UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
GEORGIA POWER COMPANY, et al.	)	Docket Nos. 50-424
	)	50-425
(Vogtle Electric Generating Plant, Units 1 and 2)	)	(OL)

AFFIDAVIT OF JOEL KITCHENS,
VICTOR L. GONZALES, AND MARK L. MAYER

County of Los Angeles)
) ss.
State of California)

We, Joel Kitchens, Victor L. Gonzales, and Mark L. Mayer, being duly sworn according to law, depose and say as follows:

1. We are employed by Bechtel Power Corporation. Our business address is Bechtel Power Corporation, 12440 East Imperial Highway, Norwalk, California 90650. Summaries of our professional qualifications are attached to this affidavit as Exhibits A, B, and C.

2. The purpose of this affidavit is to support Applicants' Motion for Summary Disposition of Joint Intervenors' Contention 10.1. The affidavit discusses the "dose-rate" phenomenon and its applicability to the proper environmental

qualification of equipment important to safety containing ethylene propylene rubber, cross-linked polyolefin, chloroprene, and chlorosulfonated polyethylene. (Other polymers are discussed in this affidavit only to put the dose-rate phenomenon in historical perspective.) We have personal knowledge of the matters set forth herein and believe ther to be true and correct.

Introduction

3. To qualify equipment important to safety to withstand accident conditions, it is necessary to take into account equipment degradation that could occur before an accident. Thus, for environmental qualification, the preconditioning (aging) of equipment to its end-of-normal life condition is considered.

4. The normal life of equipment, however, is long; most equipment has a service life equal to that of the plant -- approximately forty years. It is therefore generally impracticable to age equipment naturally. Recognizing this limitation, the Commission specifically permits accelerated aging. See 10 C.F.R. § 50.49(e)(5).

5. Radiation from the normal operation of the plant is one contributor to aging. Accordingly, the accelerated aging used in environmental qualification tests must simulate the

degradation attributable to the low dose-rate radiation environment to which equipment would be exposed over its normal life. To simulate the effects of this environment, equipment is exposed to radiation at a high dose rate for a relatively short period of time. The generally accepted industry practice has been to use dose rates on the order of 0.01 to 1.0 megarads/hr for this purpose.

6. When an artificially high dose-rate is used to simulate aging attributable to radiation, the possibility of dose-rate effects arises. The term dose-rate effect means that the amount of degradation experienced in an irradiated material is dependent not only on the total integrated dose, but also on the application rate of the radiation. Dose-rate effects are not a concern for the portion of environmental qualification testing that simulates accident conditions, since the dose rates used in testing are comparable to the actual dose rate that would be experienced during the most severe design basis accident. Therefore, the only issue is whether the use of a high dose rate to precondition equipment simulates normal aging.

7. The possibility of radiation dose-rate effects has been recognized in nuclear industry research and testing for at least the last 15 years (13, 14). Nuclear industry qualification testing standards account for such possible effects. For example, IEEE 323-1974 (15) states as follows:

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

8. A number of studies in the last several years have addressed the possibility of dose-rate effects in certain polymers. These studies were prompted by the discovery of greater than anticipated degradation in polyethylene insulation at the non-commercial, Savannah River Plant K-reactor. The particular study which formed the basis for contention 10.1 was conducted in 1981 by K. T. Gillen and R. L. Clough of Sandia National Laboratories. This study is entitled NUREG/CR-2157, "Occurrence and Implications of Radiation Dose-Rate Effects for Material Aging Studies" (June 1981), and it addressed dose-rate effects in ethylene propylene rubber, cross-linked polyolefin, chloroprene, and chlorosulfonated polyethylene.

9. The gravamen of contention 10.1 is that equipment important to safety containing any of the four polymers addressed in NUREG/CR-2157 has not been properly qualified because high dose rates customarily used in accelerated aging produce less degradation in these polymers than low dose rates. As discussed below, the dose-rate effects discussed in NUREG/CR-2157 are insignificant as applied to the environmental qualification of equipment at the Vogtle Electric Generating Plant (VEGP).

Definition of Polymers

10. Polymers are chemical compounds composed of very large molecules that are formed by the repetitious union of many small molecules. These small molecules are called monomers. The monomers in a particular polymer may be all the same, or there may be several different constituent monomers in a polymer.

11. Polymers are generally categorized as follows (3):

> Thermoplastic - polymers that soften when exposed to heat and return to their original condition when returned to room temperature. Typical examples are fluorocarbons, nylons and acrylics.
>
> Thermosetting - polymers that solidify or "set" irreversibly when heated. Typical examples are phenolics, epoxies and polyesters.
>
> Elastomers - polymers possessing the ability to be stretched to at least twice their original length and the ability to rapidly retract to approximately their original length when released. Typical examples are ethylene propylene and silicone rubbers.

12. Many generic types of synthetic polymeric materials have been developed, and they vary widely in their physical properties. Each has its own individual characteristics. The four polymers within the scope of Contention 10.1, plus polyethylene, are described below.

13. Polyethylene (PE) is the simplest of all the polymeric materials. PE is formed by the polymerization of ethylene gas (C_2H_4). It is a thermoplastic.

14. Chlorosulfonated Polyethylene, also known as Hypalon, is a compound formed from a polyethylene base polymer, with chlorine and sulfur additives. It is flexible enough to be categorized as an elastomer. Its irradiation properties are more dependent on the additives than on the base polymer.

15. Ethylene Propylene Rubber (EPR) is typically a copolymer of ethylene and propylene monomer units or a terpolymer of ethelene, propylene, and 1,4-hexadiene monomer units. EPR is an elastomer.

16. Cross-linked Polyolefin (XLPO) is a polyolefin which has been structurally modified ("cross-linked") to enhance its physical properties. Cross-linking is a bonding of polymer chains at various points. Cross-links may be achieved by the addition of chemical cross-linking agents (e.g., peroxides), or by exposure to radiation. Polyolefins are aliphatic alkene polymers. Commercially useful polyolefins are polyethylene, propylene, and isobutylene. For purposes of this affidavit, cross-linked polyolefin (XLPO) may be used interchangeably with cross-linked polyethylene (XLPE).

17. Chloroprene, also called Neoprene, is a polymer formed from the chloroprene monomer ($CH_2CCl{=}CHCH_2$).

Chloroprene is a relatively inert polymer with good resistance to oil and grease environments.

Applications of Polymers

18. Westinghouse has conducted a review of Nuclear Steam Supply System (NSSS) equipment important to safety to determine the applications of polymers in such equipment. Bechtel has conducted a similar review with respect to balance of plant (BOP) equipment. Simple polyethylene was not identified in any safety-related application at VEGP. With respect to the four polymers at issue, typical applications at VEGP are cable and wire insulation (XLPO, EPR), cable jackets (Hypalon, Neoprene), O-rings (EPR, Neoprene), gaskets (EPR, Neoprene), and diaphrams (EPR and Neoprene).

Criteria for Service

19. In order to assess the qualification of safety-related equipment, suitable criteria for service must be determined for the component under review. A suitable service criterion for polymers would be retention of a predetermined level of the appropriate physical and/or electrical properties required for the polymer to perform its safety function. For example, polymers used in electrical insulation applications must retain electrical insulation properties, while polymers used in gaskets would need only to retain sufficient elasticity to

ensure sufficient contact with the seating surfaces. Criteria for service are met if a component can be shown to be capable of performing its safety-function after exposure to its equipment qualification environment.

Definition of Polymer Degradation

20. Polymer degradation is defined as the reduction of one or more specific material properties of the polymer, such as elongation (a measure of the length to which a specimen may be stretched before it breaks, typically expressed as a percent of the original specimen length), tensile strength, resilience, and dielectric property. Changes in such properties, and therefore levels of polymer degradation, may be completely acceptable as discussed previously in the section Criteria for Service.

21. When judging the significance of component or equipment degradation, the properties of the polymer that are directly related to the critical functions to be performed by the component or equipment are of primary importance. Component and equipment environmental testing and analysis include aging and, therefore, degradation of subcomponent parts.

Radiation Aging Mechanisms in Polymers

22. When polymers absorb radiation, the energy of their atoms is increased. Free electrons are produced resulting in ionization that ruptures the chemical bonds and fragments the polymer molecules. The process of irradiation changes the chemical structure of the polymer molecules by breakup into smaller molecules (scission) and by a reformation of molecules into a more non-linear network (cross-linking). The molecules may also reform in their original linear network, leaving no net structural change (recombination). The competition between the rates of these chemical processes determine the changes in polymer properties due to irradiation. It is of interest to note that cross-linking increases the molecular weight and improves the strength of the material, making it better adapted for many applications.

23. The presence of oxygen has been found to be important in the degradation mechanism of polymers exposed to radiation (4, 6, 7). It is postulated that oxygen is required for the formation of radicals that fragment the polymer molecules. This postulation appears to be confirmed by experiments conducted in an inert atmosphere that produced only slight polymer degradation.

Dose - Rate Effects

24. As previously stated, questions regarding irradiating polymeric specimens at elevated dose-rates have been raised by studies conducted at Sandia National Laboratories (4, 6). These studies were prompted by the discovery of degraded electrical cable insulation at the non-commercial Savannah River Plant K-reactor (5). 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 underlining polyethylene (PE) insulation had alternating areas of flexibility and embrittlement.

25. The investigators at Sandia, Gillen and Clough, postulated that the degradation was due to dose-rate effect phenomena. To test their hypothesis, they conducted irradiation tests on common polymer materials used in cable insulation and jacketing. In NUREG/CR-2157 (4), they tested EPR and XLPO insulation, and chloroprene and chlorosulfonated polyethylene jacketing. These materials were stripped from the cables and irradiated in air and nitrogen at radiation dose rates ranging from approximately 0.001 to 1.0 megarads/hr. Material degradation was measured using ultimate tensile properties (elongation and tensile strength) and swelling measurements. Infrared spectroscopy was used to deduce the chemical reactions produced by irradiation.

26. Radiation dose-rate effects were found in air environments for all of the materials tested. The suggested mechanism for these effects appears to be the result of competition between cross-linking and scission. As the dose rate is lowered, there is more time for oxygen diffusion into the materials and chemical reactions to occur, and scission therefore becomes more important. Thus, the mechanism of degradation appears to be different under low dose rate exposures from the mechanism occurring under high dose rate exposures normally utilized for accelerating radiation aging.

27. The dose-rate effects observed in the four polymers examined in NUREG/CR-2157, however, were much smaller than those that had been observed in simple polyethylene (not used in safety-related applications at VEGP), and thus, evidence of low dose-rate effects in simple polyethylene cannot be extended to predict the same level of effect in other improved polymeric compounds being used in present day nuclear power plants. Gillen and Clough themselves have stated in other studies (7, 10) that dose-rate effects are minor in XLPO, chlorosulphonated polyethylene, and chloroprene; and the same can be said of EPR, since the dose-rate effects in EPR are about the same as those exhibited in chlorosulphonated polyetheylene. Moreover, 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. At and below total doses equal to the maximum total dose equipment important to safety might incur over 40 years, dose-rate effects are insignificant.

28. Figures 1 through 4 show the results of the Sandia investigation of XLPO, EPR, Neoprene, and Hypalon. In the case of ethylene-propylene rubber and Hypalon, the reduction of tensile properties is virtually the same for all dose rates up to a total integrated dose of 20 megarads. In the case of Neoprene, the reduction is virtually the same for all dose rates up to a total integrated dose of 10 megarads. At VEGP, no equipment important to safety will receive a total integrated dose for 40 years normal operation greater than 10 megarads; and most such equipment will receive less than one megarad.

29. Of the four polymers addressed in NUREG/CR-2157, only XLPO exhibited dose-rate effects that were discernible at total doses below 10 megarads. As demonstrated below, these effects do not compromise the environment qualification of equipment important to safety containing XLPO.

30. In the Sandia tests, the properties measured to detect degradation were mechanical properties, i.e., tensile strength and elongation. Other engineering properties of interest for cable, particularly electrical properties like resistivity and dielectric strength, were not measured. Yet based on review of equipment important to safety at VEGP, the

only safety-related application of XLPO identified at VEGP is cable insulation; and nuclear industry cable qualification tests and other Sandia reports (1, 9) have demonstrated that cable insulation which shows substantial degradation in mechanical properties continues to provide sufficient insulation properties to allow the cable to perform its electrical function.

31. A more recent Sandia study by Minor and Furgal (9) has demonstrated that degradation of the mechanical properties of XLPO 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 (0.062 megarads/hr) for a total integrated normal operational dose of 50 megarads. Then, after elevated temperature aging, the cables were exposed to an accident dose of 150 megarads at a rate of 0.77 megarads/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 (which includes accelerated aging), is adequate despite the dose-rate effect on mechanical properties studied by Gillen and Clough. 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.

32. Gillen and Clough have acknowledged that the dielectric constant of organic insulation may change insignificantly at a point where the mechanical properties have changed drastically (11). 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 (11). Cable qualification tests, however, currently include a mechanical durability test for cable following exposure to the simulated normal and accident environmental conditions (12). This test stresses the cable when it is in a degraded condition. VEGP 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).

33. Another limitation of the Sandia tests is that pieces of cable insulation were stripped from the wire for the tests. The insulation material was thus completely exposed to oxygen in the ambient atmosphere. Since oxygen diffusion into the materials is pc ,lated to be a major contribution to the

degradation mechanism, the applicability of the test results to plant-installed cable is questionable. In actual application, insulation is covered with a jacket material. Although the jacket is primarily for mechanical protection (protection from abrasion, cuts, etc.), this covering significantly reduces the oxygen available for radiation-induced oxidation of the cable insulation.

34. Finally, as stated above, the total integrated doses received by electrical cables at VEGP during qualification testing exceed the most severe doses the cables could experience in actual use. The test dose of 200 megarads used to qualify cables for VEGP is approximately 20% higher than the calculated dose for the 40 year full power normal operating dose plus a design basis accident dose. None of the Sandia tests has shown that this margin is insufficient to compensate for dose-rate effects.

Duke Power Tests

35. Additional information regarding dose-rate effects may be obtained from a Duke Power Company Study (reference 16). Duke Power's Oconee Nuclear Generating Unit #1 became commercially operational in 1973. As there was only a limited amount of information available on the effects of aging of cable installed in a nuclear power plant environment, Duke Power established an informal cable life evaluation program.

36. Representative specimens of control, instrumentation and power cable were placed in selected locations within the reactor building so that they would be subjected to a normal in-containment environment. The cables were for the most part insulated with EPR and had Neoprene jackets. Some samples were insulated with cross-linked polyethylene and covered with Neoprene jackets. One sample of triaxial communication cable was insulated with low density polyethylene insulation and with a PVC overall jacket.

37. For all cable samples, the average radiation exposure rate was 0.65 rads/hr during operation and 0.12 rads/hr when the unit was shut down. The actual exposure level that each sample received is considered to have varied considerably over the length of the cable dependent upon the exact location of the cable within the reactor building. These dose rates are quite low in comparison to rates used in the Sandia investigations, but are representative of the dose rates expected to occur in a commercial nuclear power plant.

38. Samples of these cables were removed after 5 years and again after 10 years of exposure. Physical and electrical tests were conducted to determine the degree of degradation of the cable components. In all cases, the cables were in good condition with no more deterioration observed than would be expected over a similar period in a non-nuclear environment. In fact, in one instance, the physical properties of the cable sample actually improved during the ten year period.

39. These data further indicate that low dose rate radiation is not significantly more harmful to cross-linked polyethylene and EPR insulations than the higher rates used for environmental qualification.

<u>Conclusion</u>

40. An analysis of the Sandia studies and the results of an ongoing cable life evaluation program at Duke Power Company, demonstrate that the dose-rate effects observed in NUREG/CR-2157 are insignificant with respect to the environmental qualification of equipment important to safety at VEGP.

Subscribed and sworn to before me
this 30th day of July, 1985.

My Commission expires: Nov. 22 1985

Joanne E. Henry

OFFICIAL SEAL
JOANNE E HENRY
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
My comm. expires NOV 22, 1985

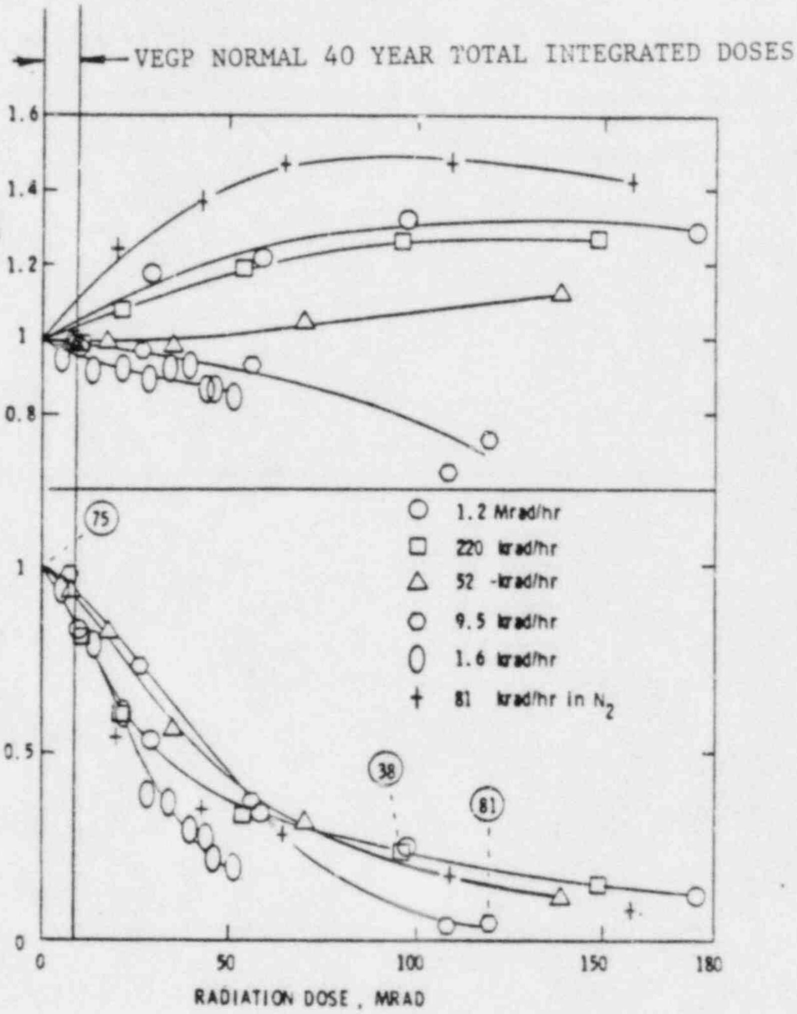

FIGURE 1

Aging of Crosslinked Polyolefin Insulation

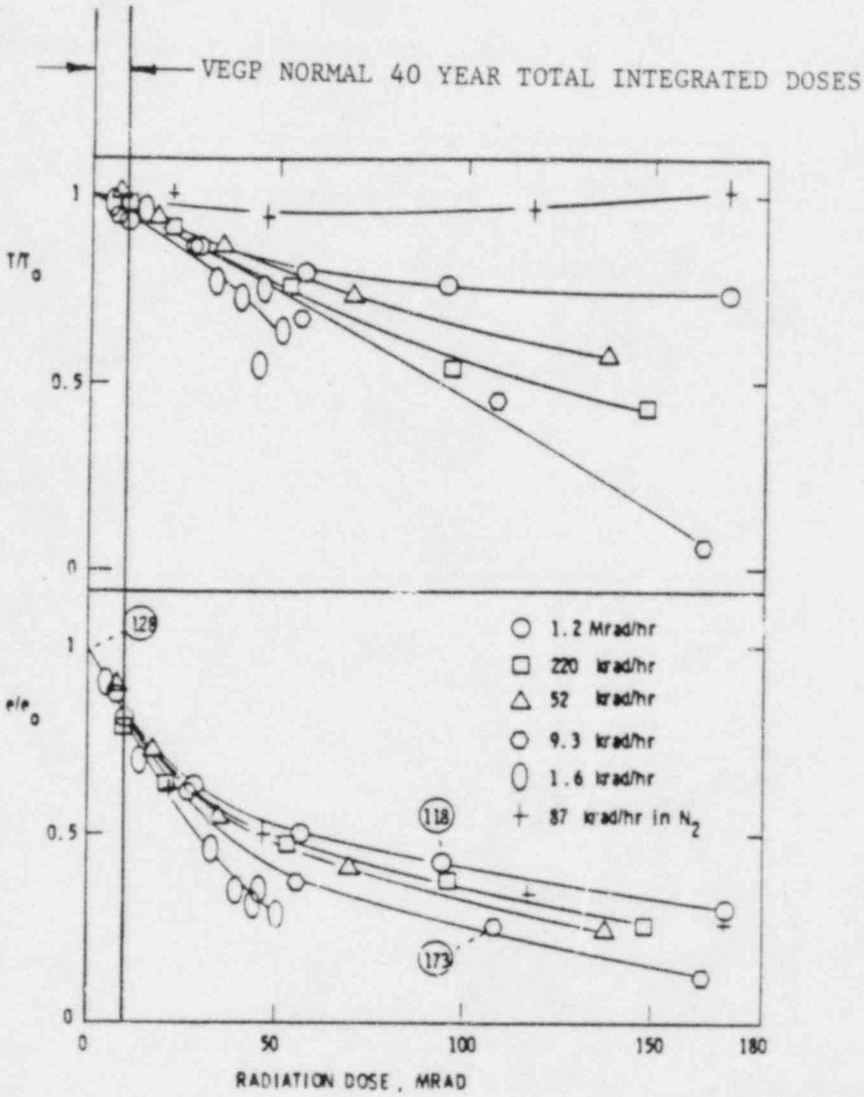

FIGURE 2

Aging of Ethylene-Propylene Rubber Insulation

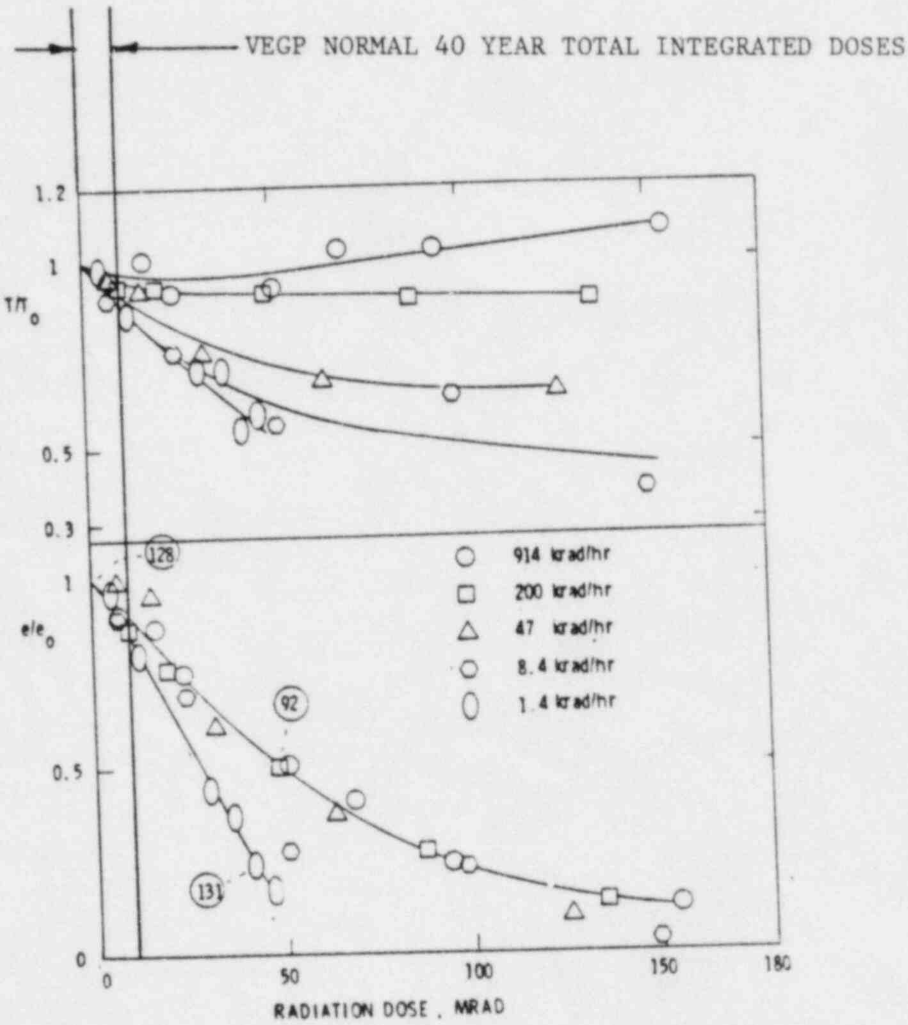

FIGURE 3

Aging of Neoprene Jacket (Polychloroprene)

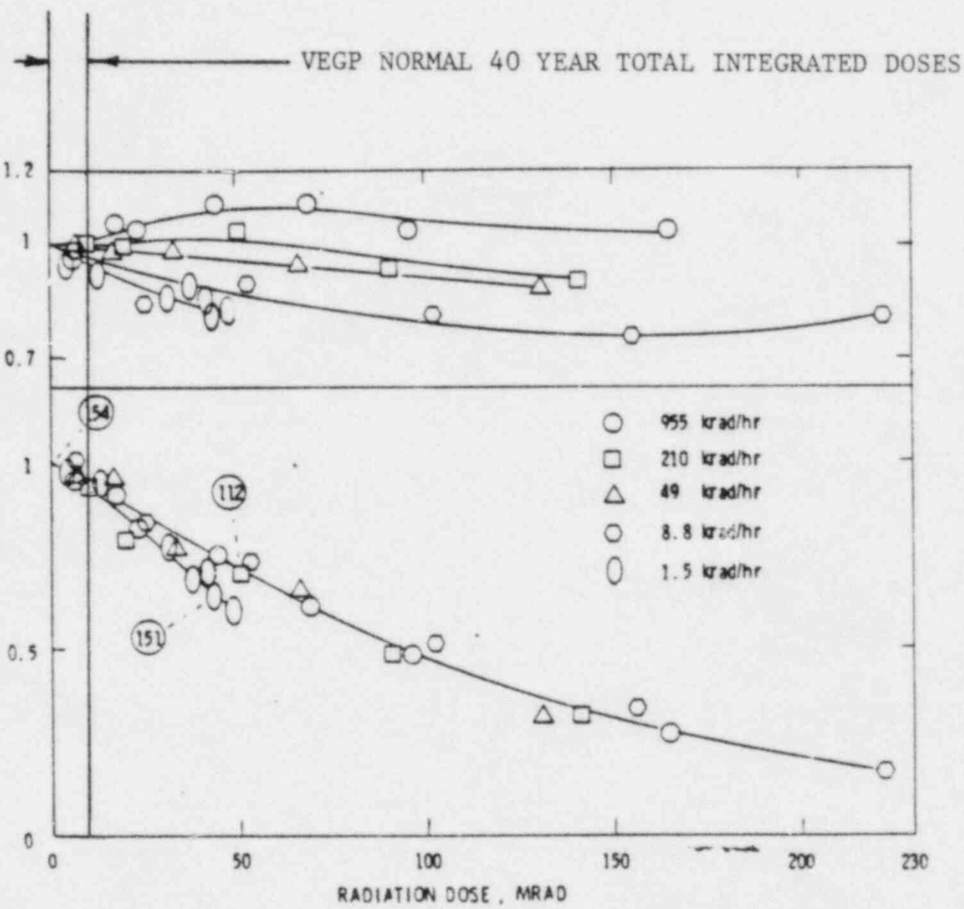

FIGURE 4

Aging of Hypalon Jacket (Chlorosulfonated Polyethylene)

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4. K. T. Gillen, R. L. Clough, "Occurrence and Implication of Radition Dose-Rate Effects for Material Aging Studies," SAND 80-1796, June 1981, NUREG/CR-2157.

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14. W. N. Parkinson and O. Sisman, Oak Ridge National Laboratories, "The Use of Plastics and Elastomers in Nuclear Radiation," Nuclear Engineering and Design 17 (North-Holland Publishing Company, 1971), p.247-280.

15. Institute of Electrical and Electronics Engineers, "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," IEEE 323-1974 (ANSI N41.5-71) (1974).

16. T. J. Al-Hussaini and J. E. Stoner Jr. (Duke Power Co.), "On-Going Qualification of Cable in a Pressurized Water Reactor Environment," Presented at the Nuclear Science Symposium, Orlando, Florida, November 1, 1984.

EXHIBIT A

JOEL KITCHENS
Assistant to the Chief Electrical Engineer
Bechtel Power Corporation, Western Power Division

PROFESSIONAL QUALIFICATIONS

EDUCATION

BSEE - University of California, Berkeley - 1948
Business Management Certificate Program, University of California, Berkeley - 1973

EXPERIENCE SUMMARY

37 years design, supervisory and management positions in power engineering fields.

EMPLOYMENT HISTORY

1966 to present:	Bechtel Group - various locations
1956 to 1966:	Anaconda Company - Wire and Cable Division New York and San Francisco
1948 to 1956:	Pacific Gas and Electric Company San Francisco

PROFESSIONAL AFFILIATIONS:

Fellow, Institute for the Advancement of Engineering
Senior Member, Institute of Electrical and Electronic Engineers
Member, IEEE Insulated Conductors Committee
Member, Project Management Institute
Registered Professional Engineer, Arizona and California

SPECIFIC QUALIFICATIONS IN THE INSULATED CABLE FIELD

Ten years with the Anaconda Company, Wire and Cable Division. These years included the following positions held and duties performed:

- o 3 1/2 years as a Cable Engineer doing cable design, specification writing, inspection and manufacturing engineering.
- o 2 years as a Regional Engineer doing application engineering and providing technical assistance for sale personnel and clients.
- o 2 1/2 years a Chief Cable Engineer with full responsibility for design, specifications and quality for the company's insulated products in the low voltage and medium voltage field.
- o 2 years as General Manager of the Cable Accessories Division in charge of design, manufacture and marketing of the accessories product line.

During 19 years with the Bechtel Group of Companies, have been a Cable Specialist with responsibility for insulated cable master specifications for all voltages and applications. Have been a member of the IEEE Power Engineering Society Insulated Conductors Committee and have represented Bechtel on this committee for this full time. Have actively participated on subcommittees and working groups responsible for maintaining and revising, as necessary, cable industry qualification standards such as IEEE Standard 383.

EXHIBIT B

V. L. GONZALES
EQUIPMENT QUALIFICATION COORDINATOR/SUPERVISOR
VEGP PROJECT

Bechtel Power Corporation, Western Power Division

PROFESSIONAL QUALIFICATIONS

EDUCATION

BS, Mechanical Engineer, California State University, Long Beach, California

EXPERIENCE SUMMARY

Present:	Engineering Supervisor
15 Years:	Increasingly responsible positions as Mechanical Systems Engineer on nuclear and fossil fueled power projects

EMPLOYMENT HISTORY

1970 to present: Bechtel Power Corporation, LAPD

SPECIFIC QUALIFICATIONS IN THE EQUIPMENT QUALIFICATION FIELD

Five years with the VEGP equipment qualification group. Mr. Gonzales is presently Engineering Supervisor/Coordinator to the Equipment Qualification Group for the Alvin W. Vogtle nuclear power project. His responsibilities include defining and reviewing electrical/controls/mechanical equipment qualification plans, procedures, and reports for compliance with project qualification documents based on IEEE 323-1974 and IEEE 344-1975 requirements. Since his appointment as Equipment Qualification Coordinator, his responsibilities also include the reconciliation of the overall project qualification program with the nuclear steam supply system (NSSS) vendor (Westinghouse) qualification program to developing NRC guidelines, for all safety-related equipment.

Prior to this, Mr. Gonzales was a Mechanical Group Leader responsible for NRC Standard Review Plan and Regulatory Guide compliance on the Alvin W. Vogtle nuclear power project. In addition, Mr. Gonzales reviewed all mechanical systems to determine their degree of compliance with the then-new NRC criteria.

EXHIBIT C

MARK L. MAYER
ENGINEER
Bechtel Power Corporation, Western Power Division

PROFESSIONAL QUALIFICATIONS

EDUCATION

BS, Nuclear Engineering, Massachusetts Institute of Technology-1981

EXPERIENCE SUMMARY

4 years as a nuclear engineer

EMPLOYMENT HISTORY

1981 to present: Bechtel Power Corporation, Western Power Division

PROFESSIONAL AFFILIATIONS:

Registered Professional Engineer, California

SPECIFIC QUALIFICATIONS IN THE RADIATION ANALYSIS FIELD

Four years with the VEGP nuclear engineering group. Responsibilities and duties have included:

- o Input to, and review of, project radiation shielding calculations. These duties required the review and understanding of the plant layout, operation and radiation sources.
- o Input to, generation of, and review of, project equipment radiation dose calculations. These duties required a review of radiation sources and accident scenarios to identify qualification doses.

July 31, 1985

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
GEORGIA POWER COMPANY, et al.	)	Docket Nos. 50-424 (OL)
	)	50-425 (OL)
(Vogtle Electric Generating Plant,	)	
Units 1 and 2)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of (1) "Applicants' Motion for Summary Disposition of Joint Intervenors' Contention 10.1 (Dose-Rate Effects)," dated July 31, 1985, (2) "Applicants' Statement of Material Facts as to Which There is No Genuine Issue to be Heard Regarding Joint Intervenors' Contention 10.1 (Dose-Rate Effects)," dated July 31, 1985, and (3) "Affidavit of Joel Kitchens, Victor L. Gonzales, and Mark L. Mayer" were served upon those persons on the attached Service List by deposit in the United States mail, postage prepaid, or where indicated by an asterisk by express mail, this 31st day of July, 1985.

David R. Lewis

Dated: July 31, 1985

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of GEORGIA POWER COMPANY, et al. (Vogtle Electric Generating Plant, Units 1 and 2)	))))))	Docket No. 50-424 50-425

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