

DISCUSSION ON "POWER-FACTOR, ALTERNATING-CURRENT INDUCTIVE CAPACITY, CHEMICAL AND OTHER TESTS OF RUBBER-COVERED WIRES OF DIFFERENT MANUFACTURERS," AT NIAGARA FALLS, JUNE 25, 1907

Henry W. Fisher: In presenting this paper to the Institute I wish it to be clearly understood that no attempt has been made to say anything or do anything that would be discourteous to the manufacturers of rubber-covered wire. The main object of the paper is to compare a large variety of rubber-covered wires, especially with reference to power-factor and dielectric loss. So far as I know these tests have not been applied commercially to any extent here.

A careful examination of the results given in the paper will show that power-factor tests are valuable in helping to determine the quality of rubber-covered wires, but that they cannot be relied upon to indicate the amount of fine Para. All the tests given are essential, especially the chemical, voltage, and insulation resistance tests.

Chas. P. Steinmetz: This paper is interesting in giving what may lead to an advance in our method of judging cables. It proposes to investigate the character of cables by measuring the energy loss in the cable as represented by the power-factor. The energy loss in the cable appears to me a very important quantity. However, I do not believe it would be safe to judge cables merely by this energy loss. What is important in a cable or any condenser is 1: the disrupted strength; that is, that the cable stands the operating voltage with a sufficiently high limit of safety, and 2: the deterioration, that the cable does not deteriorate at the operating voltage within a reasonable time. Deterioration is the effect of energy consumed in the dielectric of the cable. Therefore, if one could imagine a cable which has no energy loss whatever in the dielectric or zero power-factor, such cable would not deteriorate. This shows the importance of the energy loss in the cable. However, the deterioration is not necessarily, and probably in general is not proportional to this energy loss.

We do not know much, to tell the truth, of this energy loss in the dielectric in the alternating field. We suppose there is some kind of a dielectric molecular friction similar to the molecular magnetic friction of iron; that is, a conversion of electric energy into heat during cyclic changes of static stress. This dielectric hysteresis is harmless, regarding deterioration, because it is a conversion of the energy into heat and merely raises the temperature of the cable slightly, just as the current existing in a conductor raises it, and, if we keep the temperature of the cable sufficiently low, no deterioration will take place owing to this heat. So the production of this additional heat by dielectric hysteresis, must be taken in consideration in designing a cable system.

There is, however, a phenomenon, no analogy of which exists in the magnetic field; that is, a conversion of energy not directly into heat, but into chemical action, and that probably is what leads to the deterioration, the destruction of the dielectric. It is a chemical action exerted upon the dielectric proper, or upon gases included in the dielectric, either absorbed or as air bubbles, etc. If we could separate the energy converted into chemical action from the energy converted directly into heat, we could draw conclusions, the former may give us a clue to the probable life of the cable or condenser. But even then it may not give a direct estimate of the life, because the distribution of the destructive energy is all important. We may have cases in which the energy converted into chemical action, that is destructive energy, is moderately high but uniformly distributed over the whole cable, and the cable so has a good life, while in other cable in which much less energy is acting destructively, may rapidly go to pieces, because the total chemical action, although less is concentrated in a few spots, some air bubbles there weaken the dielectric, rapid oxidation of the rubber etc., takes place, and so disruption. That latter feature is well known to any one who has attempted to build electrostatic condensers for very high voltage. There the chemical energy is localized at some few spots where air bubbles have remained in the dielectric, and destroys it.

While we do not yet know much concerning the laws of energy loss in dielectrics, we know that a part of it, the dielectric hysteresis proper, probably does not vary proportionately to the square of the voltage, and so does not give a constant power-factor independent of the voltage, but a power-factor which probably decreases with increase of voltage, while from other observations and theoretical reasons it appears probable that the chemical destructive action at higher voltages increases more rapidly than the square of the voltage; that is, the power-factor increases with increasing voltage, and it appears to me, any conclusion which could be drawn from measurement of the power-factor of the cable could be drawn only if the power-factor is measured at the operating voltage, at which the cable is to be run, and that is the main objection I have to the paper, although in general I agree with the trend of it. I think that power-factor and energy measurement are made at 75 volts, if I am not mistaken. I believe they should be made at the voltage at which the cable is supposed to operate.

I wish to call attention to the statement that the condenser with the internal energy loss can be represented by a perfect condenser in series with a non-inductive resistance. I do not think that is quite correct. I think an imperfect condenser can be represented by a perfect condenser, shunted by a high resistance. If we consider the extreme case, where there is a very high loss, a series resistance would mean the wattless component of voltage is reduced thereby, which is hardly probable. In the

present case it makes no difference because the non-inductive resistance is very small, compared with the remaining wattless effect, but, where there is a very considerable energy loss, I think the safer way is to put it that the imperfect condenser is represented by a perfect condenser shunted by a non-inductive conductance.

The paper certainly refers to a feature that has not always been given proper attention; that is, the importance of the energy loss in the cable, not for the sake of the efficiency of the plant, but for the sake of its possible effect on the life of the cable. One great difficulty in this matter is the method of measuring the loss, which the paper says is difficult and complicated, and not very easy to do under usual factory conditions.

E. W. Stevenson: In the early part of the paper Mr. Fisher mentions something about the change of dielectric with the temperature. I would ask him if it is an admitted fact that the smaller change of dielectric resistance due to temperature shows a higher percentage of pure para? The reason I ask this is because recently I read a specification that called for a very small change of dielectric resistance per degree of increase or decrease in temperature. That is the first time such a requirement has been called for. There has been considerable argument upon it, whether it is so or not.

Henry W. Fisher: The temperature coefficients vary with the ingredients mixed with the rubber, and probably also with the steam temperature and pressure and time of vulcanization. The coefficients are generally less the higher the percentage of fine Para rubber. The coefficients are not uniform throughout a considerable difference of temperature. In some cases the curves representing the coefficients in terms of temperature are of double curvature and sometimes single curvature. I presented curves showing these peculiarities at the Asheville meeting two years ago.

Henry G. Stott: This is a subject in which I take a great deal of interest. It seems to me that the paper starts in from the wrong point of view. A number of different types of wire are taken and analyzed as closely as possible, and then the results of various tests are given to show just how the various characteristics varied with a change in composition. I think we could get a great deal more information if the manufacturers would start out with a definite composition and increase just one ingredient at a time, and follow that up so that we could get a complete curve of variation due to various percentages of that ingredient and so on, following through with the percentage of para, various extracts, mineral matter, etc. But if we could start on a definite basis and build up first one characteristic and then another, I think we would arrive at something very definite upon which specifications could be based.

The paper on specifications for rubber-covered wires by Mr. Langan, read a little over a year ago, assumed to give such speci-

fications. On trying to carry out the specifications enumerated, stretching tests and others, I found that the same results could be duplicated by entirely different compounds, African rubbers, mixtures of various sorts, reclaimed rubber could be made to give practically the same characteristics as 30 per cent. or 40 per cent. para rubber, and based on that I published a series of tests made on different types of compound to show how impossible it was to depend on anything at the present time except on the manufacturer's word, as to what the wire contained. Chemists all agree that it is extremely difficult, if not impossible, in any analysis to say exactly what the constituents are in any given rubber compound.

Henry W. Fisher: I am interested in Dr. Steinmetz's remarks and fully agree with him that tests of this sort should be conducted at higher voltages. However, at the time these tests were made the apparatus available was designed for low voltages, and the wires tested were those used generally on 100-volt lines.

It is my intention, however, soon to use higher voltages, in connection with which special apparatus like condensers, transformers, etc., will have to be designed. Probably the apparatus most difficult to obtain would be a good mica condenser of low power-factor and high capacity to operate continuously at from 6,000 to 10,000 volts.

Answering Dr. Steinmetz's criticism relative to the method of connecting the resistance in the standard condenser circuit—in getting the power-factor it is immaterial whether the resistance is in multiple or series, so long as the right formula for each case is employed. This formula for series connection was obtained from Dr. Rosa, of the Bureau of Standards and undoubtedly is correct. The resistance is used in series with the standard condenser to make the phases of the currents in the two branches of the bridge the same.

I will ask Dr. Steinmetz if he has treated this problem analytically to see if the series resistance method is incorrect, or whether he reasons from analogy that the resistance should be in multiple with the condenser?

Chas. P. Steinmetz: In the magnetic circuit, the resistance which represents the equivalent of the loss of power in the magnetic cycle, is in shunt to the circuit. In the electrostatic field we do not know enough to say whether there is a series component, but the assumption is justified that there is an electrostatic hysteresis similar to the magnetic hysteresis, and, in this case, the wattless component and the energy component should be shunted to each other, as in the case of the magnetic circuit.

I may say that, as the formula was worked out by Prof. Rosa, it was undoubtedly worked out for a case like this, where the energy quantity is very small, and where, therefore, in the first approximation, it is immaterial whether you put the resistance in series or in shunt. The question would become of importance when the energy component is considerable compared with the wattless component.

E. W. Stevenson (by letter): At the end of Mr. Fisher's paper he lays particular stress on the low breakdown voltage of the white core samples. This is a very interesting fact, especially as it comes from such an authority as Mr. Fisher. I certainly admire his courage in making the statement. I have always been strongly of the opinion that white core is nothing more than a fad. Of course it is generally understood that the white core does not contain sulphur, and therefore is used for the purpose of preventing the sulphur of vulcanization attacking the copper of the conductor. But of course all copper in rubber-covered wire is tinned, and this tinning, as everybody knows, is merely for the purpose of preventing this action, therefore if the tinning is done properly what is the use of complicating the covering process by putting on a white core?

The British navy requirements call for a pure para next to the conductor, a second covering, called a filler, in which there is no sulphur, and a third covering of vulcanized rubber on the outside, thus making three separate covers. This forces the manufacturer to use strip method of covering which, as many of us know, is not the best for all cases.
