

RADIATION EFFECTS ON ORGANIC MATERIALS IN NUCLEAR PLANTS

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by

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Final Report

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rads with rapid degradation above threshold. The value at  $8 \times 10^6$  rads was 50% of the original. Tensile and shear strength was affected at  $1 \times 10^6$  rads, but these properties were not degraded quickly. At  $2 \times 10^7$  rads, tensile and shear strength were 75% of original values and 50% at  $3 \times 10^7$  rads. Large quantities of gas are evolved.

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

Ethyl Cellulose/threshold -  $1.5 \times 10^6$  rads/impact resistance. Ethocel R-2 shows initial reduction in impact resistance at  $1.5 \times 10^6$  rads, 25% reduction at  $5 \times 10^6$  rads, and 50% loss at  $1 \times 10^7$  rads.<sup>36</sup> Elongation and shear strength are affected at  $2 \times 10^6$  rads. Elongation is reduced 25% at  $4 \times 10^6$  and 50% at  $4 \times 10^7$  rads. Tensile strength is affected above  $3 \times 10^6$  and reduced to 50% at  $2 \times 10^7$  rads. Tests reported were for static irradiations in air at ambient temperature. Reference 48 gives  $G_{\text{gas}}$  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  $2 \times 10^5$  rads/hour and ambient temperature to a total dose of approximately  $10^9$  rads. Reference 33 reports very serious degradation at  $1.3 \times 10^9$  rads for rigid PVC irradiated at  $60^\circ\text{C}$  with 1 MeV electrons. Radiation resistance is undoubtedly dependent on thermal and oxidizing conditions, as is the resistance of plasticized PVC.



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

Polyvinyl Chloride, Plasticized/threshold -  $5 \times 10^5$  rads/temperature at break.

Reference 8 reports that DC resistivity of one PVC cable insulation was affected after  $5 \times 10^6$  rads and sensitivity to hot water and steam was increased above this value. Large decreases in oxidation resistance were noted above  $5 \times 10^6$ .

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  $7 \times 10^6$  rads, but retained less than 50% after  $1 \times 10^8$  rads. The 20-mil sample lost less than 20% of original tensile strength at  $1 \times 10^8$  rads. Elongation of the 4-mil sample was reduced 20% by  $1 \times 10^7$  rads.  $7 \times 10^7$  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  $7 \times 10^6$  rads and 50% by  $1 \times 10^8$  rads.

Elongation decreased 20% at  $2 \times 10^7$  rads and 50% at  $8 \times 10^7$  rads. In vacuum, tensile strength was reduced 20% by  $7 \times 10^7$  rads and elongation was reduced 20% by  $6 \times 10^7$  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  $5 \times 10^5$  rads. After  $1.1 \times 10^7$  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  $2 \times 10^7$  <sup>rads</sup>. 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 polyfunctional materials, such as polyethylene glycol dimethacrylate. The temperature-oxidation resistance of commercial materials will vary with the effectiveness of free radical scavengers and antioxidants.

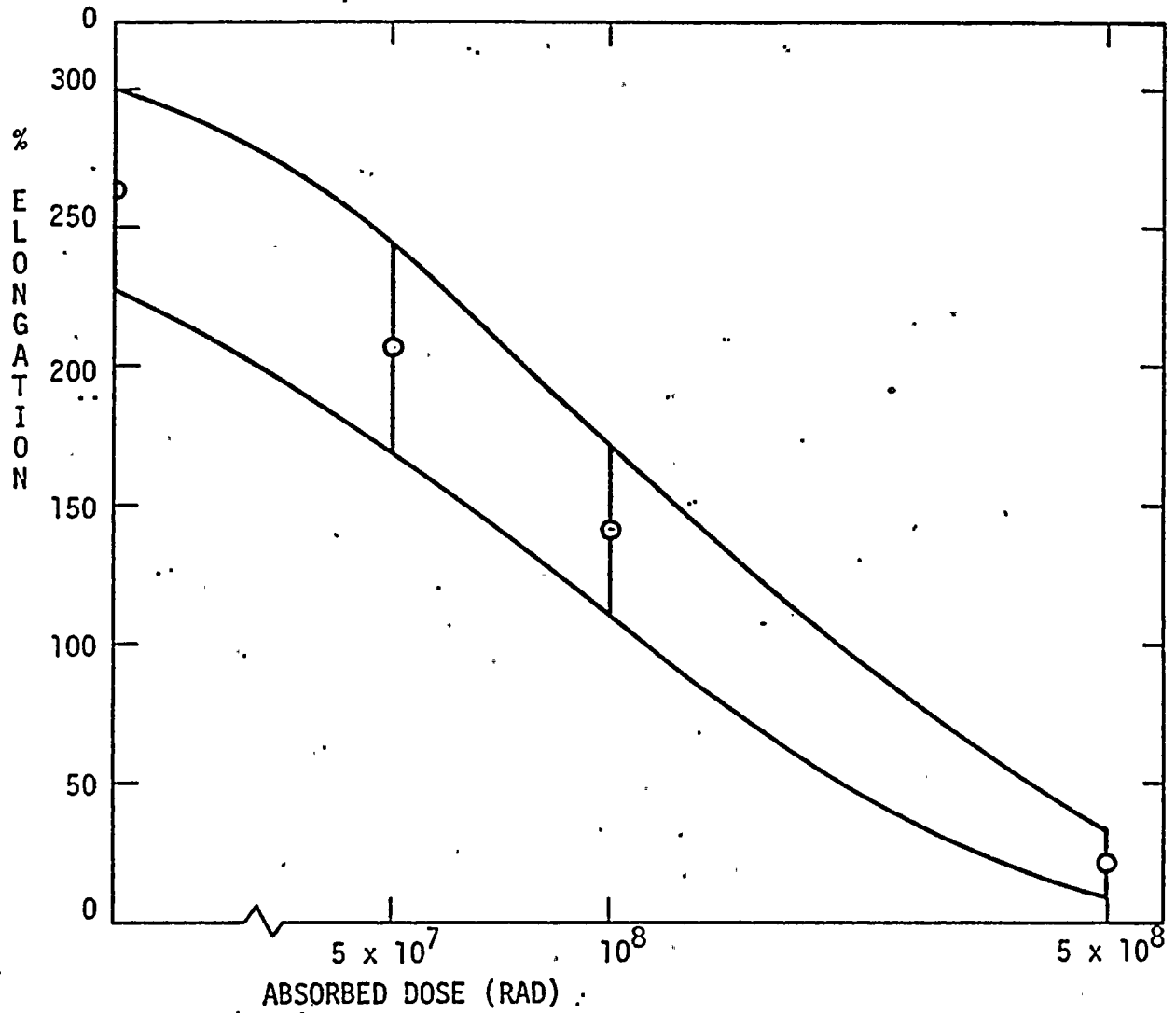
Polyvinyl Fluoride/threshold approximately  $10^7$  rads/elongation. DuPont R-20 exhibits approximately 20% loss of elongation at  $2 \times 10^7$  rads and 50% loss at  $5 \times 10^7$  rads. Tensile strength was not appreciably affected below  $1 \times 10^8$  rads. Sample thickness and dose rate were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



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Figure 3-1

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



Data for cables from 38 manufacturers

(From Reference 50)



2 4 5 6



degradation but unchanged insulation resistance and a 7% increase in dielectric constant. Dissipation factor increased one decade.<sup>33</sup>

Polytetrafluoroethylene/threshold -  $1.5 \times 10^4$  rads/elongation. Reference 47 reports a threshold change of elongation at  $1.5 \times 10^4$  rads for Teflon (TFE) in air, of tensile strength at  $2.1 \times 10^4$  rads, of shear and impact strength and elastic modulus at  $1.8 \times 10^5$  rads. A 25% decrease was noted at  $3.4 \times 10^4$  rads for elongation,  $1.2 \times 10^5$  rads for tensile strength, and  $4 \times 10^5$  rads for shear strength. Impact strength increased 25% at  $3.6 \times 10^5$  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  $1 \times 10^5$  rads when exposed to intermittent fluid pressure of 1,000 psig and at approximately  $1 \times 10^6$  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  $4 \times 10^7$  rads, although physical degradation occurs.<sup>36</sup> Sharp decreases in melting temperature were noted for irradiations above 330°C.

Teflon-FEP (copolymer of fluoroethylene and perfluoropropylene) is more resistant than Teflon-TFE. Teflon-FEP shows ten times greater radiation resistance in vacuum and sixteen times greater resistance in air for 10-mil films.<sup>46</sup> 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.<sup>33</sup> This indicates that the materials were incompatible, not that the radiation level was significant.

Tetran, Fluorlon, and Hostafion 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 thermally stable epoxy insulation system and are the same for all these motors. The lead-cable splice qualification should be verified by RGE.