Attachment 3

2.76

RADIATION EFFECTS ON ORGANIC MATERIALS IN NUCLEAR PLANTS

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rads with rapid degradation above threshold. The value at 3 x 10^6 rads was 50% of the original. Tensile and shear strength was affected at 1 x 10^6 rads, but these properties were not degraded quickly. At 2 x 10^7 rads, tensile and shear strength were 75% of original values and 50% at 3 x 10^7 rads. Large quantities of gas are evolved.

Cellulose Propionate/threshold - 3 x 10^5 rads/impact resistance. Impact resistance of Forticel samples was affected above 3 x 10^5 rads,[36] but was still 75% of the initial value after 4.4 x 10^6 rads and 50% at 1.5 x 10^7 rads. Tensile strength was reduced 25% at 5 x 10^6 rads and 50% at 1.5 x 10^7 rads. Elongation was reduced 25% at 3.5 x 10^6 rads and 50% at 1.5 x 10^7 rads. Shear strength was affected by 4 x 10^5 rads, but was still 50% of the original value at 3 x 10^6 rads. Higher values are observed for thick samples[48] and G_{gas} = 1.5 with 35 ml/gm evolved at 10^9 rads.

Ethyl Cellulose/threshold - 1.5 x 10^6 rads/impact resistance. Ethocel R-2 shows initial reduction in impact resistance at 1.5 x 10^6 rads, 25% reduction at 5 x 10^6 rads, and 50% loss at 1 x 10^7 rads.[36] Elongation and shear strength are affected at 2 x 10^6 rads. Elongation is reduced 25% at 4 x 10^6 and 50% at 4 x 10^7 rads. Tensile strength is affected above 3 x 10^6 and reduced to 50% at 2 x 10^7 rads. Tests reported were for static irradiations in air at ambient temperature. Reference 48 gives G_{gas} approximately 4.6 with 105 ml/gm evolved at 10^9 rads.

Halogenated Polymers

Many of the commercial halogenated polymers are chloride or fluoride substituted vinyls; others are substituted polyolefins.

Polyvinyl Chloride, Rigid/threshold - greater than 10^6 rads. Reference 48 reports 80% or better retention of tensile and notch impact strength of a 0.17-inch thick sample irradiated in air at 2 x 10^5 rads/hour and ambient temperature to a total dose of approximately 10^9 rads. Reference 33 reports very serious degradation at 1.3 x 10^9 rads for rigid PVC irradiated at 60°C with 1 MeV electrons. Radiation resistance is undoubtedly dependent on thermal and oxidizing conditions, as is the resistance of plasticized PVC.

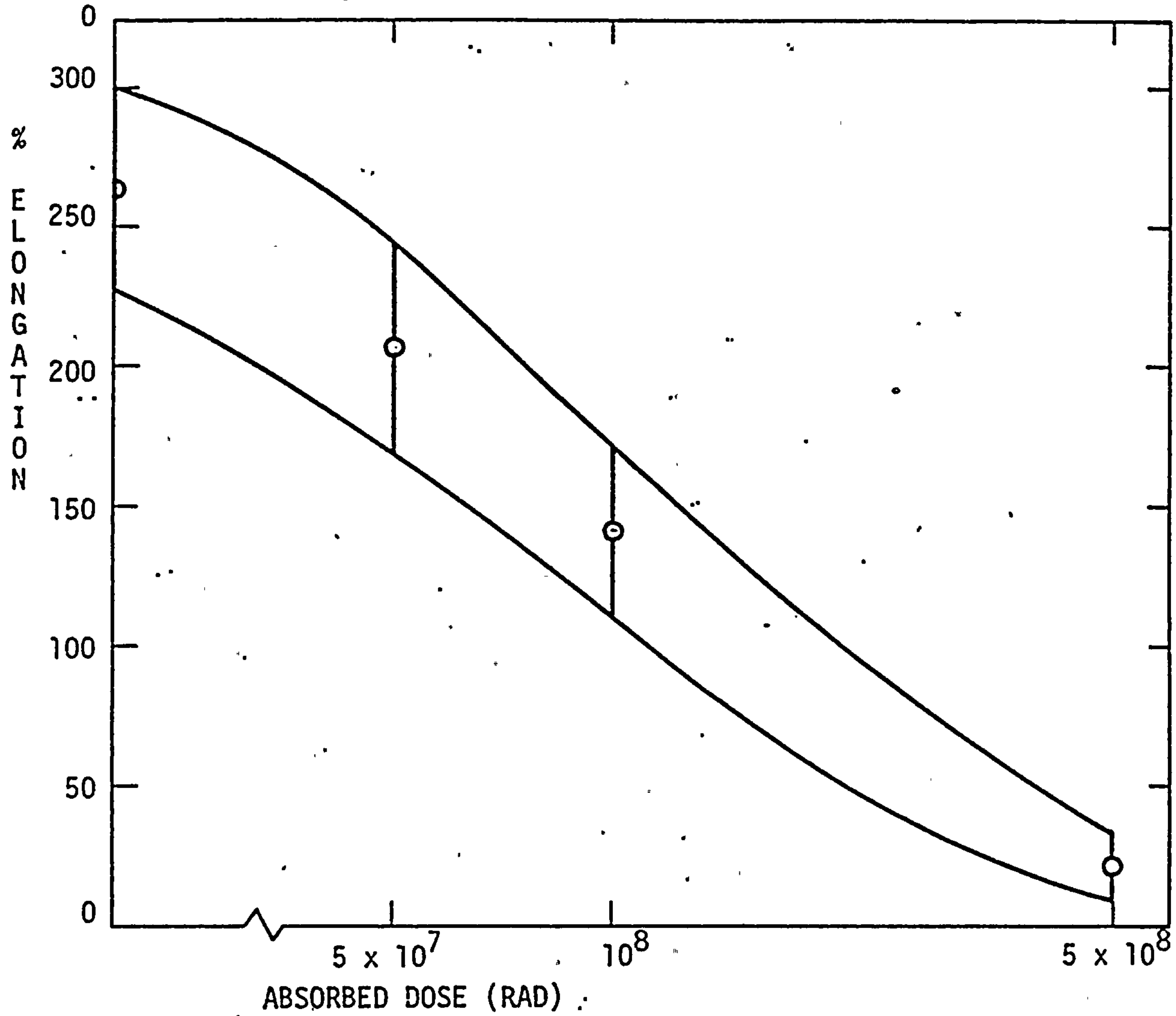
Polyvinyl Chloride, Plasticized/threshold - 5×10^5 rads/temperature at break. Reference 8 reports that DC resistivity of one PVC cable insulation was affected after 5×10^6 rads and sensitivity to hot water and steam was increased above this value: Large decreases in oxidation resistance were noted above 5×10^6.

Scission or crosslinking may predominate, depending on temperature and oxidizing conditions. Plasticizers and additives are not generally known for commercial materials, but a fairly large range of radiation resistances occur for different materials (Figure 3-1). Reference 48 reports results for 4 and 20-mil samples of Geon 8630 irradiated in air at room temperature. The 4-mil sample lost approximately 20% of original tensile strength after 7×10^6 rads, but retained less than 50% after 1×10^8 rads. The 20-mil sample lost less than 20% of original tensile strength at 1×10^8 rads. Elongation of the 4-mil sample was reduced 20% by 1×10^7 rads: 7×10^7 rads were required for the same change in elongation of the 20-mil sample. Similar indications of extensive oxidation effects were observed with 4-mil samples of Geon 8640 irradiated in air and vacuum. In air, tensile strength was decreased approximately 20% by 7×10^6 rads and 50% by 1×10^8 rads. Elongation decreased 20% at 2×10^7 rads and 50% at 8×10^7 rads. In vacuum, tensile strength was reduced 20% by 7×10^7 rads and elongation was reduced 20% by 6×10^7 rads. References 21 and 39 note marked differences in thermal properties of irradiated PVC. A reduction in the melting temperature of the polymer occurs in air (but not in vacuum). Reduction of the temperature at break of samples heated under constant stress was noted for samples after 5×10^5 rads. After 1.1×10^7 rads, a 30-40°C reduction in temperature at break was achieved. The rate of HCL evolution is affected by the temperature during and subsequent to irradiation. G_{HCL} = 5.41 (-90°C), = .13 (30°C), = 23 (70°C) after 2×10^7 rads. Diffusion and permeability constant are increased by irradiation but may decrease again at higher doses. Crosslinking is inhibited in air, but may be enhanced by inclusion of polyfunc-tional materials, such as polyethylene glycol dimethacrylate. The temperature-oxidation resistance of commercial materials will vary with the effectiveness of free radical scavengers and antioxidants.

Polyvinyl Fluoride/threshold approximately 10^7 rads/elongation. DuPont R-20 exhibits approximately 20% loss of elongation at 2×10^7 rads and 50% loss at 5×10^7 rads. Tensile strength was not appreciably affected below 1×10^8 rads. Sample thickness and dose rate were not given.[48] Polyvinyl fluoride is also marketed as Tedlar. Radiation resistance is probably less at elevated temperatures. One electron irradiation at 60°C to 1.8×10^9 rads resulted in severe physical

Figure 3-1

"SIMILAR" PVC CABLES IRRADIATED AT 20-40°C



Data for cables from 38 manufacturers

(From Reference 50)

degradation but unchanged insulation resistance and a 7% [illegible]crease in dielectric constant. Dissipation factor increased one decade.[33]

Polytetrafluoroethylene/threshold - 1.5 x 10^4 rads/elongation. Reference 47 reports a threshold change of elongation at 1.5 x 10^4 rads for Teflon (TFE) in air, of tensile strength at 2.1 x 10^4 rads, of shear and impact strength and elastic modulus at 1.8 x 10^5 rads. A 25% decrease was noted at 3.4 x 10^4 rads for elongation, 1.2 x 10^5 rads for tensile strength, and 4 x 10^5 rads for shear strength. Impact strength increased 25% at 3.6 x 10^5 rads. Oxidation effects are quite large. Radiation resistance is approximately ten times greater in vacuum or fluid. Teflon hoses tested under simulated operating conditions failed, by leakage, at 1 x 10^5 rads when exposed to intermittent fluid pressure of 1,000 psig and at approximately 1 x 10^6 rads when subjected to 1,200 psig static pressure. The radiation exposure-damage relation was relatively insensitive to temperature in the range of 100 to 350°F in that test. Teflon back-up rings (in fluid) have been found serviceable in some applications to approximately 4 x 10^7 rads, although physical degradation occurs.[36]. Sharp decreases in melting temperature were noted for irradiations above 330°C.

Teflon-FEP (copolymer of fluoroethylene and perfluoropropylene) is more resistant that Teflon-TFE. Teflon-FEP shows ten times greater radiation resistance in vacuum and sixteen times greater resistance in air for 10-mil films.[46] Temperature effects have been noted. Damage at cryotemperatures was negligible for a dose that produced 40% loss of tensile strength at 73°F and 60% damage at 350°F.

Electrical properties are affected differently for irradiation in air and vacuum. TFE volume resistivity has been observed to drop by a factor of 10^2-10^3 in vacuum radiation and to drop an additional factor of 10-10^2 after irradiation (gradual recovery may occur). One Teflon-insulated wire is reported to show slightly reduced flexibility at 10^3 rads in a 5 psia O_2 atmosphere at 90°C. A similar Teflon wire lacking a polyimide coating present on the first wire did not show reduced flexibility under the same conditions.[33] This indicates that the materials were incompatible, not that the radiation level was significant.

Tetran, Fluorlon, and Hostaflon FT are a few of the other commercial names for polytetrafluoroethylene. Main chain scission is dominant and there is little evidence of any crosslinking during irradiation.

Attachment 4

EC/CP(81)-086

Westinghouse Electric Corporation

Water Reactor Divisions

Strategic Operations Division

Box 598
Pittsburgh Pennsylvania 15230

August 13, 1981

Mr. George Wrobel
Rochester Gas & Electric Corp.
89 East Avenue
Rochester, NY 14649

Subject: ENVIRONMENTAL QUALIFICATION

Ref: EQ/CP(81)-035

Dear Mr. Wrobel:

The following responses are provided to the W action items in the referenced letter:

a) As discussed in both WCAP-7829 and WCAP-9003, the complete motor was qualified. The motor-lead splices are considered part of the thermalastic epoxy insulation system and are the same for all these motors. The lead-cable splice qualification should be verified by RGE.