UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
THE CLEVELAND ELECTRIC ILLUMINATING COMPANY, ET AL.	)	Docket Nos. 50-440 50-441
	)	
(Perry Nuclear Power Plant, Units 1 and 2)	)	

AFFIDAVIT OF SRINIVASAN KASTURI
IN SUPPORT OF NRC STAFF
MOTION FOR SUMMARY DISPOSITION OF ISSUE NO. 9

City of Washington)
: ss.
District of Columbia)

Srinivasan Kasturi, being duly sworn, deposes and says as follows:

1. I, Srinivasan Kasturi, am a Manager in the Power Services Division, EDS Nuclear Inc. My business address is 225 Broad Hollow Road, Melville, New York, 11747. I have been involved in Environmental Qualifications activities since 1972. A summary of my professional qualifications and experience is attached hereto as Exhibit "A." I have personal knowledge of the matters set forth herein and believe them to be true and correct.

2. I have reviewed the NRC Staff Motion for Summary Disposition of Issue #9, dated January 14, 1983, and supporting documents, including the Affidavit of James E. Kennedy in Support of Summary Disposition of Issue #9. I agree with the statements contained therein and give this Affidavit in support of the NRC Staff's ("Staff's") motion.

SUMMARY

3. Ohio Citizens for Responsible Energy's ("OCRE's") contention that radiation induced degradation of polymers in safety related equipment at Perry Nuclear Power Plant ("PNPP") may cause unsafe conditions to occur is not well founded. The dose-rate effect postulated in the Sandia National Laboratories studies (2,4)1/ upon which OCRE bases its contention are directly applicable to PNPP only in limited ways and, in any case, would not lead to an inability of safety related equipment to perform its proper function. This conclusion is based upon an extensive literature review, including a critical analysis of the Sandia studies themselves, and a survey of operating nuclear power plants with equipment and radiation environments identical or similar to PNPP.

4. Even if radiation induced polymer degradation in safety related equipment were to occur at PNPP, this would

---

1/ References appear at the conclusion of the Affidavit.

occur only over an extended period of time. The Cleveland Electric Illuminating Company ("CEI") is in the process of developing a surveillance and maintenance program for PNPP which will assure that polymer degradation, if it does occur, will not result in unsafe conditions.

INTRODUCTION

Definition of Polymers

5. A polymer is a macromolecule formed by the chemical union of five or more identical combining units called monomers. A polymer is typically characterized as a long, repetitive chain of identical molecules and is generally classified into three categories:

Thermosetting Plastics - polymers that solidify or "set" irreversibly when heated (11). Typical thermosets are phenolics, epoxies and polyesters.

Thermoplastics - polymers that soften when exposed to heat and return to their original condition when returned to room temperatures (11). Typical thermoplastics are fluorocarbons, nylons and acrylics.

Elastomers - polymers possessing properties similar to those of vulcanized natural rubber, namely, the ability to be stretched to at least twice their original length and the ability to retract rapidly to approximately their original length when released (11). Typical elastomers are ethylene propylene, nitrile and silicone rubbers.

6. Natural rubber was the mainstay of polymer technology until the 1930's and 1940's when polymer chemists developed synthetic materials to approximate some of the properties of natural rubber. To date, many generic types of synthetic polymeric materials have been successfully developed. Each generic type has its own individual characteristics and a wide variety of applications.

Applications of Polymers

7. Polymeric materials are used in the nuclear industry in a variety of forms and applications. The largest single nuclear application of polymers is in cable insulation and jacketing. Seals, O-rings and gaskets, which are found in many types of equipment, including motors, pumps, actuators, valves, transmitters and switches, are a second major application. Other uses include connectors, motor winding insulations and varnishes, circuit boards, terminal blocks and lubricants.

Definition of Polymer Degradation

8. The reduction of a specified property (e.g., tensile strength, elongation, compression set, insulation resistance, dielectric strength) of a polymer is termed "degradation." Depending upon the nature of its application, different levels of change in a given property or set of properties may be acceptable. Generally, a reduction by 50% of a required property of a material is considered acceptable (1) since good

engineering practice allows for a 100% safety margin in equipment design. The property of concern for the material of which a component is manufactured will be dependent upon the function of that component. For example, silicone rubber used as wire insulation should retain dielectric strength; but, when used as a gasket, it should retain compression set.

Degradation Mechanisms

9. The term "ionizing radiation" usually covers a large number of different types of radiation. Some are beams of charged particles which directly ionize the molecules of the irradiated medium. Others are types of radiation which do not produce ionizations directly but are capable of transferring their energy to charged particles which are themselves ejected from the absorbing molecules and create secondary ionizing tracks. Both of these effects could lead to polymer degradation.

10. Radiation induced degradation is due to the chemical reaction that takes place as a result of energy absorption, and is the direct effect of ionization and/or excitation of the molecules within a material. In solid polymers, free radicals are the most frequent result; in liquid systems, the production of molecular ions becomes more common. A number of competing chemical reactions may then occur, the most important of these being crosslinking (bonding between molecules or parts of a

molecule) and scission (breaking of molecular side or main chains). The formation of gaseous by-products may be an important consideration in either type of reaction.

11. Research (2,3,4,5) on the radiation induced degradation of polymers indicates that the presence of oxygen is critical to the degradation mechanisms encountered. Oxygen is required for the formation of radicals which break down the irradiated material. The importance of oxygen is illustrated by the fact that experiments performed in inert atmospheres produce relatively slight degradation.

12. In addition to oxygen, a threshold radiation dose is necessary for polymer degradation to occur. In the context used herein, threshold damage radiation dose level is defined (10) as that amount of integrated gamma dose which, when absorbed by the material at a prescribed dose rate, causes a loss of 25% (a conservative value to account for uncertainties) of the engineering property of interest. There currently exists extensive documentation (e.g., 5, 6, 7) on the threshold radiation values of polymers.

Dose-Rate Effects

13. To simulate the cumulative effects of the relatively low radiation exposure rates to which polymeric materials in nuclear power plants are normally subjected, the generally accepted industry practice has been to use dose rates on the

order of 10E4 to 10E6 rads/hr. The practice of irradiating test specimens at elevated dose rates has been questioned, however, in studies done by Gillen and Clough at Sandia National Laboratories (2,4). These investigations were prompted by the discovery of degraded electrical cable insulation at the non-commercial Savannah River K-reactor (8). On visual inspection of the cable, the polyvinyl chloride ("PVC") jacket showed no signs of visible degradation along the entire length of the cable. However, after removal of the PVC jacket, it was found that the polyethylene ("PE") insulation underneath had alternating areas of flexibility and embrittlement. Examination of dosimetry mapping performed by Savannah River personnel showed that these alternating areas of flexible and brittle cable insulation corresponded to differences in the radiation fields experienced by the cable at those points. Over the 12 year installed life of the cable, the relatively undamaged areas had been exposed to a total integrated dose of approximately 1.3 x 10E6 rads while the damaged portions had been exposed to twice that amount of radiation, approximately 2.6 x 10E6 rads.

14. Gillen and Clough postulated that the degradation was caused by the dose rate to which the cable was exposed. Dose-rate effect simply means that the amount of degradation experienced by a material is dependent not only on the total integrated dose, but also on the rate at which the radiation is

applied. The effects of radiation dose rate on polymer degradation have been discussed in the literature for many years (e.g., 14, 15, 16, 18). Gillen and Clough's hypothesis that dose rate was responsible for the degradation to the Savannah River cable apparently was prompted by the fact that the highest dose rate to which the cable was exposed was about 25 rads/hr., compared to the rates of about 10E6 rads/hr. commonly used in industry testing.

15. Gillen and Clough tested their hypothesis on a number of polymer materials used in cable insulation and jacketing. In one study (4), they tested PVC and PE cable similar to that used at Savannah River. In a second study (2), they tested ethylene propylene rubber ("EPR"), cross-linked polyolefin ("XLPO"), chloroprene and chlorosulfonated polyethylene ("Hypalon"). These materials were stripped from the cables and irradiated in air and nitrogen at radiation dose rates ranging from approximately 10E3 to 10E6 rads/hr. Material degradation was measured using ultimate tensile properties (elongation and tensile strength) and swelling measurements. Infrared spectroscopy was used as a means of gaining insight into the chemical reactions which occurred.

16. Gillen and Clough found radiation dose-rate effects in air environments for all of the materials tested. While the exact mechanism for these effects was not determined, it was suggested to be the result of competition between crosslinking

and oxidative scission, in which scission becomes more important as the dose rate is lowered, thus allowing more time for the chemical reactions and possibly for oxygen diffusion into the materials. Thus, the mechanism of degradation appeared to be quite different under low dose-rate exposures from the mechanism occurring under the high dose-rate exposures normally utilized for accelerating radiation aging.

ANALYSIS OF THE SANDIA STUDIES

17. Although the Savannah River data and the results of the Sandia tests by Gillen and Clough raise interesting questions, their applicability to PNPP is problematic.

Plant Conditions vs. Test Set-Up

18. One limitation of the Sandia tests (2, 4) is that pieces of cable insulation systems were stripped from the wire for the tests. This exposed at least twice the insulation surface area to the ambient atmosphere as would occur if the cable were installed in an operating plant. Since oxygen diffusion into the materials is postulated to be a major contributor to the degradation mechanism, the applicability of the test results to plant-installed cables may be questionable.

Properties Measured

19. A second limitation of the Sandia tests is that the properties measured to detect polymer degradation were mechanical properties, tensile strength and elongation. Other engineering properties of interest, particularly electrical properties like insulation resistance, were not measured. Yet, cable qualification tests have demonstrated that a cable with substantial degradation in mechanical properties of the jacket and insulation will still perform its electrical function.

20. A more recent Sandia study by Minor and Furgal (12) has demonstrated that degradation of the mechanical properties of polymer cable insulation does not prevent the cable from performing its required electrical function. In the study, XLPO insulated electrical cable was exposed to a relatively low dose rate (6.2 x 10E4 rads/hr.). Despite degradation of mechanical properties, the cable was able to perform its electrical function at all times. This series of tests was conducted according to industry standards (IEEE Standards 323-1974 and 383-1974) and NRC guidelines (NUREG-0588). Minor and Furgal concluded that the methodology employed by the nuclear industry to qualify electrical equipment, despite the dose-rate effect on mechanical properties found by Gillen and Clough, is adequate.

Test vs. Actual Dose Rates and Dose Rate Threshold

21. A third important limitation of Gillen and Clough's tests is that they based their conclusions on the results of testing performed over a range of dose rates that were far too high to be representative of the normal dose rates in commercial nuclear plants. As shown in Figure 1, dose rates in most plant areas at PNPP will be significantly below 1 rad/hr. during normal plant operation. In very few of the plant areas will the normal operational dose rate exceed 10E2 rads/hr. The highest dose rate in any plant area will be 3.57 X 10E2 rads/hr. In contrast, Gillen and Clough in their tests used dose rates ranging from 1.4 X 10E3 rads/hr. to 1.2 X 10E6 rads/hr.

22. The Sandia tests themselves suggest a dose-rate effect for the materials tested only in the range of about 10E3 to 10E5 rads/hr. Of course, the degraded cable from Savannah River was exposed to much lower dose rates, ranging from approximately 13 rads/hr. (for a 12 year integrated dose of 1.3 x 10E6 rads) to 25 rads/hr. (for a 12 year integrated dose of 2.6 x 10E6 rads). However, it is crucial to note that the portion of the cable exposed to only 13 rads/hr. was relatively unaffected. This strongly suggests that there is a minimum threshold dose rate below which dose-rate effects are not significant. That dose rate appears to be somewhere between 13 and 25 rads/hr. Again, the vast majority of radiation zones at

PNPP will have dose rates during normal conditions well below this threshold range.

Total Integrated Doses

23. There is another factor revealed by the Sandia tests which limits their applicability to commercial nuclear power plants, including PNPP. The Sandia data confirm that there is a threshold dose below which significant dose-rate effects do not occur. Sandia degradation curves (2) shown on Figure 2 of this Affidavit show that the threshold for significant degradation, regardless of the dose rate, occurs at an integrated dose of approximately 2 X 10E7 rads (for XLPO, EPR, Hypalon and chloroprene). In other words, until the materials in question received a total integrated dose of 2 X 10E7 rads, no significant differences in degradation were noted regardless of the dose rates used to reach that total dose; and no significant degradation occurred.

24. The integrated dose threshold for dose-rate effects undoubtedly varies to some degree from one polymer to another. For the PE cable insulation used at Savannah River for example, the threshold dose was evidently somewhere around 10E6 rads. Almost all the equipment installed in PNPP, however, will be exposed under normal conditions to a 40 year integrated dose at least 1 to 3 orders of magnitude below an integrated dose threshold of 10E6 or 10E7 rads. Such a threshold is well

above the upper limit for suggested use of many polymers found in nuclear power plant equipment. For example, the threshold for PE insulation, determined independently of dose rate considerations, has been conservatively estimated at 3.8 x 10E5 rads/hr. (5, 6, 18). A close examination of the Sandia tests thus indicates that the criteria upon which the selection and application of materials and equipment for nuclear industry use have been based in the past are conservative.

LITERATURE SEARCH

25. As part of the process of evaluating the significance of the Sandia studies for PNPP, EDS Nuclear conducted an exhaustive literature search for texts, journals, periodicals and reports discussing dose-rate effects on polymers used in a radiation environment at PNPP. (See discussion of PNPP polymer identification study, below). Most of the literature was based on tests to determine integrated radiation threshold values. These tests used dose rates of 10E4 to 10E6 rads/hr. Aside from the Sandia work, there is no evidence to suggest a significant dose-rate effect below 10E3 rads/hr., and little evidence to suggest such an effect above that dose rate.

26. In fact, a number of studies challenge Gillen and Clough's finding of significant dose-rate effects for Hypalon and chloroprene (2). One study was done by Gillen himself (13), and the results confirmed those by other researchers

(14,15,16). A close examination of Gillen and Clough's results (Figures 3 and 4 of Figure 2 of the Affidavit) shows that dose-rate effects were insignificant for those two polymers until a total integrated threshold dose of about 2 x 10E7 rads was reached.

POLYMERS AT PNPP

27. EDS Nuclear, under my direction, undertook a review of the polymers used in PNPP. The purpose of the review was to help establish whether, assuming the results of the Sandia tests and Savannah River analyses are valid, there is any potential for failures at PNPP due to polymer degradation induced by dose-rate effects.

28. To perform this task, the manufacturers and model numbers of safety related equipment at PNPP were identified. For each make/model identified, the polymeric materials of construction were then determined by vendor contacts and examination of vendor documentation, including catalogs and test reports.

29. The list of polymers contained within this equipment is attached as Table 1. A list of components showing each polymer's particular application is attached as Table 2.

30. The completeness of this list was checked by comparing it to materials analyses performed by EDS Nuclear for environmental qualification programs for similar nuclear power

plants. To insure conservatism, materials identified for these other plants, but not found in PNPP during this review, were added to the list of PNPP polymers. This polymer list was used as the basis for the literature search described above, as well as the operating plant survey described below.

OPERATING PLANT SURVEY

31. Although controlled laboratory studies and tests may have shown that some polymers may exhibit dose-rate effects, such effects cannot be fully addressed without investigating the functional capability of materials in actual nuclear power plant applications. Therefore, we surveyed the operation and maintenance history of equipment installed in several operating commercial nuclear reactor plants.

32. The plant surveys were conducted by interviewing engineering, maintenance, health physics and plant staff personnel at the plants. Discussions were verified by examination of equipment in operation, internal utility reports and files, and plant radiation surveys. The objectives were to identify any relevant polymer material degradation, and to obtain information regarding performance of polymer materials used in equipment at the plants. Efforts were concentrated on obtaining information on equipment whose design and radiation environments are similiar to equipment found at PNPP.

33. Five operating nuclear power plants were surveyed. Three are General Electric Boiling Water Reactors (BWRs), like PNPP; and the remaining two are Pressurized Water Reactor (PWR) designs. The ages of the BWRs are 14 years, 13 years and 11 years. The ages of the PWRs are 9 years and 6 years. The combined operating reactor history of these plants is 53 years, with the oldest plant operating since 1969.

34. Virtually all the safety related equipment in the BWRs was either identical (e.g., power and control cables, valve motor operators, solenoid valves) or similiar (e.g., motors, transmitters, pressure switches) in construction and application to equipment which will be used at PNPP. For the PWRs, virtually all the equipment was either identical or similiar in construction and/or application. Generally, all of the polymeric materials (of the same family group or same compound formulation) used in components of safety related equipment which will be used at PNPP were found in one or more of the BWR and PWR operating plants.

35. As will be the case at PNPP, the majority of equipment at the operating plants surveyed was located in radiation zones where the dose rate was well below the threshold dose rate suggested by the Sandia studies. However, some equipment was exposed to dose rates above 10 to 15 rads/hr.

36. The results of the survey showed no evidence that polymers used in commercial nuclear power plants exhibit any

degradation attributable to dose-rate effects. Cross-linked polyethylene ("XLPE") cable insulation (which is of the same polymeric family as the bulk of the cable insulation used at PNPP) did not exhibit embrittlement even in the plant with a total operating life of nearly 14 years, which is the length of time that the Savannah River cable had been exposed. Incipient equipment failures attributed to polymeric material degradation have occurred in a very few cases (e.g., failure of some O-rings in solenoid valves and gaskets in limit switches). These failures were evaluated by plant personnel and shown to be the result of improper application, not radiation exposure. The failures were isolated events. There have also been instances in which polymeric material degradation was detected during routine maintenance or surveillance tests (e.g., embrittlement of a section of cable insulation). This degradation also was determined to be the result of improper installation (the cable was allowed to come into direct contact with hot metal surfaces). In all cases, equipment has been replaced and installation modified. Upon modification, these failures have not reoccurred.

POLYMER DEGRADATION AT PNPP

Radiation Environments at PNPP

37. Based on the Savannah River data, OCRE has identified 10 rads/hr. as the threshold for radiation dose-rate effects on polymers. OCRE Response to "Applicants' Interrogatories and Request for Production of Documents to Intervenor Ohio Citizens for Responsible Energy (Second Set)," dated November 15, 1982, at 16. Although, as shown above, this threshold may be too conservative, OCRE's dose rate was used in identifying radiation zones of concern at PNPP.

38. Both normal and design basis accident dose rates for PNPP are found in the attached Table 3. A description of these radiation zones is found in PNPP FSAR Table 3.11-1. At PNPP, the dose rates during normal conditions in most of the plant areas will be significantly below 10 rads/hr. Only 9 radiation zones (CT-5, CT-6, DW-1, DW-2, DW-4, DW-5, AB-8, FB-6 and TB-1) will have normal dose rates which will exceed 10 rads/hr.

39. The design basis accident dose rates, with the exception of zone CB-1 (0.5 rads/hr.), will all be above 10 rads/hr., with the majority being in the range of 10E5 to 10E7 rads/hr. Unlike normal dose rates, which are relatively constant over the life of the plant, the design basis accident dose rates described above are assumed to occur instantaneously upon accident initiation (per NUREG-0588) and decay rapidly.

Typically, the rate at which gamma rays are emitted is reduced by a factor of t-1.2, where t is the time after reactor shutdown (9). Therefore, the amount of time the equipment located in these radiation zones will be exposed to elevated accident dose rates can be considered insignificant.

40. Further, the dose rates at PNPP during design basis accident conditions are within an order of magnitude of 10E6 rads/hr., the dose rate normally employed during qualification testing. Therefore, the qualification tests sufficiently simulate accident conditions. That dose-rate effects are insignificant over this range of dose rates has been shown by a number of researchers (2, 4, 5, 14, 15, 16).

<u>Applying the Data</u>

41. As described above, the literature search and plant survey were able to identify no polymers exhibiting significant dose-rate effects other than the 6 polymers tested by Gillen and Clough (PE, PVC, XLPO, EPR, Hypalon and chloroprene). Moreover, the Sandia findings, even if accepted as accurate, were shown to be subject to a number of limitations. Two of the most important of these are the dose-rate threshold and total dose threshold for dose-rate effects.

42. In the range of normal dose rates which will occur over the 40 year life of PNPP, a few plant areas were identified where dose-rate effects could occur for the 6

polymers. Radiation zones CT-5, CT-6, DW-1, DW-2, DW-4, DW-5, AB-8, FB-6 and TB-1, which contain radioactive systems such as Reactor Water Clean-up and the Reactor Vessel, may contain these polymers and will be exposed to dose rates of 10 rads/hr. or higher. Only radiation zones CT-5, DW-1, DW-2, DW-4 and DW-5, however, will also experience a 40 year integrated dose2/ greater than 10E7 rads, which is roughly the point below which polymers will not experience dose-rate effects.3/ Therefore, equipment located in radiation zones CT-5, DW-1, DW-2, DW-4 and DW-5 containing the 6 polymers of concern could exhibit a life less than the 40 year design life of the plant.

43. This conclusion is quite conservative, considering the other limitations of the Sandia studies. For example, for electrical cable, it has been shown (12, 18) that dose-rate effects on mechanical properties such as insulation embrittlement do not prevent the cable from performing its electrical function. Such studies confirm operating plant experience. The operating plant survey, and industry research on polymeric materials (17), demonstrate that generally the polymers at PNPP

2/ Total integrated doses may be calculated by multiplying the numbers in Table 3. *See also* PNPP FSAR Tables 3.11-2 through 3.11-8

3/ Although the total integrated dose threshold for dose-rate effects in PE and PVC may be closer to 10E6 rads (4), and zones AB-8 and FB-6 will experience total doses between 10E6 and 10E7 rads, these zones were eliminated because they will contain no PE or PVC components not subject to change-out before the total dose of 10E6 rads is reached.

are being used in operating plants. We are aware of no polymer material in a commercial nuclear plant which has been found to experience significant dose-rate effects and to result in equipment failure or unsafe conditions.

SURVEILLANCE/MAINTENANCE

44. It is reasonable to expect that further data on dose-rate effects will be developed in the future. It is also likely that commercial nuclear power plant experience will expand our state of knowledge on polymers. There are also uncertainties inherent in predictions of long-term materials performance. A properly designed surveillance and maintenance program will take these factors into account and will detect any unexpected degradation.

45. All operating commercial nuclear power plants have surveillance and maintenance programs developed in accordance with 10 C.F.R. Part 50, Appendix B. Failures detected in other reactors by these programs (or through other means) will be available to CEI through Licensee Event Reports, NRC IE Bulletins, and manufacturers' information notices. Since other plants will have been operating longer than PNPP, and since dose-rate effects on polymers, if they occur, will develop over long periods of time, polymer degradation should be detected at these other plants long before it could cause unsafe conditions to occur at PNPP. This data will be used to design PNPP's

surveillance and maintenance program. Detailed procedures of the program, such as inspection intervals and test procedures, will take into account industry experience on materials performance.

46. The program elements for the PNPP surveillance and maintenance program, as set forth in the Affidavit of David R. Green in Support of NRC Staff Motion for Summary Disposition of Issue No. 9, are consistent with industry guidelines. A surveillance and maintenance program incorporating these elements should detect any significant degradation of polymeric materials in PNPP, from radiation dose-rate effects as well as other causes.

CONCLUSION

47. Analysis of the Sandia studies, a review of the literature, a survey of operating plants, and a review of PNPP's planned surveillance/maintenance program demonstrate that there is no reasonable basis to believe that radiation dose-rate effects on polymers at PNPP will induce failures in safety related equipment or otherwise cause unsafe conditions to occur.

Srinivasan Kasturi

Srinivasan Kasturi

Subscribed and sworn to before me
this 4th day of February, 1983.

Angela D. Black

NOTARY PUBLIC

My Commission Expires:

My Commission Expires on July 14, 1987.

REFERENCES

1. Underwriters Laboratories, "Standard for Polymeric Materials - Long Term Property Evaluation," UL 746B, 2d ed., April 24, 1981.

2. Gillen, K. T. and R. L. Clough, "Occurrences and Implications of Radiation Dose-Rate Effects for Material Aging Studies," NUREG/CR-2157, June 1981.

3. Gillen, K.T., et al., "Loss of Coolant Accident (LOCA) Simulation Tests on Polymers: The Importance of Oxygen," NUREG/CR-2763, July 1982.

4. Clough, R.L. and K.T. Gillen, "Radiation-Thermal Degradation of PE and PVC: Mechanism of Synergism and Dose-Rate Effects," NUREG/CR-2156, June 1981.

5. Bruce, M.B. and M.V. Davis, "Radiation Effects on Organic Materials in Nuclear Plants," EPRI-2129, November 1981.

6. Parkinson, W.W. and O. Sisman, "The Use of Plastics and Elastomers in Nuclear Radiation," Nuclear Engineering and Design 17 (North-Holland Publishing Company), pp. 247-280.

7. Van de Voorde, M.H., "Effects of Radiation on Materials and Components," CERN 70-5, February 26, 1970.

8. Clough, R.L. and K.T. Gillen, "Investigation of Cable Deterioration Inside Reactor Containment," Nuclear Technology, Vol. 17, November 1982, pp. 344-354.

9. Lamarsh, J.R., Introduction to Nuclear Engineering, (Addison Wesley Publishing Co., Mass.), 1975, p. 69.

10. "A Nuclear Industry Position Paper on Radiation Considerations for Equipment Qualification" (submitted by the AIF to R.H. Vollmer, Director Engineering Division, NRC), August 24, 1982.

11. Hawley, G.G., The Condensed Chemical Dictionary, Van Nostrand Reinhold Company, New York, 1981.

12. Minor, E.E. and D.T. Furgal, "Equipment Qualification Research Test of Electrical Cable with Factory Splices and Insulation Rework Test No. 2," NUREG/CR-2932 (2 vols.), September 1982.

13. Gillen, K.T. and E.A. Salazar, "Aging of Nuclear Power Plant Safety Cables," Sandia Laboratories Report No. 78-0344, 1978.

14. Kuriyama, I., et al., "Radiation Resistance of Cable Insulating Materials for Nuclear Power Generating Station," IEEE Transactions, Vol. E1-13, No. 3, 1978, p. 164.

15. Harrington, Robert, "Effects of Gamma Radiation on Elastomers," Rubber Age, Vol. 82, No. 6, Hanford Labs Operation, General Electric Co., Richland, Washington, March 1958.

16. Harrington, Robert, "Elastomers for Use in Radiation Fields, Part IV: Effects of Gamma Radiation on Miscellaneous Elastomers and Rubber Like Plastic Materials," Rubber Age, Hanford Laboratories, June 1958.

17. EPRI-NP 1558, "A Review of Equipment Aging Theory and Technology," September 1980.

18. Blodgett, R.B. and R. G. Fisher, "Insulations and Jackets for Control and Power Cables in Thermal Reactor Nuclear Generating Stations," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-88, No. 5, May 1969.

EXHIBIT A

SRINIVASAN KASTURI

PROFESSIONAL QUALIFICATIONS

My name is Srinivasan Kasturi. I am employed as a Manager in the Power Services Division of EDS Nuclear in Melville, New York. I joined EDS in September, 1981. My duties and responsibilities include technical overview of Environmental Qualification program activities within EDS Nuclear's New York office. This encompasses establishment of project technical plans, development of solutions to Equipment Qualification problems, and review of the technical adequacy of the Equipment Qualification projects underway.

Additionally, I have been an active participant in industry Equipment Qualification groups such as the AIF Equipment Qualification Subcommittee, the EPRI Utility Advisory Group, and the IEEE.

I have been responsible for the development and issuance of several industry position papers on Equipment Qualification technical issues through the AIF and EPRI. I have been conducting several Equipment Qualification seminars and workshops on specific technical issues and I am presently coordinating the industry-sponsored Equipment Qualification Seminar under the auspices of EPRI/NSAC.

I have been involved in Equipment Qualification since 1972 in various capacities. I have personally reviewed Equipment Qualification programs on almost all types of equipment used in the industry, and I have specified and executed Equipment Qualification work through test laboratories and equipment suppliers. I have co-authored and published two papers on Equipment Qualification and presented them at the IEEE Symposium and the European Nuclear Society Symposium.

Prior to my employment with EDS Nuclear, I managed Equipment Qualification activities for NUS (1980-1981); and prior to that, I managed Instrument and Control Engineering activities which included Equipment Qualification activities for United Engineers & Constructors (UE&C) (1974-1980). I was also involved in the Qualification Testing Evaluation Program conducted by Sandia Laboratories for the NRC research branch.

Prior to my employment with UE&C, I was employed as an Instrument and Control Lead Engineer at Ebasco (1969-1974), which also included Equipment Qualification activities.

I hold a Masters Degree in Electrical engineering (Stevens Institute, Hoboken, New Jersey), and a Masters Degree in Business Administration (Drexell University, Philadelphia, PA). I hold a BS Degree in physics and a post-graduate diploma in Instrument Technology from the University of Madras in India.

TABLE 1

PERRY NUCLEAR POWER PLANT
POLYMER MATERIALS LIST

Aromatic ether-based oil
Chlorosulfonated polyethylene (Hypalon)
Cross-linked polyethylene
Cross-linked polyolefin
Diallyl phthalate
Dimethyl siloxane
Epoxy resins
Ethyl propylene terpolymer (EPT)
Ethylene Glycol
Ethylene propylene (Nordel)
Ethylene propylene diene monomer (EPDM)
Ethylene-Tetra-Fluorethylene (Tefzel)
Fluorocarbon
Fluoroelastomer (Viton)
Fluorolube compound
Fluorosilicone
Hydrocarbon oil
Isomica (Aramid Fiber)
Kalrez
Methyl silicone
Modified polyphenylene
Modified polyester compound
Natural rubber
Neoprene rubber
Nitrile rubber (BUNA-N)
Nomex
Phenolic Resins
Polyamide (Nylon)
Polyamide aromatic
Polyester (Mylar)
Polyethylene
Polymide
Polymyte
Polyolefin
Polyphenol ether
Polyphenol ether-based oil
Polyphenol-based oil
Polystyrene
Polyvinyl chloride
Silicone Rubber
Silicone fluid
Synthetic hydrocarbon grease w/fluorocarbon
Synthetic polyphenol-based grease
Tetra Fluoroethylene (Teflon)
Trifluorovinylchloride (Kel-F)

TABLE 2

POLYMERIC MATERIALS

FOR PNPP TYPICAL COMPONENTS

Type of Component	Material of Construction
Seal	Kalrez Ethylene Propvlene Polethylene Ethylene Propylene Diene Monomer (EPDM) Polymyte
Electric Coil	Nomex Isomica Glass Cloth Silicone Varnish Silicone Rubber Tefzel (Ethylene-Tetra-Fluoretylene) EPDM Mylar Kapton
O-Ring	BUNA-N Fluoroelastomer Viton EPDM Ethyl Propylene Terpolymer Flucrosilicone Fluorocarbon Elastomer Ethylene Propylene Silicone Rubber
Gasket	Neoprene Asbestos-Nitrle Asbestos Viton EPDM Silicone Rubber Nitrile Based Synthetic Fiber

TABLE 2

POLYMERIC MATERIALS

FOR PNPP TYPICAL COMPONENTS

(continued)

Type of Component	Material of Construction
Packing	Graphite Filament Braided Asbestos
Plug	Low-Density Polyethylene Neoprene
Diaphragm	Ethylene Propylene Nitrle Nylon-Coated BUNA-N BUNA-N
Fuse Block	Phenolic
Cable Insulation	XLPE Hypalon XL Polyolefin EPR Modified Polyphenylene
Seat	Viton Polyethylene Polymide Polymide Aromatic Polymide/Graphite

TABLE 2

POLYMERIC MATERIALS

FOR PNPP TYPICAL COMPONENTS

(continued)

Type of Component	Material of Construction
Adhesive	Loctite #73 Epoxy Epoxylite Epoxy (Hysolo 151)
Sealant	Silicone Rubber Methyl Silicone Teflon
Snap Action Switch	Phenolic Diallyl Phthalate Ceramic
Fill Fluid	Distilled Water Ethylene Glycol (8%/32% water) Hydrocarbon Oil Silicone Fluid (Dow Corning 200-20) Silicone Fluid (Dow Corning 703) Flourolube Compound (Hooker No. FS-5) Silicone Oil Hydrocarbon Oil (Mobil 824) Tetramethyl Tetraphenyl Trisiloxane High Phenyl (Single Silicone Component)

TABLE 2

POLYMERIC MATERIALS

FOR PNPP TYPICAL COMPONENTS

(continued)

Type of Component	Material of Construction
Terminal Strip	Bailed Phenolic Thermoset Plastic Phenolic-Asbestos Filled Thermoplastic
Grommet	Silicone Rubber Polystyrene (Epoxy Glass Laminate) Forsterite Phenolic Polyester Glass Nylon
Lubricant	Synthetic Hydrocarbon Grease w/Flucrocarbon Aromatic Ether-Based Oil Synthetic Polyphenol-Based Grease Polyphenol Ether-Based Oil Silicone Fluoroluor Grease Silicone Grease Dimethyl Siloxane

<u>TABLE 3</u>

PERRY SPECIFIC RADIATION ENVIRONMENTS

Zone	Normal Dose Rate (R/Hr)	Maximum Accident Dose Rate (R/Hr)
CT-1	2.5×10^{-3}	2.9×10^{6}
CT-2	2.5×10^{-3}	1.3×10^{6}
CT-4	2.5×10^{-3}	1.3×10^{6}
CT-5	3.57×10^{2}	1.3×10^{6}
CT-6	10.7	1.3×10^{6}
CT-7	2.5×10^{-3}	1.3×10^{6}
CT-8	2.5×10^{-3}	1.3×10^{6}
DW-1	1×10^{2}	7.3×10^{7}
DW-2	1.6×10^{2}	7.3×10^{7}
DW-3	7	7.3×10^{7}
DW-4	1×10^{2}	7.3×10^{7}
DW-5	1×10^{2}	7.3×10^{7}
AB-1	2.5×10^{-3}	39
AB-2	3.5	3.7×10^{5}
AB-3	1.1	1.3×10^{6}
AB-4	5	5.3×10^{5}
AB-5	7	4.6×10^{5}
AB-6	2.5×10^{-3}	33
AB-7	8.4	3×10^{6}
AB-8	22	1.2×10^{5}
AB-9	2.5×10^{-3}	33.3
FB-1	2.5×10^{-3}	51
FB-2	2.5×10^{-3}	51
FB-3	2.5×10^{-3}	51
FB-4	2.5×10^{-3}	3.1×10^{4}
FB-5	2.5×10^{-3}	3.1×10^{4}
FB-6	27	2.3×10^{8}
FB-7	2.5×10^{-3}	4.22×10^{3}
FB-8	2.5×10^{-2}	3.15×10^{2}
CB-1	5×10^{-4}	5×10^{-1}
CB-2	5×10^{-4}	25
CB-3	2.5×10^{-3}	25
CB-4	5×10^{-4}	25
CB-5	5×10^{-4}	25
DG-1	5×10^{-4}	None given

TABLE 3

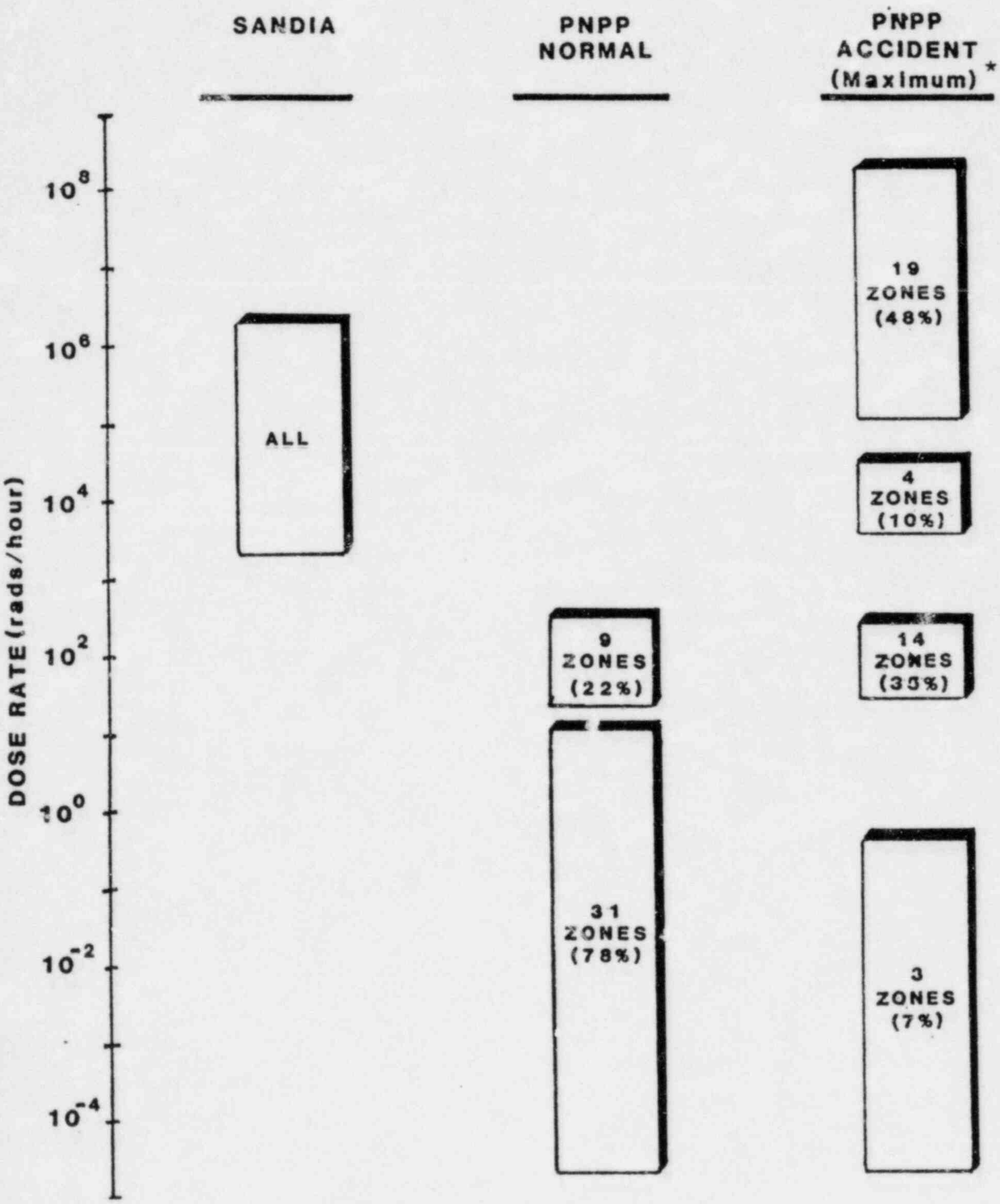
PERRY SPECIFIC RADIATION ENVIRONMENTS

(continued)

Zone	Normal Dose Rate (rads/hr)	Maximum Accident Dose Rate (rads/hr)
TB-1	10.7	25
TB-2	2.5×10^{-3}	25
OG-B	1×10^{-1}	25
ESW	4×10^{-4}	25
OU-T	None given	None given

FIGURE 1

COMPARISON OF DOSE RATE RANGES



* The Maximum Accident Dose Rate Occurs Instantaneously And Reduces Quickly To The Range Of Normal Dose Rates

FIGURE 2

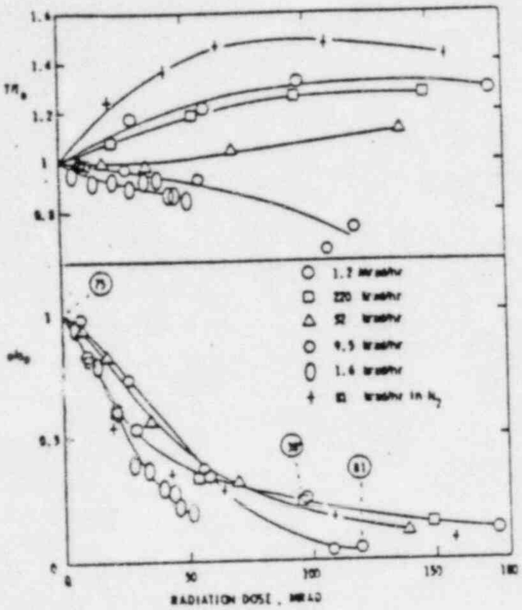


Fig. 1. Aging of crosslinked polyolefin insulation. The tensile strength after aging divided by the tensile strength before aging (T/T_O) and the tensile elongation after aging divided by the tensile elongation before aging (e/e_O) plotted against the total integrated radiation dose at the various indicated dose rates. The circled numbers refer to the weight swelling ratios corresponding to the indicated experimental conditions.

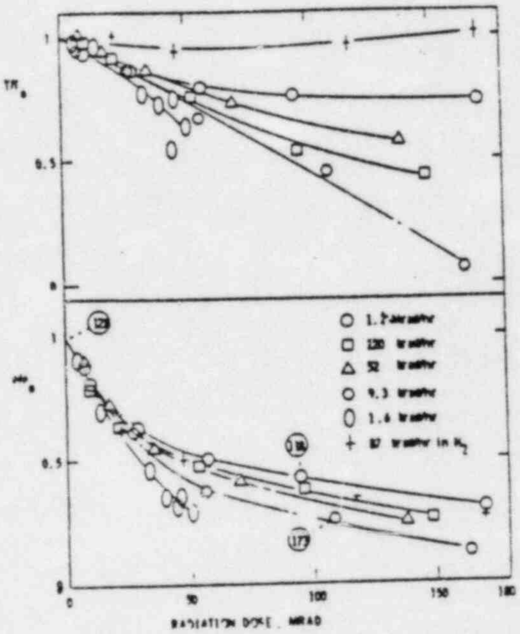


Fig. 2. Aging of ethylene propylene rubber insulation. Explanation of figure is identical to Fig. 1.

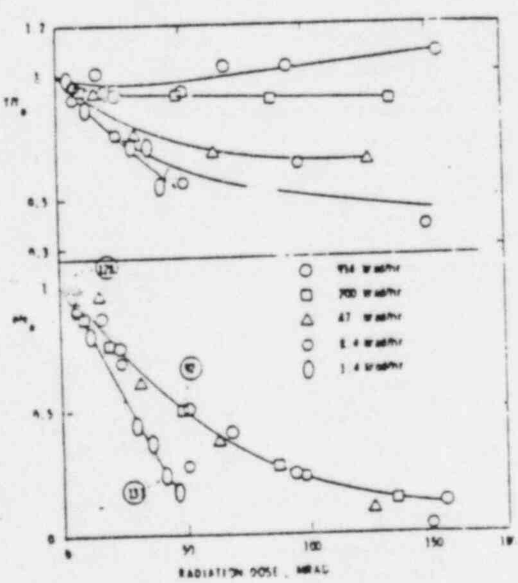


Fig. 3. Aging of chloroprene rubber jacket. Explanation of figure is identical to Fig. 1.

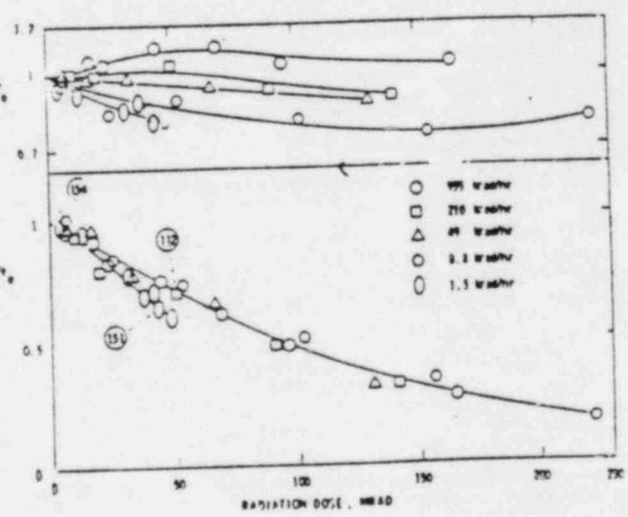


Fig. 4. Aging of chlorosulfonated polyethylene jacket. Explanation of figure is identical to Fig. 1.

(Reproduced from Reference 2)