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POLYMER CHANGES IN RADIATION ENVIRONMENTS

Radiation environments are a popular subject today and rightly so with the proliferation of nuclear generating stations, but radiation environments are not new to the world. We, and all the materials we use, are continually exposed to radiation, not only from the sun but from cosmic rays. What is different is the intensity of the radiation. It is well known that many hydrocarbon polymers like polyethylene or polystyrene, without protective fillers like carbon black, stress crack on the surface when exposed to sunlight in combination with the oxygen in the atmosphere. When exposed to larger intensities of radiation, more severe changes result and, in fact, the situation is much like that which occurs when materials are exposed to oxygen.

Both oxygen and radiation produce two types of reactions of polymers — the relative importance of the two types depending upon the conditions of the exposure and, to a large extent, upon the nature of the polymer exposed.

1. Chain scission — The main polymer chain is broken, giving rise to the formation of low molecular weight compounds.
2. Cross-Linking — This results in network structures with a higher molecular weight than the initial material. This is the same kind of reaction which goes on in our CV lines when we cross-link rubbers or polyethylene.

When the material is cross-linked its strength increases and its elongation decrease. When every polymer chain is cross-linked to another, the material can be considered one giant molecule. Eventually, just as an insulation can be over-cured in a CV line, so can excessive cross-linking by oxygen reduce elongation to an unusable level, unless one is trying to produce a hard rubber.

The properly controlled slow oxidation of some materials like drying oils produces tough adherent films which are used to paint structures. A small amount of radiation from a Cobalt 60 source will cross-link some polymers and produce well-cured insulation, as is commercially being done by several competitors.

With other materials, the slow oxidation results primarily in chain scission, as is the case when natural rubber becomes soft and tacky, or when butyl under more severe conditions becomes gummy. When wood, a complex mixture of cellulose, lignin and other organic chemicals rots or

burns slowly in oxygen, it is degraded to carbon dioxide and water and other simple compounds. This is a similar phenomena.

Unfortunately, predicting how the relative rates of reaction of chain scission and cross-linking of polymers are influenced by things like water, temperature, and chemicals, is not straight forward nor exact. The general concepts are well known, but their complete application is not. This means that cables for nuclear plants must be subjected to a simultaneous environment of oxygen, temperature, steam, chemicals, and radiation in some accelerated test (see Cable Lore No. 51) to establish that the cables will be able to resist such an environment in actual service. Tests we have run show that hypalon and EP have excellent resistance to such an environment, and both retain a good balance of electrical and physical properties. Cables based on these two components are prime candidates for class 1-E application.

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