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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of)
)
CAROLINA POWER & LIGHT COMPANY) Docket Nos. 50-400 OL
and NORTH CAROLINA EASTERN) 50-401 OL
MUNICIPAL POWER AGENCY)
)
(Shearon Harris Nuclear Power)
Plant, Units 1 and 2))

AFFIDAVIT OF RICHARD M. BUCCI

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AFFIDAVIT OF RICHARD M. BUCCI

City of New York)
: ss:
State of New York)

Richard M. Bucci, being duly sworn, deposes and says as follows:

1. I, Richard M. Bucci, am Associate Consulting Engineer, Equipment Qualification Program Manager, EBASCO, Inc. My business address is Two World Trade Center, New York, New York 10048. 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.

SUMMARY

2. Eddleman Contention 11 states that Applicants do not take into account that polyethylene, used as cable insulation, deteriorates much more rapidly under long-term doses of gamma radiation than when exposed to the same total dose over a much shorter period of time. This contention is not well founded. The low dose-rate effect on electrical cable insulation postulated in the Gillen and Clough studies at Sandia National Laboratories upon which Mr. Eddleman bases his contention (4, 5, 6, 8, 12),1/ is insignificant as applied to SHNPP and would not lead to an inability of safety-related electrical cables or other electrical equipment at SHNPP to perform their proper function. This conclusion is based on a review of the literature, including an analysis of the Sandia studies themselves, and a review of the postulated radiation environments to which safety-related electrical cables and other electrical equipment at SHNPP will be exposed.

3. Even if degradation from dose-rate effects in cable insulation or other electrical equipment insulation were to occur at SHNPP, such degradation would occur only over an extended period of time. Carolina Power & Light Company ("CP&L") is in the process of developing a surveillance and maintenance program for SHNPP which will include features that will enable identification of equipment degradation.

1/ References appear at the conclusion of the Affidavit.

INTRODUCTION

Definition of Polyethylene

4. Polyethylene is the chemical name for a plastic material formed by the chemical linkage of hydrogen and carbon atoms. The prefix "poly-" is used to distinguish this manufactured material from its chemical raw material, in this case ethylene, and indicates that it is a long, repetitive molecular "chain." Such long-chain molecules are more generally termed "polymers."

5. Polymers include the familiar plastics and rubbers of household and industrial use. Polymeric materials' large molecular size gives them properties useful in many engineering applications. Polymers are generally arranged into three categories based on certain common characteristics (1):

Thermoplastics - polymers that soften at high temperatures and return to their original condition when returned to a lower temperature. Polyethylene is a thermoplastic. Other common examples are cellulose, polyvinyl chloride and nylon.

Thermosetting Plastics - polymers that harden irreversibly at high temperatures. This characteristic generally allows this type of polymer to be used at higher temperatures than thermoplastics. Examples are phenolics and epoxies.

Rubbers (or Elastomers) - polymers that are characterized by high elasticity and are usually soft and easily extendable. Similar to thermoplastics, elastomers tend to soften at high temperatures. Their physical properties depend more on the degree of processing in manufacture (e.g., vulcanization) than on the chemical structure. Typical examples are natural rubber, ethylene propylene rubber, chlorosulfonated polyethylene (Hypalon) and fluoropolymers.

6. As can be seen from the above, polymeric materials vary widely in their physical properties. Further, the commonly used convention of designating the type of polymeric material by the chemical name or class, although acceptable for general purposes, is a questionable basis for technical categorization. Reliance on the chemical names can gloss over important differences in the fabrication process and in finished product capabilities. For example, consider the substantial differences between polyethylene, chlorosulfonated polyethylene and cross-linked polyethylene (1,2,3):

Polyethylene - This is the simplest of all the polymeric materials. However, varying the manufacturing process can yield different degrees of crystallinity and, consequently, a range of mechanical and electrical properties. Polyethylene that has been polymerized at low pressure (low density polyethylene) has markedly different characteristics from polyethylene polymerized at high pressure (high density polyethylene) (1).

Chlorosulfonated Polyethylene - This material, formed from a polyethylene base polymer, with chlorine and sulfur additives, is actually flexible enough to be categorized as an elastomer (1,2). Its irradation properties are more dependent on the additives than on the base polymer (1).

Cross-linked Polyethylene - Cross-linking increases the molecular weight of a polymer and improves retention of mechanical and electrical properties at higher temperatures (1). The properties of a cross-linked polymer are a function of the density of cross-links in the molecular structure, and are little governed by the chemical structure. The cross-linking process changes the softer polyethylene into a rubbery material. This change substantially improves the material for use as electrical insulation (1).

Applications of Polyethylene in Electrical Cable

7. Polyethylene, due to its electrical and mechanical properties, ready availability and low cost, has been used as cable insulation in many applications. It was widely used in nuclear plants built prior to the mid-1970s (4). At that time, however, certain unfavorable properties, such as flammability and low thermal resistance, led to its rejection for general use as electrical cable insulation in nuclear, and other, power plant applications. Elastomers, which were known to exhibit better properties of thermal and radiation resistance, began generally to be applied as cable insulation for nuclear power plants.

8. Nevertheless, because of the simplicity of its chemical structure, polyethylene has served as a prototype for studying the mechanism involved when polymers are exposed to radiation (1). For example, Gillen and Clough of Sandia National Laboratories used polyethylene cable insulation samples

taken from a non-commercial nuclear reactor when studying the effects of low radiation dose rate on cable insulation (6).

Definition of Polymer Degradation

9. The term "degradation" refers to the reduction of a specified property (e.g., tensile strength, elongation, resistivity, dielectric strength) of a polymeric material. Depending upon the nature of the material's application, different levels of degradation in a specified property or set of properties may be acceptable. The properties of concern when judging the significance of equipment degradation are those properties directly related to the critical functions to be performed by the material in the particular application. This is the reason that "application" tests normally employ failure criteria for inability to perform critical functions. Research tests such as the Gillen and Clough tests (5, 6), on the other hand, measure specific property changes in order to study the degradation mechanisms involved, and do not employ failure criteria.

Radiation Aging Mechanisms in Polymers

10. When radiation is absorbed by polymers, the energy of their atoms is increased, producing free electrons (called "ions"). Ionization leads to the rupture of chemical bonds, which in turn yields fragments of the large polymer molecules. These fragments may then react to change the chemical structure of the molecule.

11. Two important effects of this process on the molecule are scission (breakup into small molecules) and cross-linking (recombination into a network-type structure). The fragments may also recombine into their original form, with no net change. The type and rate of change in the physical properties of the polymer depend on the competition between scission, cross-linking and recombination. Net cross-linking increases molecular weight and improves several other properties of a material. In polyethylene, for example, which tends to cross-link, low and sometimes intermediate doses of radiation are beneficial (3). This is why commercial cross-linked polyethylene is an improvement on regular polyethylene. The effects of scission are in most respects opposite to those of cross-linking. Here, as the molecules are broken into smaller fragments, the properties are degraded.

12. Research (5, 8, 9, 12) on the radiation induced degradation of polymers indicates that the presence of oxygen is critical to the above-described degradation mechanisms. 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. Because the importance of oxygen to polymer degradation has long been recognized (1, 2), cable insulation often includes antioxidants which assist in reducing degradation.

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 10E6 rads/hr.2/ 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 (5, 12). These investigations were prompted by the discovery of degraded electrical cable insulation at the non-commercial Savannah River K-reactor (4). On visual inspection of the cable, the polyvinyl chloride jacket showed no signs of degradation along the entire length of the cable. However, after removal of the jacket, it was found that the polyethylene 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. Continuous measurements were not made. However, over the 12 year installed life of the cable, the relatively undamaged areas had been exposed to a dose rate of approximately 13 rads/hr. while the damaged portions had been exposed to a dose rate of approximately 25 rads/hr.

2/ Accelerated aging is expressly permitted by 10 C.F.R. § 50.49(e)(5).

14. Gillen and Clough postulated that the degradation was due to 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. A low dose-rate effect is the occurrence of greater degradation for a given total dose administered over a time period T1, than would occur for the same total dose administered over a time period T2, where T1 is greater than T2. The effects of radiation dose rate on polymer degradation have been discussed in the literature for many years (e.g., 2, 3, 13). 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 (5), they tested polyvinyl chloride and polyethylene cable similar to that used at Savannah River. In a second study (12), they tested ethylene propylene rubber, cross-linked polyolefin, chloroprene (neoprene) and chlorosulfonated polyethylene. 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. The mechanism for these effects was suggested to be the result of competition between cross-linking and oxidative scission, in which scission becomes more important as the dose rate is lowered, thus allowing more time for the chemical reactions and for oxygen diffusion into the materials. Gillen and Clough concluded from the Savannah River experience and these and subsequent laboratory studies (7, 8) that, although there is a lower range of dose-rates below which radiation-induced oxidation effects disappear (7), that range is lower than previously recognized.

ANALYSIS OF THE SANDIA STUDIES

17. Research testing must be carefully considered when applying the results to an engineering application. The Sandia tests performed by Gillen and Clough involve a number of important limitations regarding their applicability to SHNPP.

Plant Conditions vs. Test Set-up

18. As discussed above, Gillen and Clough have attributed the phenomenon of dose-rate effects chiefly to radiation induced oxidation (5). One limitation of the Sandia tests (5, 12) is that pieces of cable insulation systems were stripped from the wire for the tests. The insulation material was thus completely exposed to oxygen in the ambient atmosphere.

Polyethylene, in particular, is quite susceptible to oxidation, evidenced by its behavior when exposed to radiation in thin films (3). In actual application, insulation is covered with a jacket material. Although the jacket is primarily for mechanical protection purposes (protection from abrasion, cuts, etc.), this covering significantly reduces the oxygen available for radiation induced oxidation of the cable insulation.

Test vs. Actual Dose Rates and Dose-Rate Threshold

19. A second 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 Table 1, dose rates in most plant areas at SHNPP will be significantly below 1 rad/hr. during normal plant operation.[3] The highest normal operational dose rate in any plant area will be 9.99 rads/hr., in Zone C5. 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.

20. 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

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[3] The dose rates in Table 1 conservatively assume a worst case location of equipment within each radiation zone.

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. All of the radiation zones at SHNPP fall below this threshold. See Table 1.

Total Integrated Doses

21. A third factor revealed by the Sandia tests which limits their applicability to commercial nuclear power plants, including SHNPP, has to do with the total integrated doses received by the materials tested. The results from several tests at different dose rates have been reproduced as Figures 1 and 2 of this report. Although dose-rate effects are apparent, the differences in the rate of degradation caused by the various dose rates decrease as the total dose decreases. In other words, dose-rate effects are most pronounced for higher total doses. Further, Fig. 2 shows rather minor degradation for polyethylene until somewhere between 10E6 and 10E7 rads. This data agrees with the data from Savannah River, where the unaffected portions of the cable were exposed to a total integrated dose of 1.3 x 10E6 rads.

22. As stated above, the highest dose rate in any plant area at SHNPP will be 9.99 rads/hr., for a 40 year total integrated normal dose of 3.5 x 10E6 rads. For all polymers tested by Gillen and Clough except the simplest polyethylene, no significant differences in degradation were recorded for the

different dose rates at a total dose of 3.5 x 10E6 rads; and neither was any significant degradation recorded. Figures 4a through 4d, based on figures from Reference 12, illustrate where the SHNPP highest total integrated normal dose lies in comparison with Gillen and Clough's test results for ethylene propylene rubber, cross-linked polyolefin, chloroprene and chlorosulfonated polyethylene.

Differences in Materials

23. A fourth limitation of Gillen and Clough's work concerns the differences in test results among the various materials tested. A close examination of the Sandia test results (5, 12) indicates that certain materials are much less sensitive to low dose-rate effects than others. Gillen and Clough themselves have stated in other studies (8, 14) that dose-rate effects are minor in polymers such as cross-linked polyethylene, chlorosulfonated polyethylene, chloroprene and silicone materials. Evidence of low dose-rate effects in simple polyethylene thus cannot necessarily be extended to predict the same effects in other, improved compounds being used in present day nuclear plant designs.

Properties Measured

24. A fifth, and perhaps the most serious, limitation of the Sandia tests is that the properties measured to detect degradation were mechanical properties - tensile strength and elongation. Other engineering properties of interest, particularly electrical properties like resistivity and dielectric

strength, were not measured. Yet, nuclear industry cable qualification tests have demonstrated that a cable with substantial degradation in mechanical properties of the insulation continues to provide sufficient insulation properties to allow the cable to perform its electrical function.

25. A more recent Sandia study by Minor and Furgal (15) has demonstrated that degradation of the mechanical properties of electrical cable insulation does not prevent the cable from performing its required electrical function. In the study, cross-linked polyolefin-insulated electrical cable was exposed to a relatively low dose rate (6.2 x 10E4 rads/hr.) for a total integrated normal operational dose of 5 x 10E7 rads. Then, after elevated temperature aging, the cables were exposed to an accident dose of 1.5 x 10E8 rads at a rate of 7.7 x 10E5 rads/hr. Despite severe 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 323-1974 and IEEE 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 studied by Gillen and Clough, is adequate.

26. It should be pointed out that Minor and Furgal's environmental test conditions, consistent with standard industry practice, were much more severe than the potential exposures in an operating nuclear power plant. To illustrate this, Figure

3, extracted from the Minor and Furgal report (15), has been marked to indicate the worst case SHNPP (normal plus accident) conditions. Cable qualification tests performed for SHNPP also include total exposures which are much more severe than actual potential exposures. For example, the SHNPP total integrated test exposures used to qualify safety-related cable inside containment range from 1 x 10E8 to 2 x 10E8 rads.

27. Gillen and Clough have acknowledged that the dielectric constant of organic insulation may only change insignificantly at a point where the mechanical properties have changed drastically (7). Gillen and Clough nevertheless chose to study mechanical properties of insulation materials because they are conveniently measured and are related to the function of the materials in a number of different applications. In the case of electrical insulation, Gillen and Clough have suggested that mechanical properties are primarily of interest for considering a catastrophic failure under the influence of some applied stress (7). Cable qualification tests, however, currently include a mechanical durability test for cable following exposure to the simulated normal and accident environmental conditions (11). This test severely stresses the cable when it is in an extremely degraded condition. All SHNPP safety-related electrical cables have passed this test while energized at elevated voltage levels (i.e., at voltages higher than the cables will see in service).

28. The Minor and Furgal study, as well as the performance of electrical cables during qualification testing, demonstrate that the results of research tests, such as the Gillen and Clough tests, which do not employ failure criteria, cannot be directly applied to materials in actual nuclear power plant application.

Industry Practice

29. The possibility of radiation dose-rate effects has been recognized in nuclear industry research and testing for at least the last 15 years (13, 1). Nuclear industry qualification testing standards account for such possible effects. IEEE 323-1974 (10) states as follows:

> In determining the total required test radiation equivalent to that of service life, consideration shall be given to oxidation gas-diffusion effects.... Thus, to allow for these effects, a greater total dose than the service lifetime dose should be applied.

30. As stated above, the total integrated doses received by electrical cables at SHNPP during qualification testing far exceed the most severe doses the cables could experience in actual use. Test doses of 1 x 10E8 to 2 x 10E8 rads were used to qualify cables for a maximum calculated dose of 1.3 x 10E7 rads. This maximum calculated dose includes the 40 year full power normal operating dose plus the accident dose. None of the Sandia tests has shown that a low total dose occurring over a long period of time, as in the 40 year normal operating life of a commercial nuclear power plant, causes more degradation

than an extremely high total dose applied over a short period of time, as in qualification testing.

DOSE-RATE EFFECTS AT SHNPP

Electrical Cable Insulation Materials at SHNPP

31. Table 2 is a list of all safety-related electrical cables at SHNPP.4/ The type of insulation and jacket material is given for each cable. As can be seen, simple polyethylene is not used either as cable insulation or jacketing. Chlorinated and chlorosulfonated polyethylene are used as jacketing for some cables. However, these are improved versions of simple polyethylene and are not as subject to dose-rate effects. At any rate, cable jacketing is used only for mechanical protection of the insulation and performs no electrical safety function.

32. In addition to insulation for electrical cables, polymer materials also are used as insulation for other types of electrical equipment, such as component wiring in electrical equipment, motor windings and terminal lugs. For example, cross-linked polyethylene is used at SHNPP as insulation on component wiring in electrical penetrations. I am unaware of any instance, however, in which simple polyethylene is used as insulation for any type of electrical equipment inside containment at SHNPP.

4/ This list was an attachment to a letter from M. A. McDuffie to Harold R. Denton (April 26, 1983).

Radiation Environments at SHNPP

33. Regardless of the materials used for cable and other electrical insulation at SHNPP, in none of the radiation environments calculated for SHNPP will electrical equipment be exposed to conditions in which dose-rate effects are of concern. No electrical equipment will be exposed either to dose rates or total integrated doses at which significant dose-rate effects have been shown to occur.

34. Dose rates for all radiation zones at SHNPP during normal, full-power operating conditions are provided in Table 1. A description of these zones is found in SHNPP FSAR Appendix 3.11.b. The dose rates for all radiation zones except one are under 1 rad./hr. The exception is Zone C5, which will have a normal dose rate under 10 rads/hr.[5] As discussed earlier, at Savannah River cable insulation exposed to approximately 13 rads./hr. for 12 years did not show significant degradation.

35. Total integrated doses for the 40 year normal life of the plant also are shown in Table 1. The highest total integrated dose is, of course, found in Zone C5, which will have a 40 year normal dose of 3.5 x 10E6 rads. Again, with the exception of simple polyethylene, this dose is below the total integrated dose at which Gillen and Clough found significant

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[5] These calculated dose rates are conservatively high, since they assume continuous reactor operation at 100 percent power for 40 years plus 1 percent failed fuel contribution. In all cases, maximum values rather than average or expected dose rates (as permitted by NUREG-0588) are used.

dose-rate effects or significant degradation to occur. See Figures 4a through 4d.

36. Design basis accident conditions at SHNPP are not of concern with respect to radiation dose-rate effects either. Design basis accident dose rates are typically in the range of 10E5 to 10E7 rads/hr. (16). Unlike normal dose rates, which are relatively constant over the life of the plant, design basis accident dose rates are assumed to occur instantaneously upon accident initiation (per NUREG-0588) and decay rapidly. Considerations of long-term aging effects thus are not applicable in the post-accident environment. Further, the relatively high dose rates normally employed during qualification testing sufficiently simulate accident conditions. It is undoubtedly for these reasons that Gillen and Clough have stated that their work is concerned with the aging (non-accident) portion of qualification testing (7).

OPERATING EXPERIENCE AT BRUNSWICK AND ROBINSON

37. Although controlled laboratory studies and tests may have shown that polyethylene used as electrical cable insulation may exhibit dose-rate effects under certain conditions, such effects cannot be fully addressed without examining the functional capabilities of materials as currently used in actual commercial nuclear power plant application. The Affidavit of Peter M. Yandow, Edward M. Steudel and Harold W. Bowles ("CP&L Affidavit") states that a review of the operation and maintenance history of CP&L's Brunwick and Robinson plants,

which have a combined operating reactor history of 29 years, reveals no evidence of degradation of electrical cable insulation or other electrical insulation due to radiation dose-rate effects. Neither am I aware of any instance of such degradation in any other commercial nuclear power plant application.

SURVEILLANCE/MAINTENANCE

38. The main goal of the continuing NRC sponsored research program at Sandia is to develop improved accelerated aging techniques which may ultimately be of value to the nuclear industry generally. In addition, information about such industry concerns is continually exchanged through industry organizations such as the Institute of Nuclear Power Operations and the American Nuclear Society. It is thus 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 dose-rate effects. A properly designed surveillance and maintenance program will allow for improvements in our understanding of long-term materials performance and will detect any unexpected degradation from radiation dose-rate effects.

39. 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 CP&L through Licensee Event Reports, NRC IE Bulletins, and manufacturers' information notices. Since other

plants, such as Robinson and Brunswick, will have been operating longer than SHNPP, and since dose-rate effects on electrical cable insulation, if they occur, will develop over long periods of time, degradation from dose-rate effects should be detected at these other plants long before it could cause unsafe conditions to occur at SHNPP. As stated in the CP&L Affidavit, at ¶ 14, such data will be incorporated into SHNPP's surveillance and maintenance program. Detailed procedures of the program, which are being developed, such as inspection intervals and test procedures, will take into account industry experience on materials performance. See CP&L Affidavit at ¶¶ 14-16.

40. The program elements for the SHNPP surveillance and maintenance program, as set forth in the CP&L Affidavit, are consistent with industry guidelines. The program will include features that will enable identification of equipment degradation.

CONCLUSION

41. Analysis of the Sandia studies as applied to SHNPP, CP&L's review of the operation and maintenance history of the Brunswick and Robinson plants, and SHNPP's planned surveillance/maintenance program as described in the CP&L Affidavit, demonstrate that there is no reasonable basis to believe that radiation dose-rate effects on cable insulation or other electrical insulation at SHNPP will induce failures in electrical equipment or will otherwise cause unsafe conditions to occur.

Richard M. Bucci
Richard M. Bucci

Subscribed and sworn to before me
this 25th day of May, 1984.

Hugh T McCarthy
NOTARY PUBLIC

HUGH T. McCARTHY
Notary Public, State of New York
No. 31-2601970
Qualified in New York County
Commission Expires March 30, 1986

My Commission Expires:

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TABLE 1

SHNPP SPECIFIC RADIATION ENVIRONMENTS

Zone No.	Normal Dose Rate (RADS/HR)	Total Integrated Normal Dose (RADS)
C1	1.42E-1	5.0E4
C2	1.42E-1	5.0E4
C3	1.42E-1	5.0E4
C4	1.42E-1	5.0E4
C5	9.99E-0	3.5E6
C6	2.28E-1	8.0E4
R1	2.85E-3	1.0E3
R2	2.85E-3	1.0E3
R3	2.85E-3	1.0E3
R4	2.85E-1	1.0E5
R5	2.85E-1	1.0E5
R6	2.85E-3	1.0E3
R7	2.85E-3	1.0E3
R8	2.85E-2	1.0E4
R9	2.85E-3	1.0E3
R9A	2.85E-3	1.0E3
R10	2.85E-3	1.0E3
R11	2.85E-3	1.0E3
R12	2.85E-3	1.0E3
R13	2.85E-3	1.0E3
R14	2.85E-1	1.0E5
R15	2.85E-3	1.0E3
R16	2.85E-3	1.0E3
R17	2.85E-3	1.0E3
R18	2.85E-3	1.0E3

TABLE 1 (Cont'd)

SHNPP SPECIFIC RADIATION ENVIRONMENTS (Cont'd)

Zone No.	Normal Dose Rate (RADS/HR)	Total Integrated Normal Dose (RADS)
R19	2.85E-3	1.0E3
R20	2.85E-3	1.0E3
R21	2.85E-3	1.0E3
R22	2.85E-3	1.0E3
R23	2.85E-4	1.0E2
R24	2.85E-3	1.0E3
R25	2.85E-3	1.0E3
R26	2.85E-3	1.5E3
F1	2.85E-2	1.0E4
F2	2.85E-3	1.0E3
TA1	2.85E-2	1.0E4

TABLE 2- SHEARON HARRIS NUCLEAR POWER PLANT
CABLE INFORMATION

Sheet 1 of 2

Spec No.	Cable Vendor	B/M Number	Voltage Class	Insulation and Jacket Type	Applicable ICEA Nos.
E-14A	Anaconda Ericsson	D10-01	6.9KV	INS-Ethylene Propylene Rubber	S-19-81
		D10-02	6.9KV	JACKET-Chlorinated polyethylene	S-68-516
		D10-03	6.9KV		S-61-402
E-14B	Kerite	D25-01 to	600V	INS-Ethylene Propylene Rubber	S-19-81
		D25-11	600V	JACKET-Vulcanized Chlorinated Rubber	S-68-516
		D50-01 to	600V	INS-Ethylene Propylene Rubber	S-61-402
		D50-15	600V	JACKET-Vulcanized Chlorinated Rubber	
*E-14C	American Insulated Wire	D60-01 to	300V	INS-Ethylene Propylene Rubber	S-19-81
		D60-08	300V	JACKET-Hypalon (chlorosulforated polyethylene)	S-68-516
		D62-01 to	300V		S-61-402
		D62-03	300V	*Cables covered by Spec E-14C are for use outside containment only.	
		D64-01	300V		
		D67-01 to	Telephone		
		D67-05	Telephone		
		D68-01	Telephone		
E-14D	Samuel Moore & Company	D70-01	Thermocouple	INS-Ethylene Propylene Diene Monomer	S-19-81
		D72-01		JACKET-Hypalon (Chlorosulforated Polyethylene)	S-68-516
		D83-01			S-61-402
E-15A	Anaconda Ericsson	D61-01 to	300V	INS-Ethylene Propylene Rubber	S-19-81
		D61-08	300V	JACKET-Chlorinated Polyethylene	S-66-524
		D65-01	300V		S-68-516
		D80-01	600V		P-54-440
		D80-04	600V		T-22-294
		D86-01	600V		
		D86-02	600V		

TABLE 2- SHEARON HARRIS NUCLEAR POWER PLANT CABLE INFORMATION

Sheet 2 of 2

Spec No.	Cable Vendor	B/M Number	Voltage Class	Insulation and Jacket Type	Applicable ICEA Nos.
E-15A	Anaconda	D82-02	600V	INS-Silicon Rubber	
(Cont'd)	Ericsson			JACKET-Chlorinated Polyethylene	
		D85-02	600V	INS-Flame Retardant Ethylene Propylene	
		D87-01 to	600V	JACKET-Chlorinated Polyethylene	
		D87-08	600V		
		D88-01	Thermocouple		
		D88-02	Thermocouple		
		D89-01	600V		
		D90-01 to	300V		
		D90-05	300V		
*E-15B	American	D80-03	600V	INS-Ethylene Propylene Rubber	S-19-81
	Insulated	D94-01	300V	JACKET-Hypalon (chlorosulforated polyethylene)	S-66-524
	Wire	D95-01 to	300V		S-68-516
		D95-03	300V		P-54-440
				*Cables covered by Spec E-15B are for use outside containment only.	T-22-294
E-15C	Boston	D84-01	Triaxial	INS-Fluoropolymer	S-19-81
	Insulated		Cable	JACKET-Chlorosulphonated Polyethylene	S-66-524
	Wire &		(Rg-11u)		S-68-516
	Cable Co.				P-54-440
					T-22-294

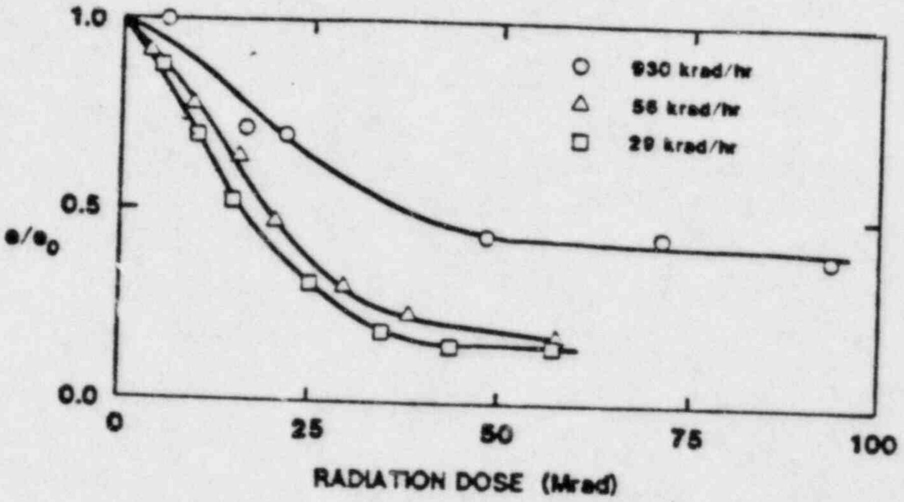


Figure 15. Tensile elongation results for PVC jacketing as a function of dose at 43°C using three different dose rates.

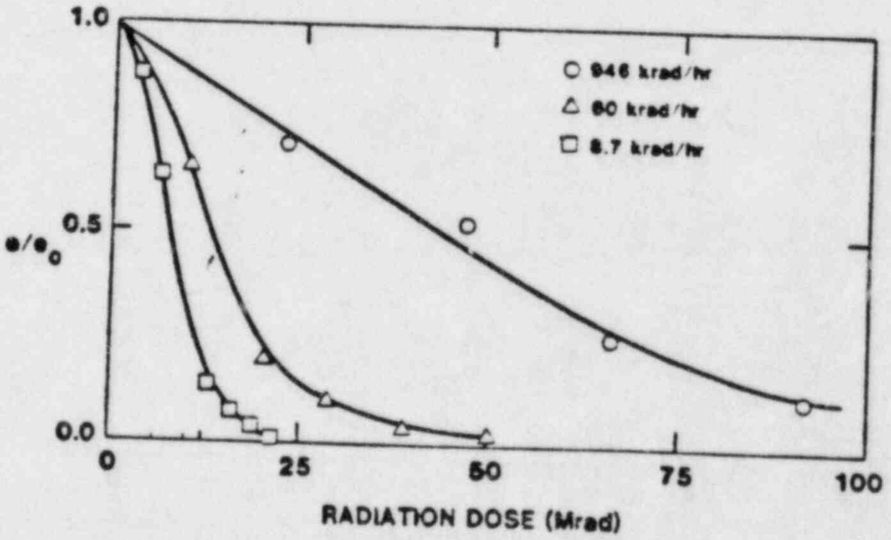


Figure 16. Tensile elongation results for PE insulation as a function of dose at 43°C using three different dose rates.

FIGURE 1

(Reproduced From Reference 6)

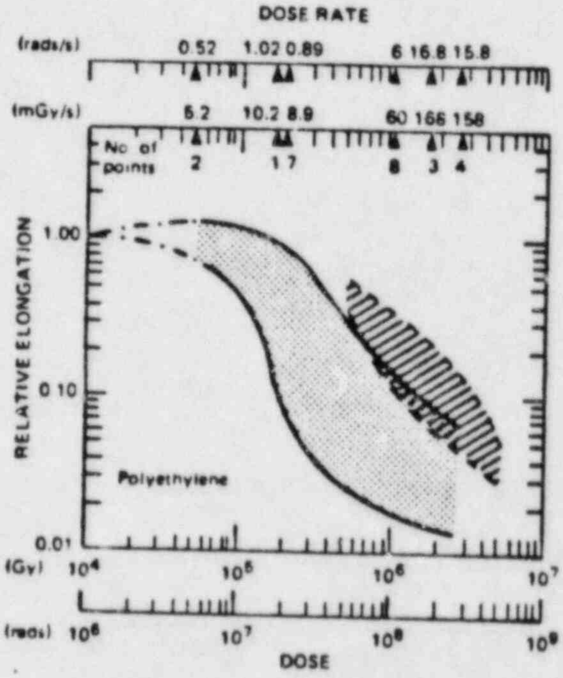
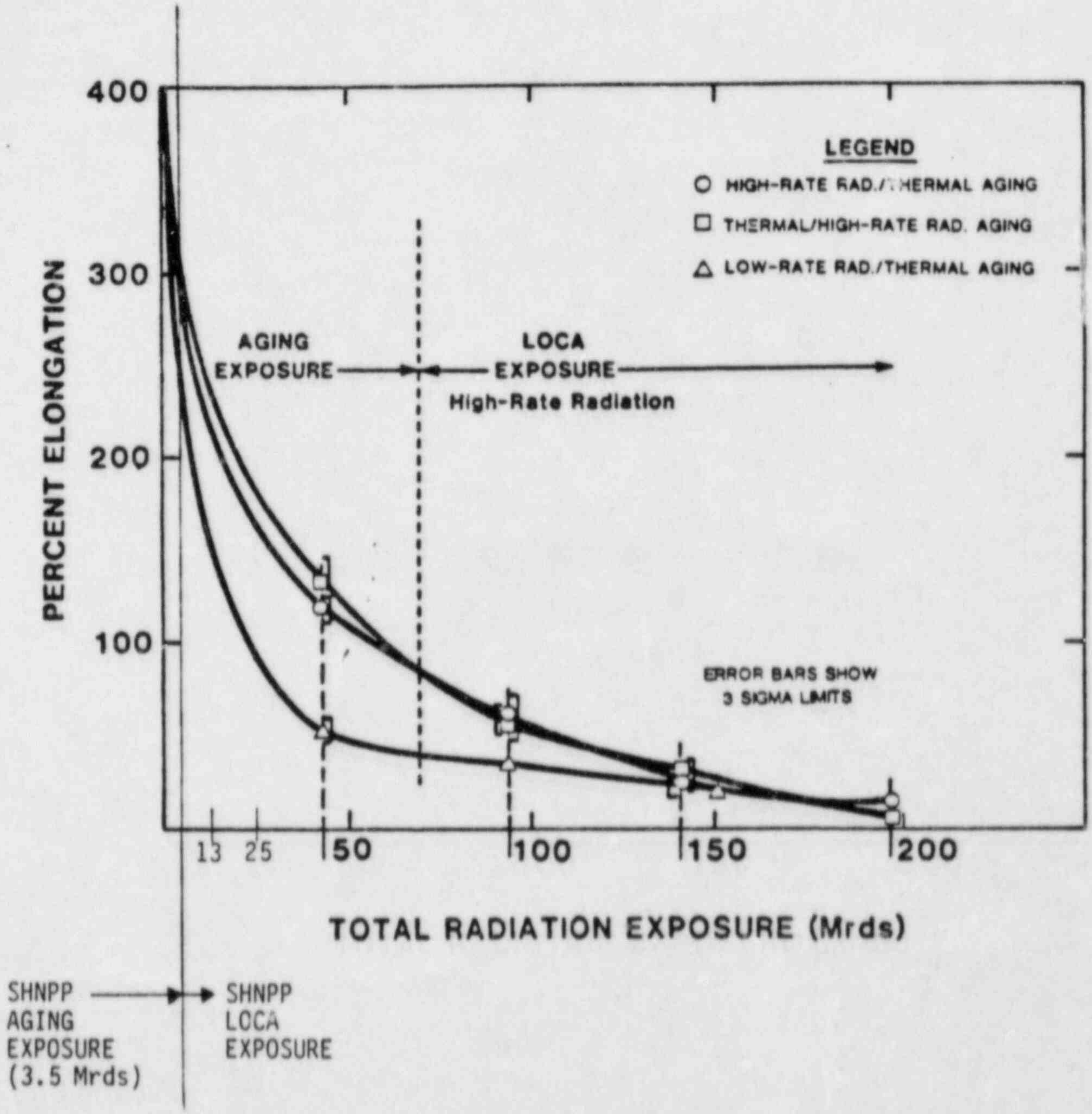


Fig. 6 Elongation at break normalized to the value before irradiation for 11 commercial polyethylene cable-insulating materials as a function of absorbed dose. The measured points fall within the shaded regions for different dose rates: the dotted area for low-to-intermediate dose rates, as shown on the upper scale, and the hatched area for irradiation at high dose rates of 50 Gy/s (1.8×10^5 Gy/h, 1.8×10^7 rads/h). The data clearly show a pronounced dose-rate effect. Based on P. Maier and A. Stolarz, *Accelerated and Long-Term Radiation Effects on Commercial Cable Insulating Materials*, European Organization for Nuclear Materials (Conseil Europeen de Recherche Nucléaire), Geneva, in preparation.

FIGURE 2

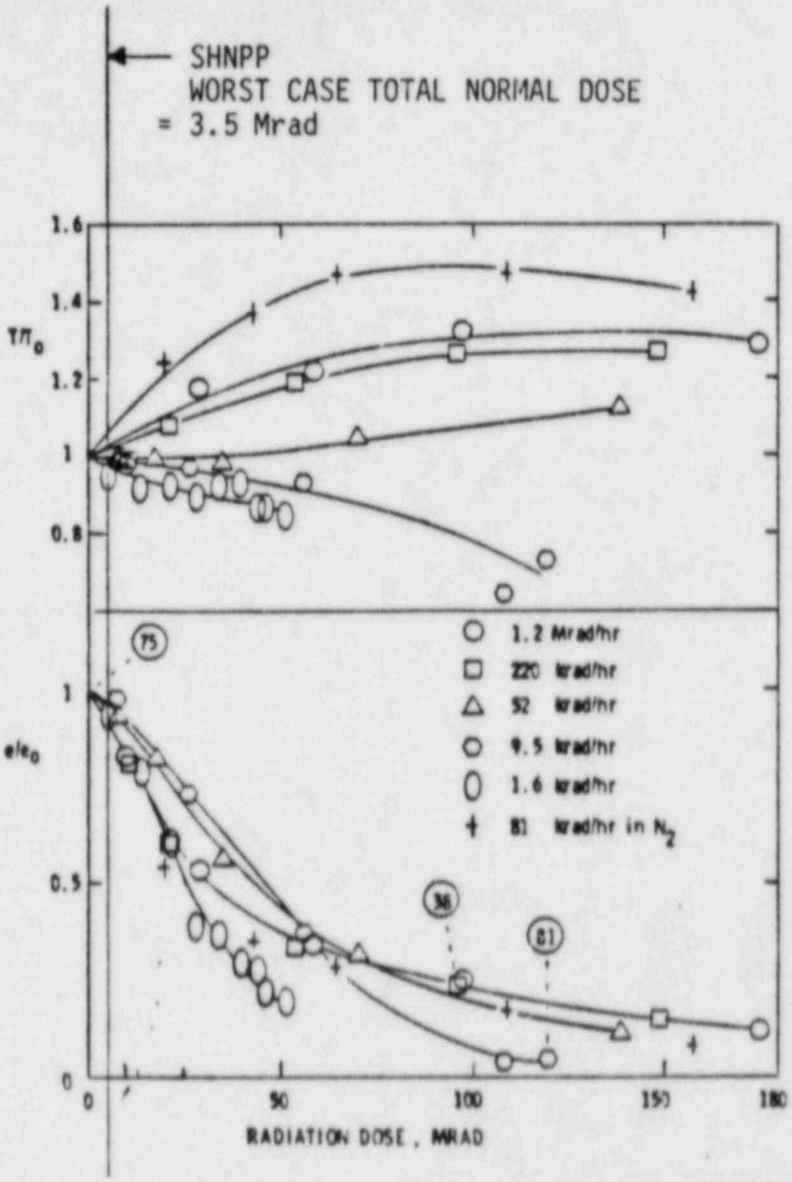
(Reproduced From Reference 7)



Elongation vs. Radiation Exposure

FIGURE 3

(Reproduced from Figure 3-1 of Reference 15)



SHNPP
WORST CASE TOTAL NORMAL DOSE
= 3.5 Mrad

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.

FIGURE 4a

(Reproduced from Reference 12)

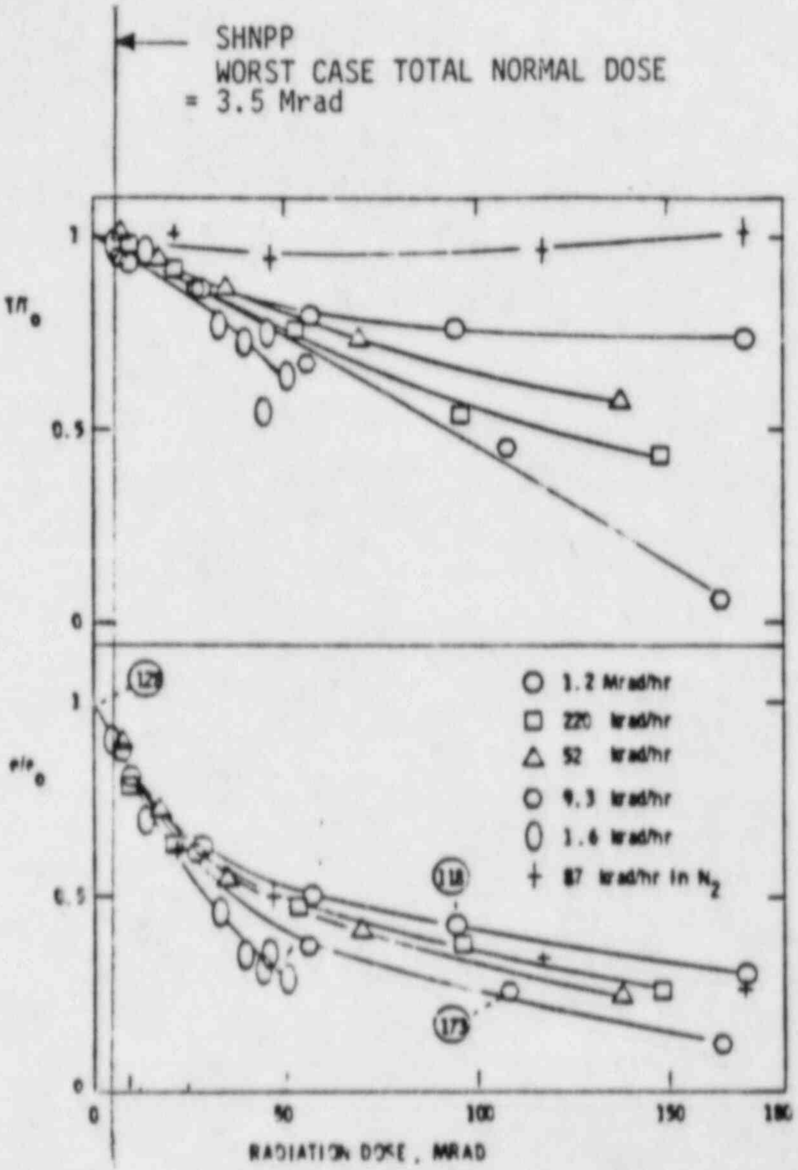

SHNPP
WORST CASE TOTAL NORMAL DOSE
= 3.5 Mrad

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

FIGURE 4b

(Reproduced From Reference 12)

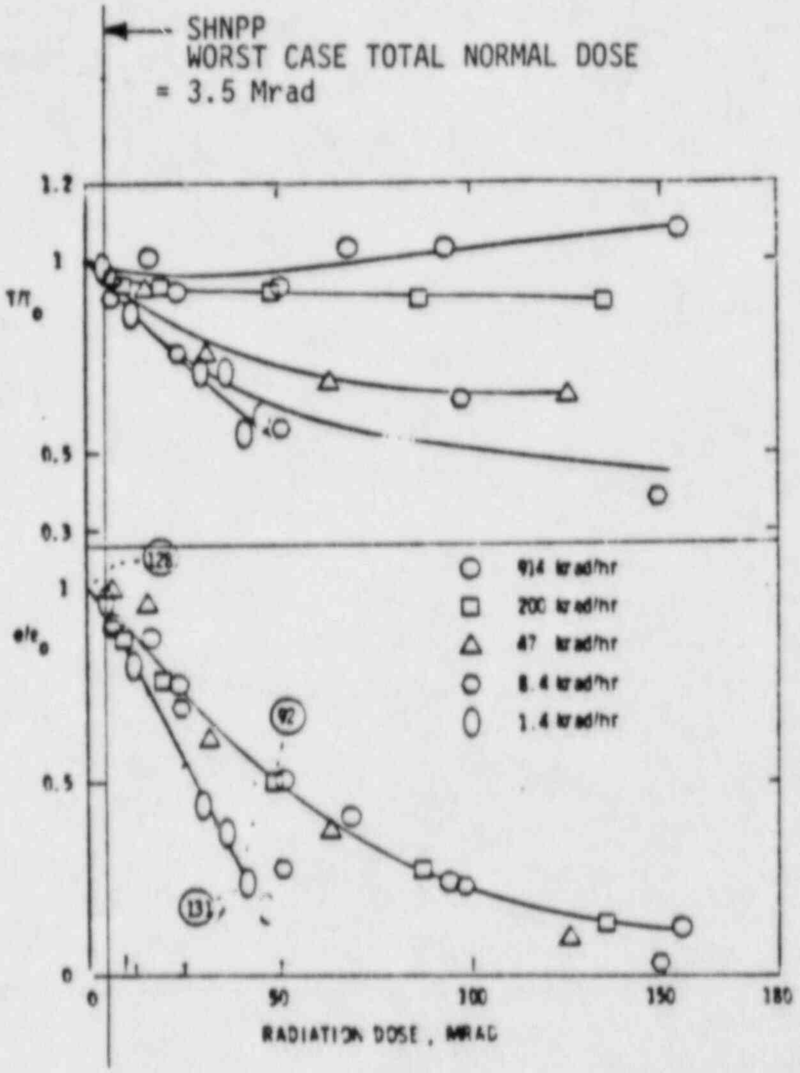


Fig. 3. Aging of chloroprene rubber jacket. Explanation of figure is identical to Fig. 1.

FIGURE 4c

(Reproduced From Reference 12)

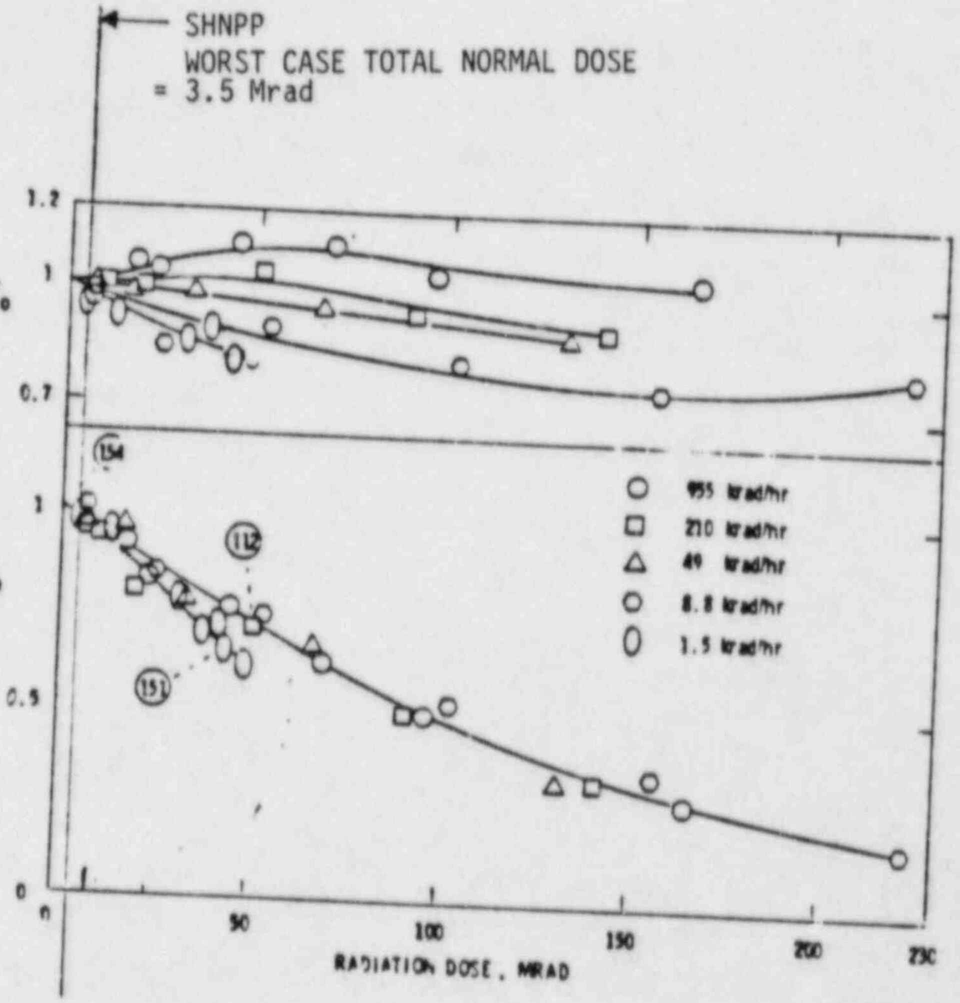


Fig. 4. Aging of chlorosulfonated polyethylene jacket. Explanation of figure is identical to Fig. 1.

FIGURE 4d

(Reproduced From Reference 12)

EXHIBIT A

RICHARD M. BUCCI

Associate Consulting Engineer
Equipment Qualification Program Manager

EXPERIENCE SUMMARY

Registered Professional Engineer with over ten years experience in electrical and related power engineering for fossil and nuclear power plants, including five years experience in Technical Supervision of engineering and design teams for nuclear power plants. Responsible for managing nuclear consulting services (electrical), development of corporate programs, guidance and positions on nuclear plant electrical systems, equipment qualification and computer aided design (CAD) programs.

Technical responsibilities have included developing, implementing and consulting on system and physical design criteria; preparation and review of electrical one-line diagrams, physical drawings and specifications; review/analysis of equipment qualification; economic and technical equipment evaluations; monitoring vendor information, specification conformance and delivery; engineering support of plant construction, start-up and operations; preparation of electricl and equipment qualification sections of PSAR, FSAR and responses to NRC. Developed and applied computer-aided methods for electrical auxiliary system studies, cable and raceway system design monitoring system start-up packages, analyses of plant design for conformance with safety requirements, preparation/maintenance of equipment qualification documentation and electrical design/graphics.

Administrative responsibilities included planning and implementing corporate engineering programs, project implementation of QA and Equipment Qualification Programs, development of schedule and budget, manpower forecasts and performance evaluations, job control by monitoring/reporting on accomplishments, schedule and workdays, training and development of design engineers, and management of multidiscipline corporate equipment qualification program efforts and electrical consulting projects.

REPRESENTATIVE EXPERIENCE

Client	Project/Station	Type	Position
Ebasco Corporate and Consulting Engineering Dept.	Nuclear Services, Development/Consulting Electrical	Nuclear	Section Leader
Ebasco Corporate and Consulting Engineering Dept.	Corporate Equipment Qualification Program	Nuclear	Program Manager

Ebasco Corporate and Consulting Engineering Dept.	CAD Development Program		Electrical Section Leader
Carolina Power & Light Co.	Shearon Harris Units 1 & 2	Nuclear	Lead Electrical Engineer
Florida Power & Light Co.	St. Lucie Units 1 & 2	Nuclear	Electrical Consultant
New York Power Authority	Indian Point Unit 3	Nuclear	Electrical Consultant
Houston Lighting & Power Co.	Allens Creek Units 1 & 2	Nuclear	Electrical Engineer
Houston Lighting & Power Co.	Cedar Bayou Fuel Oil Conversion	Oil	Electrical Engineer
Houston Lighting & Power Co.	PH Robinson Fuel Oil	Oil	Electrical Engineer

EMPLOYMENT HISTORY

Ebasco Services Incorporated, New York, N.Y.: 1974-Present

- Associate Consulting Engineer, 1984-Present
- Principal Engineer, 1982-1984
- Senior Engineer, 1980-1982
- Engineer, 1978-1979
- Associate Engineer, 1976-1977
- Assistant Engineer, 1974-1975

University of Illinois, School of Engineering, Urbana, Illinois, 1972-1974

- Research Assistant, Computer Applications

Litcom Division, Litton Industries, Melville, N.Y. 1972

- Junior Test Engineer, 1972

EDUCATION

Pratt Institute - BEE - 1972
University of Illinois-Graduate Study in Electrical Engineering, 1972-1973

REGISTRATIONS

Professional Engineer - New York

PROFESSIONAL AFFILIATIONS

IEE - Member: Power Engineering Society, Computer Society

American Nuclear Society - Member: Power Division, Nuclear Reactor Safety Division

Tau Beta Pi Engineering Honor Society

Eta Kappa Nu Electrical Engineering Honor Society

PUBLICATIONS

Author, "Developing and Maintaining Equipment Qualification Programs: A Computer-Aided Approach", TRANSACTIONS of the 1983 ANS Winter Meeting.