we have been able to do in our laboratory in making tests is to get a spray which, measured by the rain gauge, taking successive squares in the spray, showed a variation of very approximately that given in the specification, that is, 0.2 to 0.3 inches per minute. I do not believe it makes very much difference whether it is a little more or a little less. I think that with that amount of water the results will be about the same. Mr. Mershon referred to a rate of one inch in five minutes—which is equivalent to 0.2 inch per minute. In all the communications that I received, I did not hear of the method mentioned by Dr. Sharp, although I was in communication with some of the German porcelain manufacturers. As a matter of fact, their letters did not give me very much information in regard to their method of obtaining the spray. I think that it would be impossible to use a fan and blow the spray the same on two successive days—that it would be out of the question to repeat tests of that kind.

The steam test suggested by Mr. Hewlett I think is virtually covered by what I called the dew test here. It is merely gotten at in a little different way, and in a way which is frequently met in practice; that is, the insulator is cooled down during the night, and in the morning, particularly in the tropics, and in places where the temperature rises suddenly, the insulator becomes completely coated over its entire surface with a layer of moisture.

The immersion test suggested by Dr. Steinmetz I think would be a very good one to add to the performance test, but I think it would be rather burdensome to make on all insulators.

In regard to the over-potential test of one and a quarter and one and a half times, I would refer to the introduction of the paper, in which I disclaim any great responsibility for the data there given; my own idea is that the tests specified are rather too low. I would like to see them higher, and if insulators can be purchased at a reasonable price for use on transmission lines under the more severe conditions, I would like to see the double-potential test substituted for the one given.

Ralph D. Mershon: As regards the dew test, both as suggested by Mr. Skinner and by Mr. Hewlett, it does not seem a definite test. Moist atmosphere—what does that mean? It would make a great deal of difference in the condition of the insulator just how long it is left out, and just what that moist atmosphere means—how can you give any definite condition?

C. E. Skinner: I have not made the dew test myself. It was proposed by two or three other persons who claimed

they had made this test and found it perfectly satisfactory. If the air contains a fair amount of moisture, there will be a sufficient collection of moisture on the surface of the insulator to make it flash over, *under the test specified*.

E. M. Hewlett: We have made the steam test, and find it is easier to make the steam test than it is to get up in the morning early so as to find the insulator cool enough to test it with the dew test. We put the steam on the insulator with a hose until the surface is covered with condensed steam, and then make the voltage test.

N. J. Neall (by letter): Routine test. Inspection. I doubt very much the wisdom of allowing so large a variation as ± 5 per cent. in general over-all dimensions from the designed size. This is particularly critical for extra high-potential designs, where an insulator 14 inches in diameter and 14 inches high may have a considerably lower arcing test than one 15 inches in diameter by 15 inches high. I think ± 2.5 per cent. would be safer.

Dielectric tests. This is a good commercial rule for testing parts, but due consideration should be given the potential gradient of the insulator as a whole as well as the individual electrostatic capacities of the parts in series therein. Actually I would expect the top of an insulator to get almost line potential strain, particularly if the pin be grounded. I would call for three times the usual line voltage, 2.5 times is not high enough. There is no designation as to what constitutes a "lot." I should suggest a selective test from each kiln fired.

Design test. This permission to test as many as 5 per cent. is generous indeed. In general, a much smaller percentage than this should suffice.

Rain tests. 1.5 times normal voltage is too low; it should be at least 2 times. Likewise for dew test,—of shorter duration than 5 minutes, say 1 or 2 minutes. In none of these specifications is the important requirement, "with pin grounded," mentioned.

Methods of making tests. Rain test. The proposed angular position of the insulator with respect to a vertical rain does not appeal to me, because the whole combination of static field and reflected rain as found in service is apparently inadequately reproduced in this way. I prefer the rain at an angle instead. This detail requires further working out.

In addition to the preceding details, I wish to add the following: For testing insulators local conductors should be of large diameter to cut down the excessive ionization usually present in such tests. There should be some "table" of the number of insulators of given size that it is permissible to simultaneously test with a testing transformer of given capacity. In testing large insulators in large numbers for extra high voltage, the charging current alone may impair the value of the test. There must be some recognized method of measuring

the voltage. Just as soon as the true character of spark-gaps is known it should be applied to this work authoritatively. In the meanwhile I would suggest the use of shielded spark-gaps with spherical tips—needles being more liable to error and burdensome in practice. For general testing, the voltage by ratio is desirable, provided it can be kept free of error; and the specification as to appropriate size of apparatus might include among its requirements a description of the apparatus.

I have already called attention, in my recent paper on lightning before the Institute, to the desirability of equivalent spark-gap measurements of insulators as indications of their non-arcing power. The arcing-over test of the insulator is no more indicative of its efficiency than the same test on a lightning arrester.

The tendency of the proposed specification seems to be a letting down rather than a stiffening of those requirements heretofore generally followed. I think the record of operation of high-tension transmission systems will show the wisdom of making this element thereof stronger than is proposed in these specifications.

Aside from these criticisms of details, I wish to state my belief that such a specification as here proposed by Mr. Skinner is highly desirable.