# Cable Lore

## Laboratory Experimentation

Number 66

Date: April 30, 1979

by Power Cable Engineering and Research

ANACONDA

Laboratory experimentation plays a key role in predicting cable longevity, and the cable engineer requires the best available methods of testing in developing information to predict cable behavior in the field. These methods must yield as much information as possible and help the engineer avoid mistakes in predictions.

One such method, which has proven very effective, is called multi-factorial experimentation. Unlike the popular concept of scientific experimentation, this type of research is structured to consider more than one variable while still maintaining control over the experiment. The following is a comparison of the old and new methods.

A researcher in a well-known cable manufacturer's laboratory suspects that both voltage stress and temperature influence the rate of cable aging. To check his belief, he sets up two experiments. In one, he takes two identical cable samples and applies 10 kV to both. One of the samples is kept at 25° C, the other is kept at 75° C.

In the other experiment, the researcher takes two more identical cable samples and puts them in a 25° C room. He energizes one of the samples at 10 kV and the other at 20 kV. After one month of test, the samples are removed and tan delta is measured. The test conditions and results, shown below, reveal an interesting relationship.

| Applied Stress | Temperature | Tan Delta x 100 |
|---|---|---|
| **Experiment I** | | |
| 10 kV | 25° C | 0.32 |
| 10 kV | 75° C | 0.38 |
| **Experiment II** | | |
| 10 kV | 25° C | 0.32 |
| 20 kV | 25° C | 0.41 |

From these results, it is clear that raising the temperature from 25° C to 75° C increased tan delta by 0.06 and that raising the applied stress from 10 to 20 kV increased tan delta by 0.09. The engineer is satisfied with these results and predicts that in the field a cable at 75° C and 20 kV would have a tan delta higher by 0.06 + 0.09, or 0.15, than one at 25° C and 10 kV.

Another investigator, in a competitor's laboratory, also suspects that voltage stress and temperature influence the rate of cable aging. But to check his concern, he sets up a multi-factorial experiment.

One cable sample is placed in a 25° C room with 10 kV applied, another is placed in a 75° C oven with 10 kV applied, a third is placed in a 25° C room with 20 kV applied, and a fourth is placed in a 75° C oven with 20 kV applied.

After one month on test, the samples are removed and tan delta is measured. Interestingly, these test conditions and results, which are shown below, reveal much more.

| Applied Stress | Temperature | Tan Delta x 100 |
|---|---|---|
| 10 kV | 25° C | 0.32 |
| 20 kV | 25° C | 0.41 |
| 10 kV | 75° C | 0.38 |
| 20 kV | 75° C | 1.79 |

Just like the first researcher, this investigator notes that raising the temperature from 25° C to 75° C increased tan delta by 0.06 when the applied stress was 10 kV. Additionally, he notes an increase in stress from 10 to 20 kV at 25° C increases tan delta by 0.09. But he sees that at 20 kV, raising the temperature from 25° C to 75° C increased tan delta much more from 0.41 to 1.79!



(Continued)

This investigator now has experimental evidence and doesn't need to make a prediction. This is in contrast to the first investigator who had to make a prediction which was wrong.

Situations like this, in which two or more factors interact to produce a result either more or less intense than would be expected, if only one factor at a time were considered, happen frequently in nature. And experiments which are designed to consider the effect of non additive or synergistic factors such as these yield the most comprehensive information.

The lesson of the two examples is quite clear. The cost of the second investigator's results was essentially the same as the first's, yet much more useful information came from the second experiment. In fact, knowledge that temperature and voltage were synergistic, a fact missed entirely by the first researcher, would be critical to accurately predicting cable reliability.

The above is a hypothetical example, but consider the fact that polyethylene insulated cables are now known to be sensitive to water and electrical stress; "water trees" form and reduce dielectric strength. Twenty years ago, the high dielectric strength of dry PE cables, and the high retention of dielectric properties when soaked in water (in the absence of electrical stress except for dielectric measurements), convinced most cable engineers that PE was the ideal dielectric for underground applications.

**Bill Wilkens**