G.P.

Corona:

What it is;
Damage it causes;
How to avoid it

By Louis G. Galambos, P.E.
Ass't. Prof. Comm-Tech, Univ. of Toledo
Consultant to
Rowe Industries, Inc.
Toledo, Ohio

Corona:

What it is; Damage it causes; How to avoid it

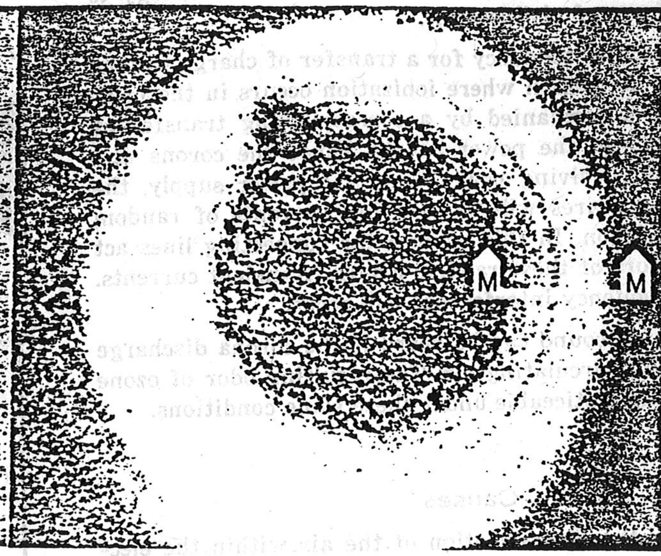

Fig. 1. Deterioration of Teflon due to corona.

By Louis G. Galambos, P.E.
Ass't. Prof. Comm-Tech, Univ. of Toledo
Consultant to
Rowe Industries, Inc.
Toledo, Ohio

A knowledge of the presence or absence of corona discharge can be helpful in controlling quality and reliability of high voltage connectors and cable terminations and other components.

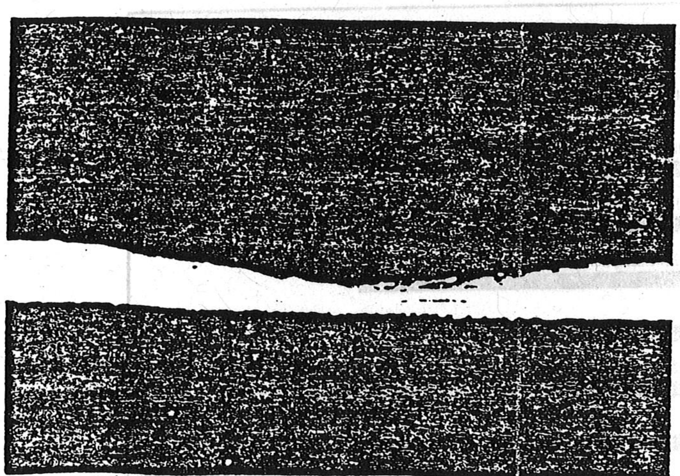

Fig 2. Cross section of region M-M in Fig. 1 shows reduction in dielectric thickness due to corona.

ARE YOU AS DESIGNERS and specifiers of electronic components giving enough attention to the effects of corona?

Will it cause a vehicle to fail in flight after elaborate static ground tests have been performed?

Should you not consider the existence of corona a factor causing premature component failure?

Shall its absence be considered an indication of high reliability?

What is Corona?

Air in a void located within a dielectric or adjacent to the surface of a dielectric that separates two conductors conducting high voltage will ionize. This ionization is caused by the movement of electrons within the gas (air) due to the electrostatic field between the conductors. If the electron velocity is great and if the electron has sufficient freedom for motion in the gas, the electron may acquire so much dynamic energy that in a collision between this electron and a neutral molecule an electron is detached from the molecule by the impact of the collision. This action will continue and be cumulative like an avalanche. The available electrons will continue their motion towards the positively-charged electrode leaving behind positively-charged ions. The presence of these positive ions will tend to present a space charge and reduce the field strength and decelerate the ionization until it ceases. Such is the process of ionization or corona discharge of air under constant polarity (direct) voltage and in confinement.

During the collision process, the disassociation of the air will reveal the presence of corona in several ways.

- Some of the positive ions that were produced in the ionization process may have so much energy imparted to them during the collision and subsequent loss of the electron, that the emission of this imparted energy is in the form of visible light.
- The natural tendency for a transfer of charge to take place in the region where ionization occurs in the insulation is accompanied by a corresponding transfer of charges from the power supply. Since the corona discharge is receiving power from the power supply, the connecting wires will be carrying currents of random pulse duration. In this manner the connecting lines act as radiators of these random-length, transient currents. Radio frequency interference will occur.
- A hissing sound can be heard if the corona discharge is in freely circulating air. The resulting odor of ozone will become noticeable under these same conditions.

Damage Corona Causes

During the disassociation of the air within the electrostatic field, high-velocity electrons and positively-charged ions will be generated. The corona discharge, due to the electron or ion bombardment, will erode almost all dielectrics. This erosion is definite and cumulative. The dielectric will *not* break down under a brief dielectric-strength test, but the cumulative effects of corona attack will cause failure without warning at a later date, after installation within a system of assumed high reliability. For an example of the degrading effects of corona upon TFE-fluorocarbon,[5] see Fig. 1. This widely used dielectric was placed between two electrodes. The corona discharge is shown in the form of a ring where the electrode contacted the specimen. The reduction in dielectric thickness is quite evident in Fig. 2.

The cable shown in Fig. 3 illustrates the deterioration encountered when the cable was exposed to corona-generated ozone. The cable has a butyl dielectric. A study of corona resistance versus applied voltage is shown in Fig. 4. A comparative analysis of various dielectrics and their resistance to corona at 25 kv is illustrated in Fig. 5.

The capabilities of various materials have been under careful study by a leading cable company[1]. It appears from these findings of Fig. 4 that the corona intensity at 25 kv had marked influence upon hours to failure of some materials. A further study resulted in the comparative chart shown in Fig. 5 for various materials. The undesirable condition shown in Fig. 3 was the subject of intensive study at Bell Telephone Laboratories[2] on a problem area in the Nike-Hercules power supply.

The concluding remarks in the report stipulated the desirability of *removing* the sources of corona-generating ozone. It should also be pointed out that the cable and its termination was of a corona-free design, but the items to which they were secured needed improvement. Connectors and terminations were previously developed to meet corona-free requirements of the subject power supply. Yet several other components in the system haven't been designed to the same standards. The

Fig. 3. Cable deterioration due to corona.

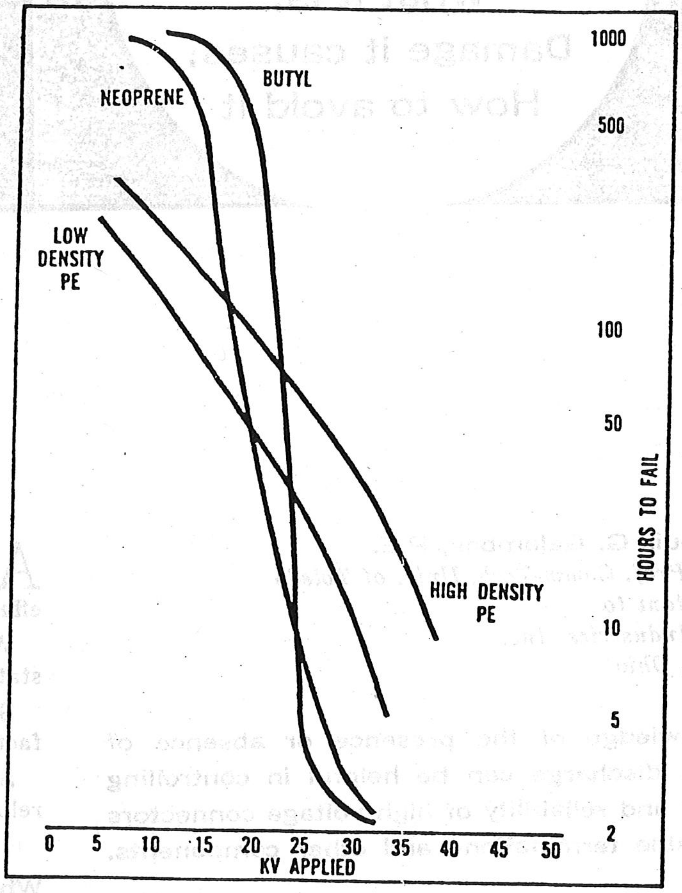

Fig. 4. Corona resistance versus applied voltage.

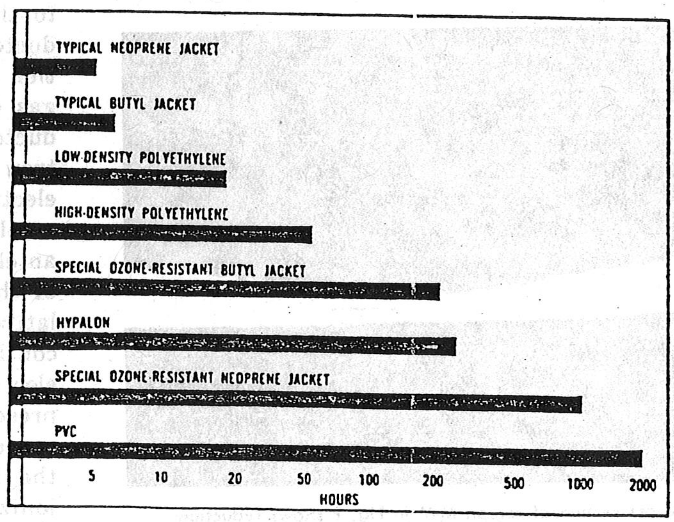

Fig. 5. Corona life of various dielectric at 25 kv.

continued efforts of the investigating team have done much for the high reliability of the system under their study. The general policy has been to eliminate the source of corona rather than to tolerate corona and then select materials to withstand it.

Corona-Prone Designs

Many electrical devices that incorporate conductors with suitable insulated regions may exhibit a tendency to corona. Some typical designs that frequently exist in practice are as follows:

- The edges of the braid on a coaxial cable are usually folded back prior to an installation. Sharp edges are inevitable.
- Air pockets or voids are allowed to exist around the center conductor of most multi-contact or single-contact connectors.
- Air is allowed to exist at the interfaces of many "high-reliability" connectors.
- The insertion of a good dielectric as a barrier between two conductors will result in a voltage stress distribution inversely proportional to the dielectric constant and subject adjacent air surfaces to a stress exceeding that if the dielectric were not present.

With reference to the first condition, corona may be quite harmless to the dielectric *if* the air is free to circulate. However, if the air is trapped corona will have degrading effects upon the dielectric. In all cases the presence of corona will constitute a source of radio-frequency noise with possible interference through the connecting conductors as previously described.

How to Test for Corona

Although corona discharge is sometimes visible, visual inspection for presence of corona is grossly inadequate. The voltage at which visible corona can be observed is at a threshold well above the level of actual corona inception. Also, the corona that is visible is external and free to circulate. Therefore, it is not usually damaging. Of far greater concern is the internal corona within a device.

Corona originating within an enclosed item has all the requisites for damage and degrading of the dielectric. Because the corona is internal and not visible, the transient currents it sets up in the connecting conductor are used as the indicator.

The transient current bursts due to corona may be detected with specially designed corona detectors. A detailed description on the latter is available[3].

How to Avoid Corona

To avoid the generation of corona discharge, several basic design concepts must be considered.

1. Air gaps or pockets within a high field strength must be eliminated by introducing a cohesive bond between the conductor and the dielectric.

2. Dielectric material of uniform density with no voids or porosity must be employed.

3. The contours of the conductors adjacent to the dielectric shall have no sharp edges.

4. If the elimination of air pockets seems unavoidable, the electrical stresses must be reduced to a level below that required for ionization (about 75 volts per mil at sea level).

5. The use of field-assembled, high-voltage connectors should be discouraged whenever possible. The use of molded-on dielectric to conductors will yield a more corona-free device than any other assembly available[4]. See Fig. 5.

6. When an encapsulating compound is used, an intimate cohesive bond should exist between it and the other dielectric it may contact.

The information available to date indicates the presence of corona within an electrical system will cause degradation and eventual failure. It seems that specification writers have failed to take this factor into account.

Too much emphasis has been placed upon dielectric strength tests and not enough upon the level of corona inception. If a component is to be considered highly reliable, then it should have a corona-free level above the operating voltage and applicable environment. Only economy will dictate the margin between minimum corona level and operating voltage. On the other hand, how well can the system afford failure? Therefore, when competitive items are being evaluated, the corona level of one product versus the other should be a significant figure of merit and a simple standard for purchasing people to follow. ⊕

REFERENCES

1. R. F. Grossman, "Degradation of Polymers," Wire and Cable Symposium, 1962, pg. 7.
2. J. P. Sumner, and J. Barvir, "Memorandum: Investigation of Hercules MTR and TTR High Voltage Cable Failures — case 27362-1-106-2," Bell Telephone Laboratories, Whippany, N. J.
3. O. H. Heinrich, "Corona Measuring Techniques," Technical Bulletin 66T1, May 1964 of J. Biddle Co., Philadelphia, Pa.
4. "Plans Studied for Voltage Pulse Cable with Connectors," BuShips Journal, 1955, pp 32, 33.
5. "The Effects of High Voltage on TFE," Insulation, May 1964, p 35, J. C. Reed, Dupont.

Reprinted from ELECTRONIC PRODUCTS Magazine April 1965 Issue