Selection of 3kHz spark testing potentials for insulated wire

Proper potentials may be easily established by a simple experimental procedure for any given product.

by Henry H. Clinton

In recent years increasing reliance has been placed on in-line high potential testing of insulated wire products as a means of discovering insulation flaws.

Studies made in the late '60s established that if the spark test potential of either a high-frequency sine wave or impulse waveform was properly selected, the results were equivalent to those obtained by immersing the product in water and applying a 60Hz high potential between the conductor and the water.

The Impulse Spark Test was subsequently adopted by the National Electrical Manufacturers' Association (NEMA) as a substitute for a water immersion test. This led to the inclusion of this test in military specifications for insulated wire.

In 1968, the Underwriters Laboratories (UL) approved the use of high frequency potentials (3000Hz) for the testing of labeled products.

The Canadian Standards Association (CSA) adopted the 3kHz test in 1976 and use of this method spread rapidly throughout the wire and cable industry.

Test voltage levels were carefully specified by UL, CSA, and the military to insure the detection of flaws, and were generally based on the dielectric strength of the insulation coating rather than the rated operating voltage of the product.

Some products, however, have specified spark test potentials based on a multiple of the operating voltage; for example, if the rated operating potential is 12 DC volts, then 50 times this value, or 600 AC volts, might be specified as a very safe test level which would certainly detect any insulation flaws. The reality of the situation is, however, that any number of patently obvious insulation pinholes or skips could pass through a spark tester electrode at this level without detection. The reasons for this are twofold:

1. If the test voltage is applied to a metallic sleeve fitted closely around the insulation circumference, a pinhole flaw through the insulation constitutes an airgap equal to the insulation wall thickness. As shown in Fig. 1, the expected flashover potential can be somewhere between 30 and 100 volts peak per mil of thickness. Thus, if the product has a 0.01 in. wall thickness, a minimum of 1,000 peak volts should be allowed to detect a flaw even with the ideal electrode described.

2. Most spark test electrodes are far from ideal and allow large air gaps between various points on the insulation surface and electrode elements. For a large product in a bead chain electrode these gaps can approach half the product diameter (see photograph, Fig. 2). For smaller products with thin insulations air gaps of several times the insulation thickness can easily occur because wire tension can draw the bead drape to one side, or vibration can throw the beads away from the product. Again, applying the figure of 100 peak volts per 0.001 in. of air gap, it is easy to see that a peak potential of several thousand volts may be required to initiate the electrical discharge through a pinhole defect even for thin-walled products.

AC, DC striking potentials

A number of product samples were tested in the laboratory with positive DC, negative DC and 3kHZ test potentials. Pinholes were created in each sample and each defect was held stationary in a bead chain electrode. Peak currents were limited to small values to minimize insulation damage in the pinhole area, and the striking potentials determined for each type of test. The sequence was repeated for each sample to establish the repeatability of results.

In general, the value of a negative direct potential required to initiate an arc was from 20% to 50% greater than the peak value of a 3kHz waveform having the same effect. A positive electrode potential ranged from 20% to 25% higher. The reason for these differences is not clear, but it is conjectured that in the DC case the onset of air ionization redistributes the charges and potential differences in the mixed dielectric so as to retard total ionization of the air path. At 3kHz, the same process would take place during the first half cycle, but during the second half the redistributed charges would be of opposite polarity and would increase potential differences to enhance ionization. A similar explanation was put forward by N. Parkman regarding the electrical behavior of insulation voids.[1]

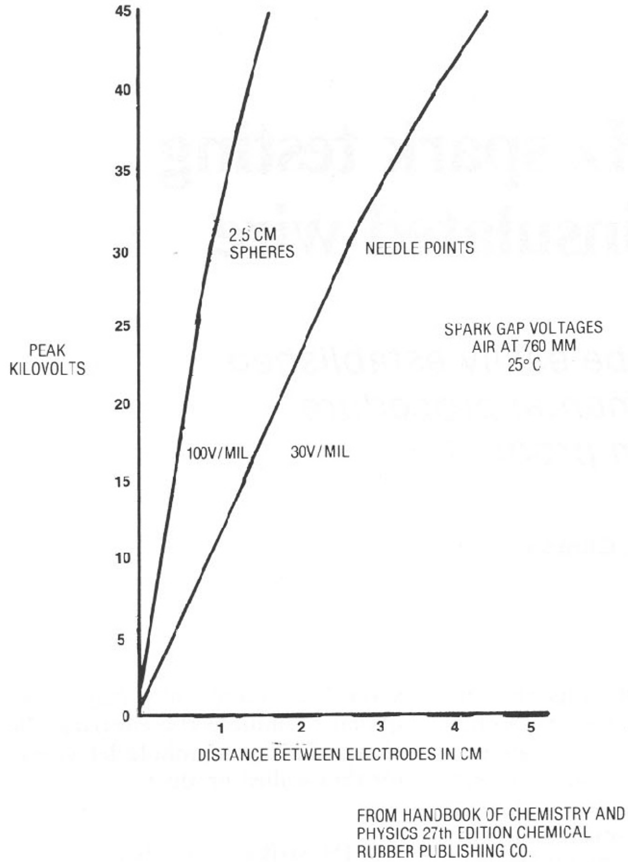

Fig. 1.

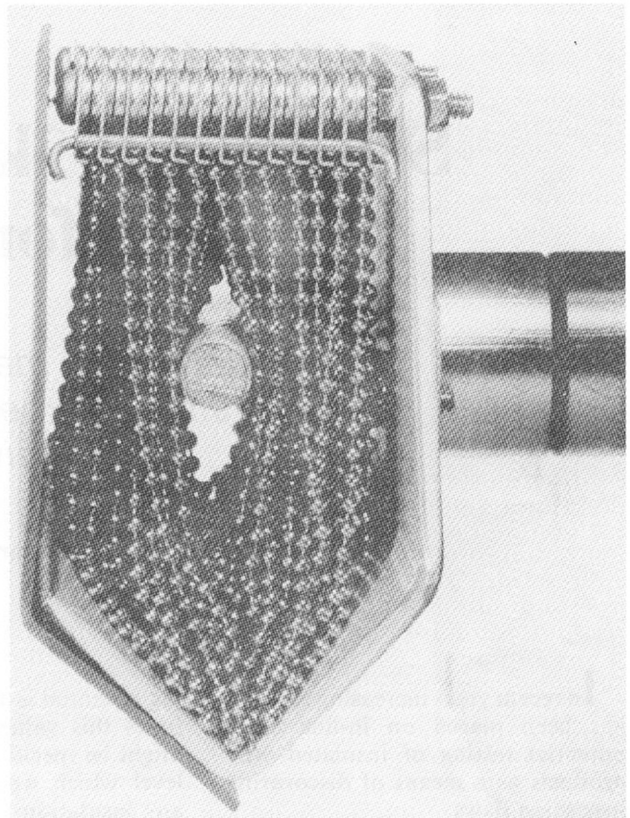

Fig. 2.

If an insulated wire specimen is placed in an electrode excited by a 3kHz potential and the voltage is advanced slowly, a violet glow can be observed immediately adjacent to the insulation surface. The effect is best viewed in darkness.

Glow formation begins in spots where the electrode elements touch the insulation surface. As the potential is increased the glow extends from these points to encompass more and more of the insulation surface. Finally the insulation surface is completely enveloped by the glow.

Experiments have shown that this potential required for complete coverage is the minimum required for reliable pinhole detection.

Upper limit of 3kHz test potential

The test potential obviously must be held below the value required to cause failure or breakdown of the insulation, or even cause degradation of its insulating quality. Since the factors which cause insulation breakdown are so diverse, published ASTM test figures on the insulating material are not especially useful in predicting the breakdown potential of a given product in a spark test electrode. At even the slowest wire line speed, the important effects of increased temperature and erosion due to corona do not have time to come into play. As a result, the potential required to cause any measurable degradation of insulation nearly coincides with the breakdown value.

The breakdown potential can easily be determined by placing a product sample in the electrode, moving it continually back and forth in an excursion of a few inches. The test voltage is then advanced until failure occurs. The process should be completed within 10 or 15 seconds to avoid heating.

It will be found that some samples will not fail at the maximum 15KV voltage of the 3kHz generator. Others will exceed the output power capability of the generator prior to either failure or the maximum voltage limit.

Selection of 3kHz potential level

For a given constriction, once the lower and upper limits of the test potential have been defined, it is usually apparent that a wide latitude in its selection is possible without appreciable effect on defect detection. For example, if the lower limit is 3KV and the upper limit is 12KV, anywhere in the 5-8KV range would be satisfactory.

Weak insulation problems

Some insulations, for example, paper or foam, cannot tolerate the level of test potentials required to overcome air gaps in a beaded electrode. For these cases a low voltage (below 1,000 volts) test can be carried out using water electrodes or highly redundant brush-type electrodes.

Conclusion

Proper 3kHz spark test potentials may be easily established by a simple experimental procedure for any given product, as follows:

- Determine the potential required for full corona flow envelopment.
- Determine the potential at which electrical breakdown occurs.
- Select an intermediate value.

References

1. Physics of Plastics, P.D. Ritchie, d. Van Nostrand Co. 1965, p. 305

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