Purified Textile Insulation for Telephone Central Office Wiring

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This paper outlines methods by which silk and cotton insulation can be purified and improved. It gives the results of tests on the insulation properties of these materials before and after purification and explains the testing procedures. One of the findings is that the purified cotton may be substituted for ordinary commercial silk.

IN a contemporary paper, *The Predominating Influence of Moisture and Electrolytes upon Textiles as Insulators*, Messrs. Williams and Murphy have shown that the electrical properties of textiles are closely associated with the moisture content and impurities in the textiles. In particular, water-soluble salts become ionically conducting in the presence of moisture and the ions migrate along the paths of initially low resistance to the electrodes with which they react chemically, causing serious corrosion. The resulting corrosion products, themselves electrolytes, accelerate the process of current transfer and may easily lead to a complete failure of the insulating textile at the point of greatest concentration. Conversely, if the impurities are removed, the insulating properties of the textile are improved initially and, furthermore, are not subject to cumulative deterioriation due to concentration of conducting salts and electrolytic corrosion products at the weaker points. It is the purpose of this paper to show how these principles are borne out by field observations and laboratory tests, and to show in a general way the extent to which the insulating properties of silk and cotton can be improved commercially with particular application to telephone central office wiring.

Since the early days of telephone development work, silk and cotton have been the standard insulating materials for wire insulation in telephone central office apparatus, supplemented in later years by enamel insulation. Relatively low voltages have always been used in the telephone plant, 24 to 48 volts being the usual voltages which are carried continuously in cables, while intermittent a.c. and d.c. potentials generally do not exceed 100 to 150 volts. Therefore it has been generally accepted that telephone cables once installed and properly protected from accidental high voltages, could be depended upon to have a substantially indefinite life. In general the

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insulation of these cables has been satisfactory, but breakdowns have occurred which could not be attributed to faulty operating conditions or to manufacturing defects. A study of this subject showed that it was possible under certain conditions to get discolored or faded spots in the insulation and corresponding corroded or pitted spots in the tinned copper conductors. It was also observed that the textile insulation at such spots showed a strong concentration of water soluble salts. Also, cables in which such conditions occurred measured relatively low in insulation resistance with the current leakage concentrated at these points. These observations led to the conclusion that silk and cotton would be decidedly improved as insulating materials if they were made less susceptible to deterioration under telephone service conditions.

Aside from the consideration of improving silk and cotton to assure greater insulation stability, considerable thought has been given to the possibility of improving the insulating characteristics of cotton to such a degree that it could be substituted for the more expensive silk. The importance of this work with respect to its bearing on the cost of telephone service can be better appreciated from the fact that about 2,000 pounds of silk are required daily to provide for the growth of the country's telephone requirements, which if replaced with cotton would reduce raw material costs by a very substantial sum.

The desirability of reducing the quantity of silk required in the telephone plant does not arise entirely from this phase of the economic question. The problem of supply and demand has at times entered into the matter. For example, shortly after the close of the World War the supply of insulating silk was limited and the price prohibitively high. Substantially the same condition arose a few years later, which leads to the conclusion that silk is inherently much more subject to violent fluctuations in available supply and cost than cotton. Therefore, with demands for telephone equipment rapidly increasing, we have decidedly greater assurance of an adequate supply of insulating material at reasonable cost if cotton instead of silk is used.

Purification Process

With the foregoing as an introduction to indicate the economic advantages to be gained by improving the electrical characteristics of cotton and silk, the following is intended to show what has been accomplished by the commercial application to silk and cotton thread of the processes referred to by Messrs. Williams and Murphy for removal of objectionable impurities.

Since such impurities are soluble in water, it will be inferred that the purifying process consists in a thorough washing with water. In effect, this is the case. The process, however, for both silk and cotton, being based on substantially complete removal of the ionically conducting salts, especially those of sodium and potassium, prescribes the use of water of low saline content. It also means that the washing

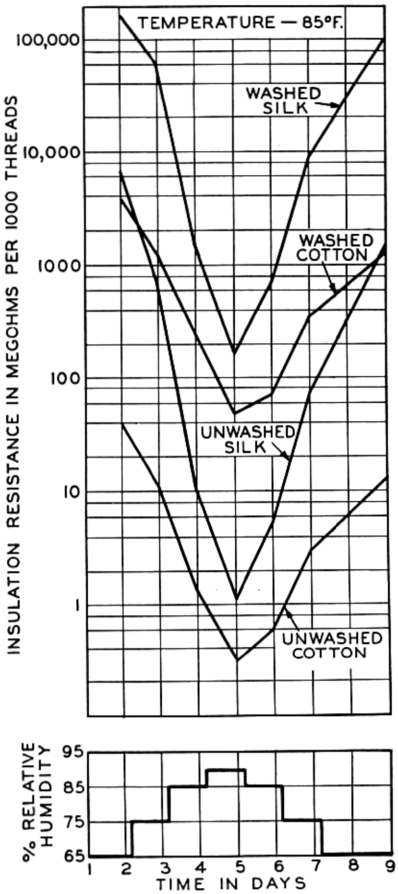

Fig. 1—Typical d.c. resistance characteristics of washed and unwashed silk and cotton threads of equal size.

is best accomplished by a continual flow which after passing through the textile is considered to be contaminated and is not used again.

Where cotton is to be dyed and washed, the washing consists in an additional operation applied to the cotton immediately following the dyeing operation without the necessity of drying between processes.

Characteristics of Purified Insulations

Obviously, the first consideration in the insulation of electrical conductors is to provide an insulating medium of sufficient dielectric strength to withstand the working potentials to which it is subjected. Also, the d.c. insulation resistance must be high enough

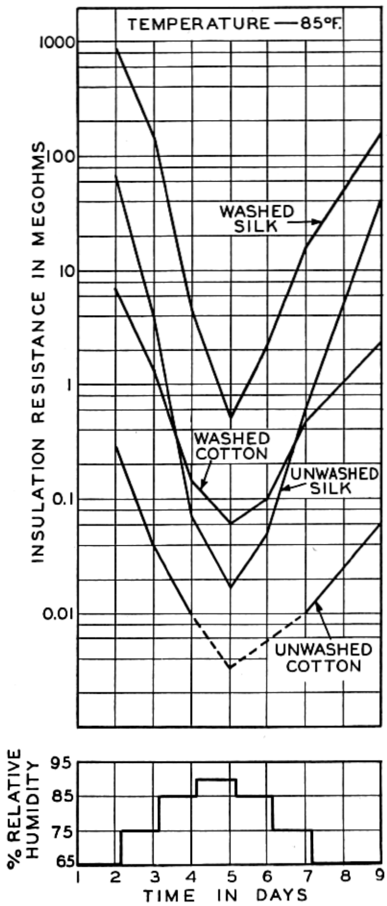

Fig. 2—D.C. insulation resistance of 50 ft. of twisted pair wire insulated with double servings of equal thickness.

to prevent undue d.c. energy loss. A comparison of the electrical resistance of the cotton and silk at relative humidities ranging upward from 65 per cent to 90 per cent and down again to 65 per cent, before and after washing, is shown by the graphs in Fig. 1 as determined by samples prepared and tested by the method and testing apparatus shown in Figs. 6, 7 and 8 and described later. The same comparison is shown in Fig. 2 except that these graphs show the insulation resistance of wire insulated with the washed and unwashed textiles. In addition to the insulation resistance requirement, it is required that the energy losses at talking and carrier current frequencies must be maintained at the minimum point consistent with the space limitations permitted for the conductors. The effect of purification of the textiles on this characteristic expressed in capacitance and conductance, measured at 1,000 cycles per second between the wires of twisted pairs is shown in Fig. 3 and Fig. 4. The data represented by these graphs converted into transmission loss units are illustrated in Fig. 5. As the same thickness of insulation was used in all cases, the graphs are on a comparative basis. It should be noted that the graphs are illustrative of the effects of purification on the electrical properties of cotton and silk as insulation and should not be considered as applying quantitatively to telephone circuits.

From a telephone transmission point of view, perhaps the most significant fact to be observed is the large reduction in capacitance and conductance at relative humidities of 75 per cent and higher. These characteristics which largely determine transmission efficiency are relatively low for both silk and cotton at 65 per cent and below, but in commercial textiles in general use for insulating purposes they increase very rapidly as the relative humidity increases. The characteristics of purified textiles are not as markedly different from those of unpurified textiles at 65 per cent relative humidity as at higher humidities, but their rate of increase as the humidity increases is greatly reduced. This fact is of particular importance in the maintenance of a standard level of voice transmission through toll offices where suitable repeater gains and balance must be maintained. Losses, if fixed in value and not excessively large, can be compensated for, but if they change with every change in atmospheric moisture content the compensation problem becomes serious.

Method of Testing

Two fundamental characteristics of silk and cotton made it necessary to do a large amount of experimental work before a practicable shop test method could be established to determine whether or not the textiles were washed to the point of meeting the requirements established. One of these characteristics is the high electrical resistance of both washed and unwashed textiles at the lower relative humidities and the other the extreme sensitivity to change, with minor change in relative humidity especially at the higher humidities. The first mentioned characteristic precludes the use of any but measuring instruments of the highest degree of sensitivity and makes desirable the use of comparatively high humidities, and the second characteristic

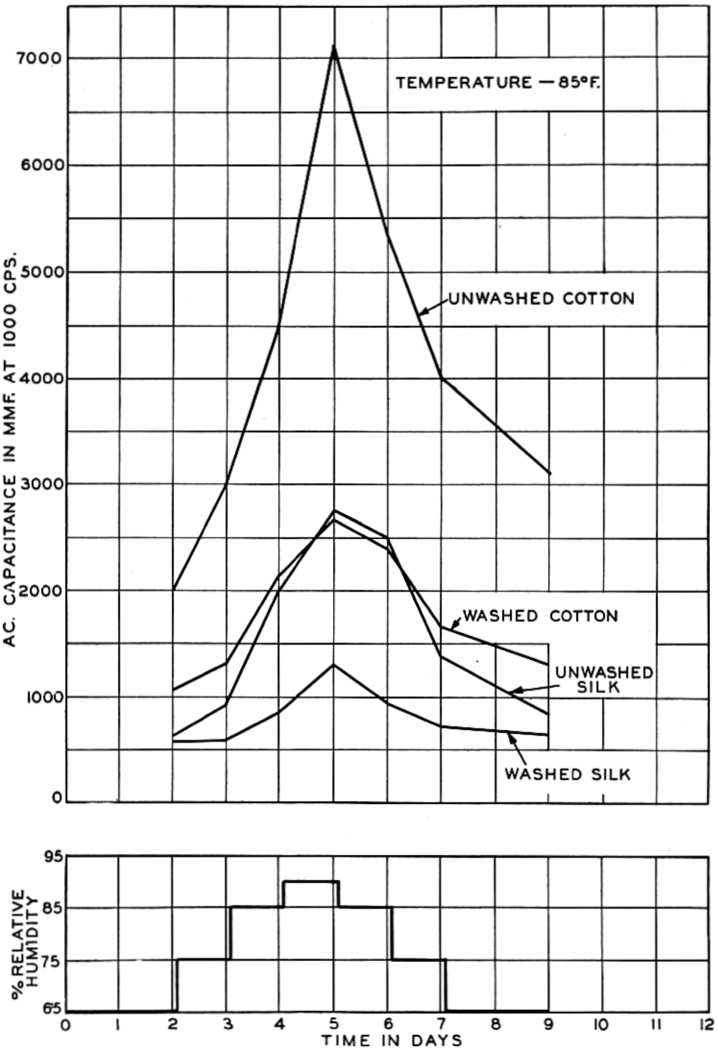

Fig. 3—A.C. capacitance of 50 ft. of twisted pair wire insulated with double serving of equal thickness.

means that the specimen must be tested under exceedingly well controlled relative humidity conditions. Furthermore, the problem is complicated by the polarization effect discussed in the paper by Williams and Murphy, and the fact that this effect varies in magnitude with humidity and with the degree of purity of the textiles. The problem was finally solved by the development of the test equipment shown in Figs. 6, 7 and 8.

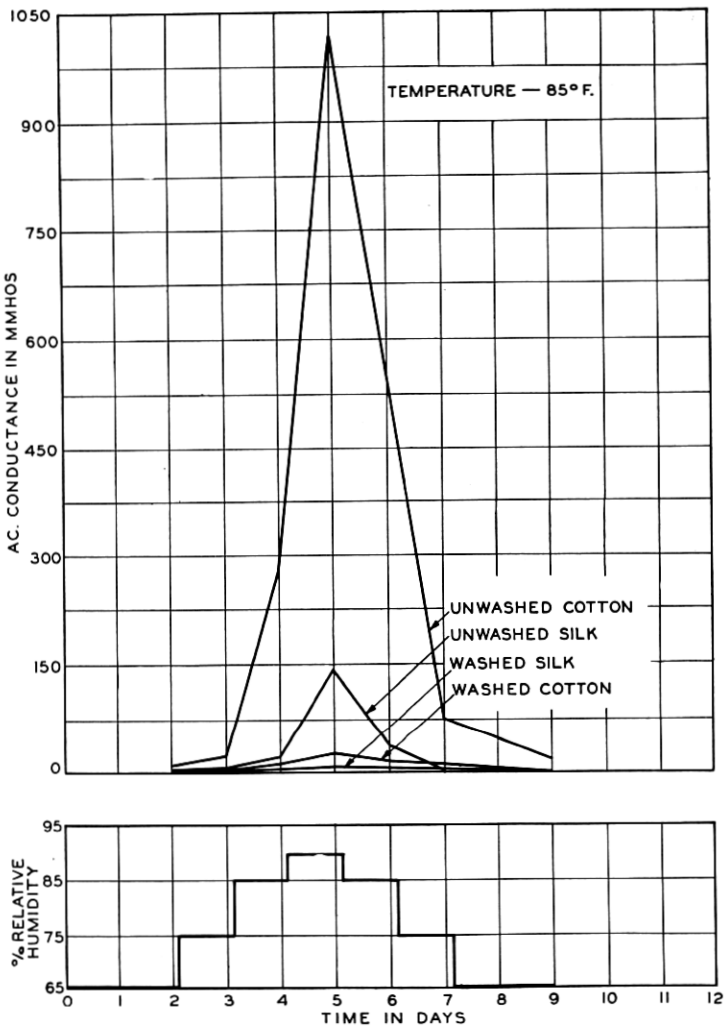

Fig. 4—A.C. conductance of 50 ft. of twisted pair wire insulated with double servings of equal thickness.

Figs. 6 and 7 show a heat-insulated glass tank of about one cubic foot capacity fitted with an insulating cover in which holes normally closed with stoppers are used to introduce the test samples. The humidity is maintained by means of sulphuric acid or a saturated salt solution in the bottom of the tank and constant temperature within very narrow limits is maintained in the tank by placing the entire assembly inside a cabinet or oven automatically controlled to ± 0.5 degrees Fahrenheit. Due to the heat insulation it has been

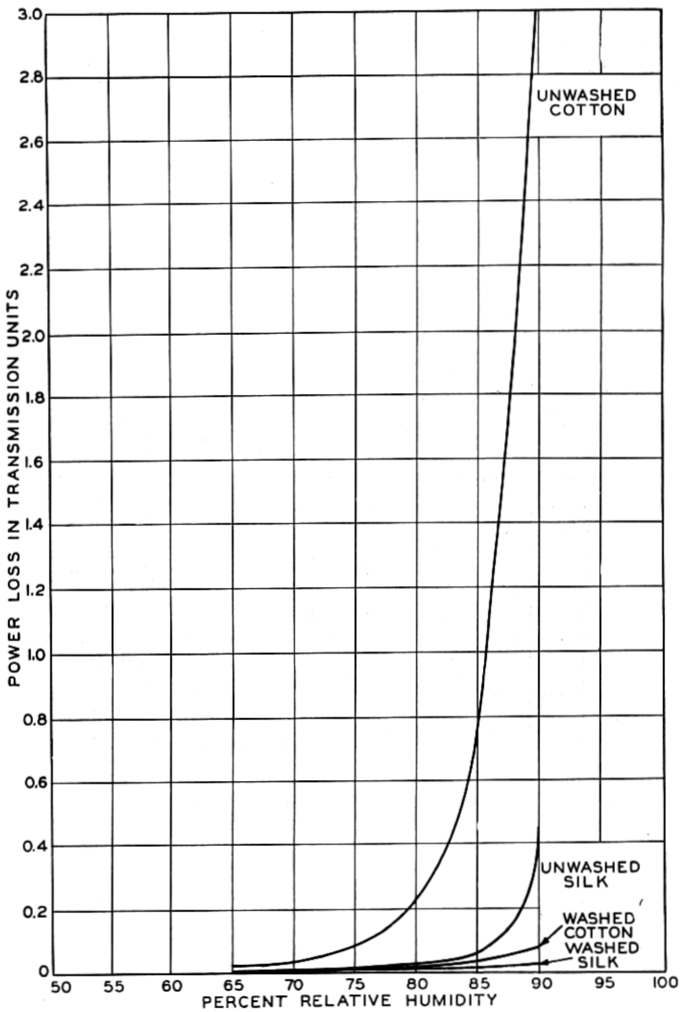

Fig. 5—Transmission loss in 50 ft. of twisted pair wire insulated with double servings of equal thickness.

found that temperature variations within the tank are reduced to the vanishing point for all practical purposes.

This is very important as it has been found that fluctuations in the temperature of the test chamber introduce large errors in the insulation resistance of the samples. The errors, however, are attributed not to temperature effects on the samples but to variations in relative humidity produced by the temperature changes and the considerable time required for equilibrium to be restored after such changes occur.

Another source of error in textile testing is found in the fact that the values of insulation resistance are affected by the humidity condition to which the sample has been exposed prior to the test.

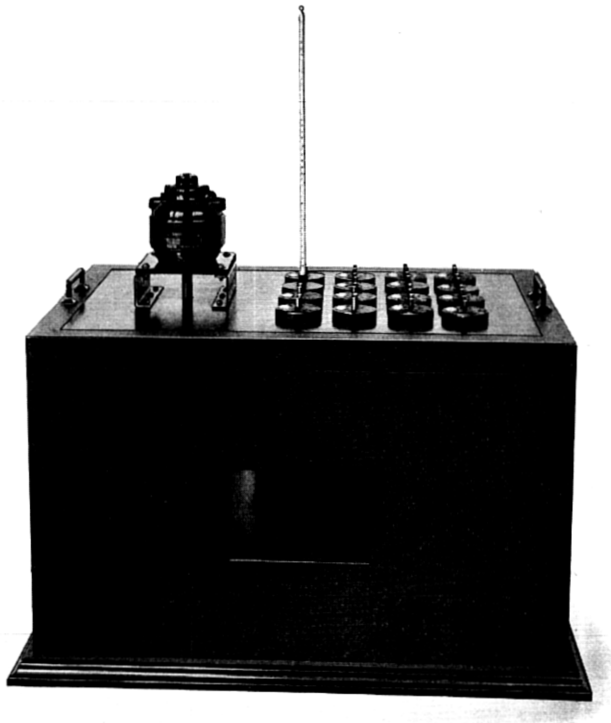

Fig. 6—Humidity cabinet for conditioning samples.

To avoid error from this source, all test samples are conditioned by drying in a desiccator at the approximate temperature of the test tank before being placed in the tank.

The samples are prepared by winding a number of turns of the textile around the electrodes inserted in the stoppers as shown in Fig. 8. Care is taken not to handle the textile itself during the winding process as perspiration from the hands is likely to contaminate the thread. Samples are left in the tank over night as there is considerable evidence to show that several hours are required for them to come to complete equilibrium. A temperature of 100 degrees Fahrenheit and relative humidity of 75 per cent has been found suitable for cotton testing and 100 degrees Fahrenheit and 87 per cent relative humidity for silk.

The number of turns of yarn or thread wound around the electrodes will vary with the size of the thread since the winding space is fixed and a single layer of thread is applied. For No. 30/2 cotton approximately 90 turns, 180 parallel threads, have been found to give satisfactory readings. This same space accommodates about 256 turns, 512 parallel threads, of No. 62/1 spun silk.

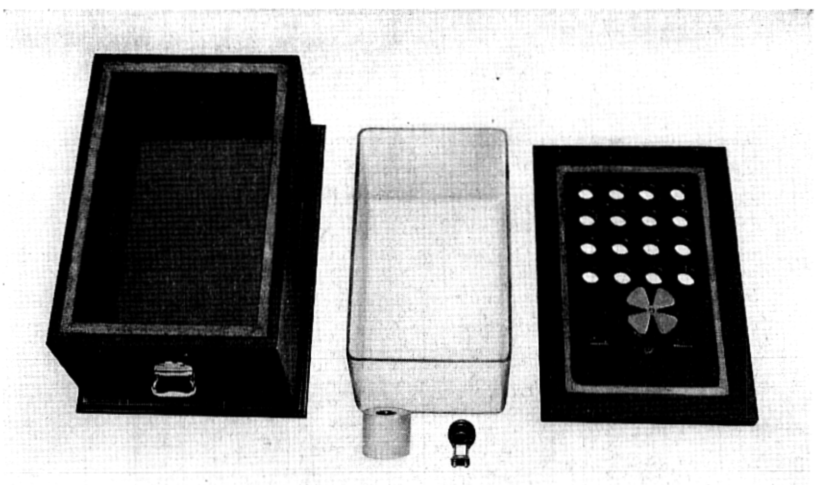

Fig. 7—Humidity cabinet disassembled.

The distance between the electrodes is not particularly critical. That is, it is not important, for example, whether the distance is 5/8 in. or 3/4 in. It is important, however, that having decided upon a certain separation, say 3/4 in., this separation be accurately maintained for all electrodes if the readings are to be comparative. Of course if the separation is too great, an unreasonable number of turns of textile is required to bring the resistance of the sample within the range of the galvanometer. On the other hand, if the separation is too small, the error due to variation in separation for different sets of electrodes increases in magnitude.

In actual practise, 3/4 in. separation with a winding space of 2 in. accommodating, as mentioned above, about 90 turns of No. 30/2 cotton has been found to be fairly satisfactory. This arrangement gives galvanometer readings of the order of 2000 megohms for washed silk and 1,000 megohms for washed cotton as compared with 12 meghoms and 5 megohms for unwashed silk and cotton respectively. It is obviously necessary to maintain a high degree of insulation resistance between the electrodes. This is accomplished by using hard rubber for the stoppers in which they are mounted and preventing surface leakage by coating the end of the stoppers with ozokerite wax.

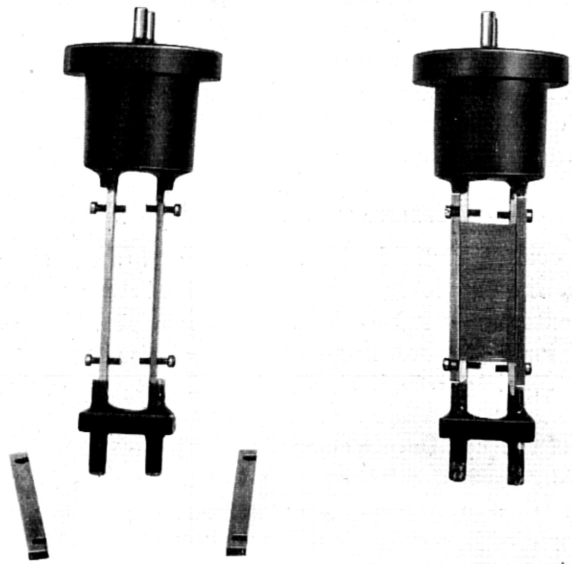

Fig. 8—Electrodes on which samples are wound for test.

The electrodes themselves are gold or platinum plated to prevent oxidation or corrosion. Observing these precautions, it is possible to obtain readings sufficiently consistent to distinguish not only between washed and unwashed textiles but to determine differences in degree of purification in various lots of washed textiles.

The question may be asked as to why 75 per cent relative humidity and 100 degrees Fahrenheit were selected for cotton and 87 per cent relative humidity and 100 degrees Fahrenheit for silk. These values were, within reasonable limitations, more or less arbitrarily selected and further experience may show that some other values are preferable.

However, for the following reasons, 75 per cent and 87 per cent at 100 degrees Fahrenheit were selected as offering definite promise of giving consistent results.

The main considerations in the choice of humidity conditions were, first, that the humidity should be high enough so that insulation resistance measurements of sufficient accuracy could be made using a band of threads as described above and a commercial galvanometer of reasonably high sensitivity; second, that the humidity be lower than that at which polarization effects would introduce serious error. The humidities chosen are within the range found suitable for cotton and silk under these limitations. Furthermore, these conditions are readily obtainable by the use either of saturated salt solutions or sulphuric acid solutions, thereby increasing the flexibility of the test. The temperature of 100 degrees Fahrenheit was chosen arbitrarily as one which could be maintained in the shop at any time of the year without artificial cooling.

Application to Apparatus

From an economic standpoint the most important conclusion to be drawn from the graphs is that cotton can be improved by washing to such an extent that it becomes a better insulator than the ordinary commercial insulating silk in general use. Since the cost of washing silk and cotton is nominal, usually less than 5 per cent of the cost of the material, the engineer given purified textiles may either take advantage of marked improvement in quality of electrical characteristics by using washed silk, or may substitute washed cotton for silk and realize substantial economies without degrading the product. As an example of how this applies to Bell System apparatus, central office distributing frame wire with annual requirements of more than 400 million conductor feet is now insulated with two coverings of silk where three were formerly required. The resultant wire is superior electrically to the old wire and the annual saving in silk amounts to about 70,000 pounds.

As another example, telephone cords of various types have been reduced substantially in cost with no impairment in quality by substituting two washed cotton braids for the cotton and silk braids formerly used. Altogether, various types of textile insulated wire aggregating annual requirements in excess of two billion conductor feet have either been changed to employ washed textile insulation or are scheduled for change as soon as possible because of corresponding economies in manufacturing cost or improvement in electrical properties.

The foregoing is intended to show what has been accomplished on a commercial scale at reasonable cost in the way of improving the insulating properties of silk and cotton. There still exists a rather wide margin in insulating properties between washed silk and washed cotton at high humidities which further study may show can be reduced. The graphs do not show the magnitude of improvement in cotton which has been obtained occasionally in laboratory experiments which leads us to hope that presently it may be possible to process cotton in a way that will result in its having electrical properties equal to those of washed silk for many practical purposes.

The question naturally arises as to the permanence of the improvement effected by the purification process. We have attempted to answer this question by periodic tests of washed silk and cotton insulated wire over an extended time, the test samples being exposed to ordinary room conditions where they could accumulate the normal quantity of dust. The results show no tendency for the insulation to revert to the constants of unwashed insulation. This appears logical since there is no particular reason to expect contamination by accumulation of such impurities as sodium or potassium salts from ordinary exposure to the air. Furthermore, in service, telephone office wiring is protected from the effects of dust by braided textile coverings or by the application of waxes or varnishes where the individual wires are exposed.

Conclusion

The discussion has been confined primarily to telephone central office cabling where silk and cotton are used in the cable core without impregnation. However, it is believed that the whole subject of purification of textiles becomes of general interest when it is stated that the improvements obtained by washing are not nullified by the supplementary use of impregnating waxes or varnishes. That is, the improvement in dielectric properties and reduced electrolysis obtained by washing and by impregnating are apparently substantially additive. While the studies have not proceeded far enough to cover comprehensively all of the better known impregnating waxes, asphalts, varnishes, etc., they have proceeded to the point where we can say that this is the case for the beeswax-paraffine waxes and certain asphaltic compounds. These findings are in line with the generally known fact that impregnation of textiles with wax compounds does not prevent, though it does retard, the absorption of moisture which in the presence of soluble salts causes conducting paths to be established, probably through the embedded textile fibers. Consequently, such materials as fabric base insulating tapes, varnished linens and cambrics, electromagnet coil winding insulation, all being sensitive electrically to moisture, should be benefited to a substantial degree by purification of the fibrous components.

Therefore, while there is still much to be learned about the behavior of silk and cotton with respect to their electrical characteristics under various treatments and conditions, the study has progressed to the point where the following statements can be made.

1. The removal of water soluble salts which are present in both silk and cotton not only results in a very decided improvement in their insulating properties, but reduces the sensitivity to change of the a.c. characteristics with changes in atmospheric moisture conditions.

2. The improvement which can be realized is great enough to permit the substitution of washed cotton for silk where ordinary commercial silk has been found to give satisfactory results.

3. The use of purified textiles in cables carrying continuous d.c. potential will reduce electrolysis and consequently prolong the useful life of such cables about in proportion to the extent to which the purification process is carried.

In presenting the foregoing discussion, the authors wish to acknowledge their indebtedness to engineers of the Western Electric Company whose work in cooperation with silk suppliers has been largely responsible for the development of commercial methods of purifying insulating silk. Acknowledgment must also be made of the importance of the fundamental and research work which underlies the engineering result briefly described by this paper.