UNITED STATES OF AMERICA

June 29, 1984

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

Glenn O. Bright
Dr. James H. Carpenter
James L. Kelley, Chairman

In the Matter of	
CAROLINA POWER AND LIGHT CO. et al. (Shearon Harris Nuclear Power Plant, Unit 1)	Docket 50-400 OL ASLBP No. 82-468-01 OL

Wells Eddleman's Response to Summary Disposition on Eddleman Contention 11 (Cable Insulation Degradation)

Since the Harris plant doesn't evidently use polyethylene cable insulation, I have been trying to track down data on radiation-related degradation of neoprene insulation. This has been without success so far, though I was given to understand (by nonwitness experts I asked for information) that radiation-dose-rate related degradation effects do exist in neoprene insulation. Since Harris is using neoprene insulation, I would respectfully suggest that the Board might look into these effects and see if a Board question on such effects is appropriate. The standards cited by the Staff (Response, p.7) (Reg. Guide 1.33, ANSI N-18.7 (1976)-ANS-3.2) appear to date from 1976 and do not take into account the extensive research performed on dose-rate related cable degradation since that time. For the Board, Staff & Applicants I enclose a copy of a recent study of LOCA dose-rate problems in cable. WE

[1]Filing date approved by NRC Staff counsel, Applicants' counsel Baxter, and Judge Bright in Judge Kelley's absence. This is a one day extension since I received the Staff's response 6/23/84.

(1)

SAND83-2018C

International Symposium on Aging in Tests of Safety Equipment for Nuclear Power Plants
Paris, France
May 15-16, 1984

The Effect of Aging on EPR Cable Electrical Performance During LOCA Simulations*

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ABSTRACT

When exposed to a LOCA environment, some EPR cable materials experience substantial moisture absorption and dimensional changes. These phenomena may contribute to mechanical damage of the cable insulation resulting in electrical degradation. Recent experiments illustrate that the extent of moisture absorption and dimensional changes during an accident simulation are dependent on the EPR product, the "accelerated age," and the aging technique employed to achieve that age. Results for several commercial EPR materials are summarized.

* This paper was supported by the U.S. Nuclear Regulatory Commission, Office of Reactor Safety Research, as part of the Qualification Testing Evaluation (QTE) Program (FIN #A-1051) being conducted by Sandia National Laboratories, under Interagency Agreement DOE-40-550-75.

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EXTENDED ABSTRACT

When exposed to a LOCA environment, some EPR cable materials experience substantial moisture absorption and dimensional changes. These phenomena may contribute to mechanical damage of the cable insulation resulting in electrical degradation. Data is presented illustrating that the extent of moisture absorption and dimensional changes occurring during an accident simulation are dependent on the EPR product, the "accelerated age", and the aging technique employed to achieve that age.

In one experiment, eight different EPR products were exposed to sequential and simultaneous aging and LOCA simulation techniques. Three of the EPR products (EPR B, C, and E) absorbed relatively small amounts of moisture when compared to the other five EPR products (EPR A, D, F, 5, and 1483). Dimensional changes occurring during the accident simulation also depended on the EPR product. In the same experimental program, four EPR products (EPR D, F, 5 and 1483) were aged to different "accelerated ages" and then exposed to a simultaneous steam and radiation LOCA simulation. The moisture absorption of the four EPR products was enhanced by increased "age."

In another experiment, two of the EPR products (EPR A and 1483) were preconditioned by various radiation doses and dose rates. The two EPR products were then exposed to three LOCA steam simulations in which the oxygen concentration during the steam exposures was varied. For EPR A, increasing the preconditioning dose or decreasing the rate at which the dose was applied resulted in enhanced moisture absorption. Interestingly, moisture absorption for EPR A decreased when oxygen was present during the steam exposure.

As part of another experiment, EPR A and 1483 were aged by several different aging acceleration techniques. Both simultaneous and sequential exposures to irradiation and elevated temperatures were employed. Following accelerated aging, the EPR samples were exposed to three LOCA simulations. The moisture absorption dependence on aging technique was vastly different for the two EPRs. For EPR-1483, the moisture absorption, percent volume increase, and the degradation of the normalized tensile strength are all maximized by simultaneous irradiation and thermal aging techniques. This behavior was not observed for EPR A.

During recent French/U.S. cooperative research experiments the moisture absorption of EPR D was examined. It also was enhanced by simultaneous aging techniques.

In conclusion, the extent of moisture absorption and dimensional changes of EPR products during accident simulations depend on the EPR product, the "accelerated age", and the aging technique employed to achieve that age.

INTRODUCTION

When exposed to a LOCA environment, some ethylene propylene rubber (EPR) cable materials experience substantial moisture and dimensional changes. These phenomena have recently been employed as part of a hypothesis to explain mechanical damage leading to electrical degradation of EPR multiconductors during Loss-of-Coolant Accident (LOCA) simulations. It was hypothesized that dimensional swelling of the insulation caused stress buildup within the multiconductor geometry. When the jacket split to relieve the stress, the sudden release of constrictive force on the insulators may have caused cracking or breakup of the insulation. Alternatively, sections of insulation which adhered to the jacket during the splitting were pulled away from the conductor. Bare copper conductors which were observed are suggestive of such a multiconductor degradation process. The multiconductor cable did experience substantial moisture absorption resulting in excessive dimensional changes during simultaneous steam and radiation LOCA simulations.[1]

Experiments illustrate that the extent of moisture absorption and dimensional changes during an accident simulation are dependent on the EPR product, the "accelerated age", and the aging technique employed to achieve that age. In this presentation results for several commercial EPR materials will be summarized.

MATERIALS

Six commercial EPR products were tested during three experimental programs. These are identified as EPR A through EPR F. Test specimens for EPR A, B, D, and F were obtained by carefully disassembling multiconductor (A and D) or single conductor (B and F) cables that were received from the manufacturers. The insulation was carefully stripped from stranded copper conductors. For EPR C and E, compression-molded sheets of the EPR insulation were obtained from the cable manufacturers and cut into strips.

In addition to the commercial cable materials, an EPR formulation used in Sandia National Laboratories fire-retardant aging studies[2, 3] (EPR-1483) was tested, as well as an EPDM formulation used in Japanese research tests[4] (Japanese EPR-5). Both of these materials were in the form of compression-molded sheets which were cut into strip tensile specimens.

EPR C, D, and F, EPR-1483, and the Japanese EPR-5 are fire-retardant EPR insulations. For EPR A, B, and E, Hypalon jackets are used to provide fire-retardancy to the cable construction.

Characteristics of the various EPR products are summarized in Table 1.

EXPERIMENTAL TECHNIQUES

Two experimental programs have been reported. An additional experimental program is in progress. Gillen, et al.[5] exposed two EPR materials (EPR A and EPR-1483; reported in their report as EPR and EPR-5 respectively) to LOCA simulation tests in which the oxygen concentration during the LOCA exposures was an experimental variable. Prior to performing the LOCA simulations, different radiation doses and dose rates were used to "age" the specimens. Moisture absorption and tensile properties were monitored during their testing program.

We also monitored these parameters.[1] We performed three LOCA simulations; obtaining data for each of the eight EPR materials (EPR A through F, EPR-1483, and the Japanese EPR-5). The effects of EPR product, accelerated age, and aging technique were investigated. Because of experimental limitations, some experiments were performed for only a few of the EPR materials.

Currently in progress is a French/U.S. Cooperative Research Program.[6] EPR C and D (EPR 1 and 2, respectively, in the Cooperative Program) were aged by five different aging techniques. These specimens, as well as unaged specimens, are being exposed to six different LOCA accident simulations at the French CESAR facility. Moisture absorption and dimensional changes for the EPR samples are being monitored during testing.

RESULTS

The influence of EPR product on moisture absorption (as determined by weight gains) is shown in Table 1 (Reference 1). EPR B, C, and E absorbed relatively small amounts of moisture when compared to EPR A, D, F, EPR-5, and EPR-1483. Dimensional increases are also shown in Table 2 (Reference 1). An EPR product dependence is also evident.

The effect of "accelerated age" on EPR moisture absorption is demonstrated by Table 3. The moisture absorption by EPR D, F, EPR-5, and EPR-1483 is enhanced by the accelerated age (Reference 1).

The aging procedures employed for Tables 2 and 3 included both radiation and thermal-stress environments. In contrast, Table 4 illustrates moisture-absorption data for two EPR products which were preconditioned using single-stress irradiation exposures[5]. The LOCA environments for Table 4 were vastly different than those employed for Tables 2 and 3. (The accident simulations did not include irradiation; the steam profiles were different.) Therefore, cross comparisons of moisture-absorption magnitude should not be made. The influence of radiation exposure on EPR A's behavior is clear, especially at the larger total doses or the lower dose rates, where moisture absorption is enhanced with respect to the unaged specimens. Interestingly, oxygen presence during the LOCA simulations reduced EPR A's moisture absorption. For EPR-1483, only larger dose rates were employed as part of the experiment. A 22 Mrd irradiation did not enhance EPR-1483's moisture absorption. Neither the 22 Mrd irradiated nor the unaged specimens absorbed significant moisture.

We also showed the effect of aging technique on EPR A and EPR-1483.[1] Both EPR A and EPR-1483 were aged by eight different techniques and then exposed to three different LOCA simulations. During the LOCA simulations, several of the EPR A samples experienced reversion and loss of form. Dimensional and weight measurements were therefore not always possible; tensile measurements were not attempted. In contrast, EPR-1483 did maintain its form allowing for dimensional, weight, and tensile measurements.

Figure 1 illustrates EPR A's moisture absorption for various aging and accident simulations.[7] Figure 2 provides similar data for EPR-1483. The moisture-absorption dependence on aging technique is vastly different for the two EPR products. Figures 3 and 4 illustrate that the percent volume increase and degradation of the normalized tensile strength for EPR-1483 are maximized by the simultaneous irradiation and thermal aging techniques (7d T + R; 30d T + R). Figure 5 replots the moisture absorption and tensile strength, T/T_o, data for EPR-1483 to illustrate the inverse relationship between these two parameters. The percent volume change of EPR-1483 is also inversely related to the tensile strength.

EPR C and EPR D were aged by five different aging techniques as part of the French/U.S. Cooperative Research Program. These specimens, as well as unaged specimens, were exposed to a simultaneous irradiation and steam exposure at the French CESAR facility. A nitrogen gas overpressure was applied during the steam exposure; all air was removed. The EPR C specimens absorbed negligible moisture, consistent with our previous conclusion that EPR C absorbs relatively small amounts of moisture when compared to some other EPR products. The EPR D moisture absorption was enhanced by simultaneous thermal and irradiation aging techniques (Figure 6). This is consistent with EPR-1483 results shown in Figure 2.

DISCUSSION

Some EPR cable materials experience substantial moisture absorption and dimensional changes when exposed to the steam environments of postulated Loss-of-Coolant Accidents. We hypothesize that dimensional swelling of the insulation can cause stress buildup within multiconductor geometries sometimes resulting in mechanical damage leading to cable electrical degradation. Recent experiments on tensile specimens illustrate that the extent of moisture absorption and dimensional changes during an accident simulation are dependent on the EPR product, the "accelerated age", and the aging technique employed to achieve that age. Thus, the choice of these parameters will help determine the extent of stress buildup within multiconductor geometries.

For one EPR material, EPR-1483, the extent of moisture absorption and dimensional changes is clearly correlated to degradation of the ultimate tensile strength.

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2. E. A. Salazar, D. A. Bouchard, D. T. Furgal, "Aging with Respect to Flammability and Other Properties in Fire-Retardant Ethylene Propylene Rubber and Chlorosulfonated Polyethylene," NUREG/CR-2314, SAND81-1906, March 1982.

3. R. L. Clough, "Aging Effects on Fire-Retardant Additives in Organic Materials for Nuclear Plant Applications," NUREG/CR-2868, SAND82-0485, August 1982.

4. Material obtained from Dr. T. Seguchi of the Japan Atomic Energy Research Institute.

5. K. T. Gillen, R. L. Clough, G. Ganouna-Cohen, J. Chenion, and G. Delmas, "The Importance of Oxygen in LOCA Simulation Tests," Nuclear Engineering and Design 74, 271-285, (1982).

6. L. D. Bustard, "U.S./French Cooperative Research Program: U.S. Test Results for Cable Insulation and Jacket Materials at the Completion of Accelerated Aging." SAND83-2019C.

7. Moisture absorption data for EPR A during LOCA simulations was not presented in Reference 1 but was obtained as part of the experimental effort described in Reference 1.

EPR MATERIAL

Characteristic	A	B	C	D	E	F	1483	5
Experimental Samples								
Extruded	X	X		X		X		
Compression Molded			X		X		X	X
Commercial Product Status								
Single Conductor		X				X		
Multiconductor	X		X	X	X	X		
Non-Commercial or Unknown							X	X
Fire-Retardancy								
Within EPR Formulation			X	X		X	X	X
Hypalon Jacket	X	X			X			
Cross-Linking Technique								
Chemical	X	X		X		X	X	X
Irradiation			X		X			

Table 1: Characteristics of EPR Products

Table 2

Insulation Specimens: Percentage Weight Increases and Dimensional Increases (O.D./Length or Width/Thickness/Length

Cable Material	Sequential Test *	Simultaneous Test #1*	Simultaneous Test #2**
Percentage Weight Increases			
EPR A	+50	?	
EPR B	+4	-1	
EPR C	+9	+23	
EPR D	+121	+173	+172
EPR E	+0	+7	
EPR F			+94
EPR-5			+77
EPR-1483	+55	+45	
Percentage Dimensional Increases			
EPR A	+19/0	?	
EPR B	-18/0	-5/0	
EPR C	+5/+20/0	+7/+20/+5	
EPR D	+38/+5	+53/+35	+51/+42
EPR E	+2/0/0	0/0/0	
EPR F			+31/+19
EPR 5			+18/+30/+21
EPR-1483	+17/+46/+7	+20/+46/+16	

* Both the sequential and simultaneous #1 LOCA profiles were interrupted at day 9 by an unanticipated steam cooldown. The test was continued and measurements were made at the end of 21 days of steam exposure.

** Measurements made during unanticipated steam cooldown starting at day 16 of LOCA profile.

Table 3

The Effect of "Accelerated Age" on EPR Moisture Absorption During Simultaneous Steam and Irradiation LOCA Simulation (Reference 1)

EPR Material	Accelerated Age	Moisture Absorption (% Weight Increase)
EPR D	Unaged	16
	40-yr equiv*	172
EPR F	Unaged	20
	40-yr equiv*	94
Japanese EPR-5	Unaged	49
	40-yr equiv*	77
EPR-1483	Unaged	17
	5-yr equiv**	22
	40-yr equiv***	67

Table 4

The Effect of "Radiation Aging" on EPR Moisture Absorption During Simultaneous Steam and Oxygen LOCA Exposures (Reference 5)

EPR Material	Aging Condition	LOCA O_2 Content (%)	Moisture Absorption (% Weight Increase)
EPR A	Unaged	5	
	22 Mrd @ 909 krd/h	0	8
	26 Mrd @ 27 krd/h	0	23
	47 Mrd @ 927 krd/h	0	19
	Unaged	10	3
	22 Mrd @ 909 krd/h	10	9
	26 Mrd @ 27 krd/h	10	10
	47 Mrd @ 927 krd/h	10	7
	Unaged	21	4
	22 Mrd @ 909 krd/h	21	12
	26 Mrd @ 27 krd/h	21	10
	47 Mrd @ 927 krd/h	21	9
EPR-1483	Unaged	0	1
	22 Mrd @ 927 krd/h	0	1
	Unaged	21	0
	22 Mrd @ 927 krd/h	21	1

* A 7d 139°C thermal exposure with simultaneous irradiation for 6 d to 40 Mrd (air-equiv.).

** A 94 h simultaneous exposure to 120°C and 4.9 Mrd (air-equiv.).

*** A 30 d simultaneous exposure to 120°C and 39 Mrd (air-equiv.).

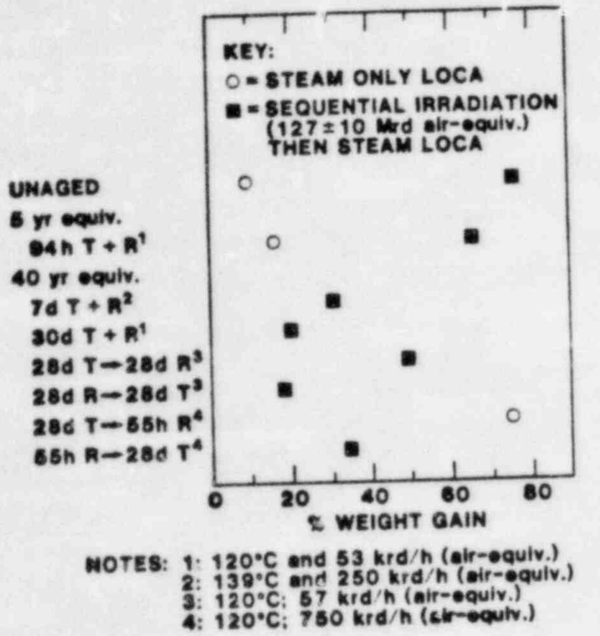


Fig. 1. Effect of Aging and Accident Accident Techniques on EPR A's Weight Gain (Moisture Absorption)

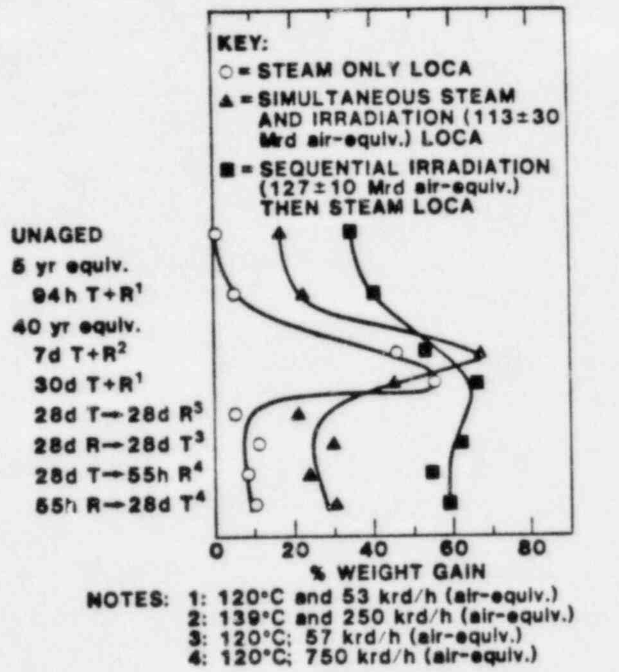


Fig. 2. Effect of Aging and Accident Techniques on EPR-1483's Weight Gain (Moisture Absorption)

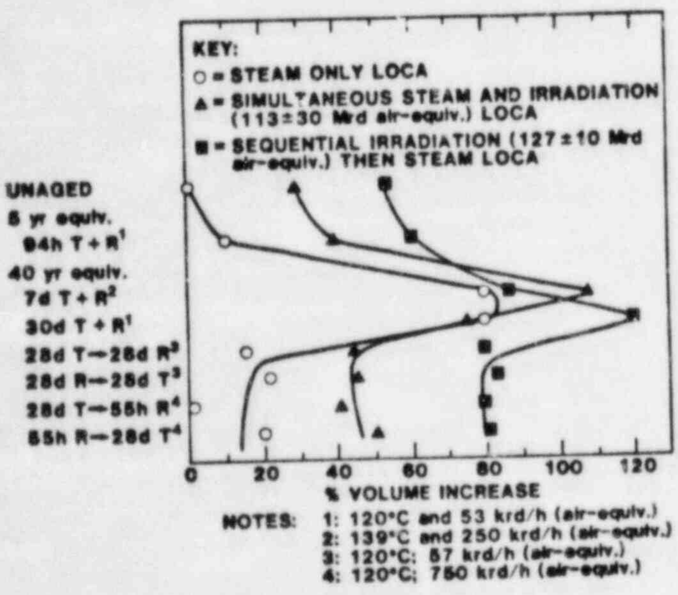


Fig. 3. Effect of Aging and Accident Techniques on % Volume Change of EPR-1483

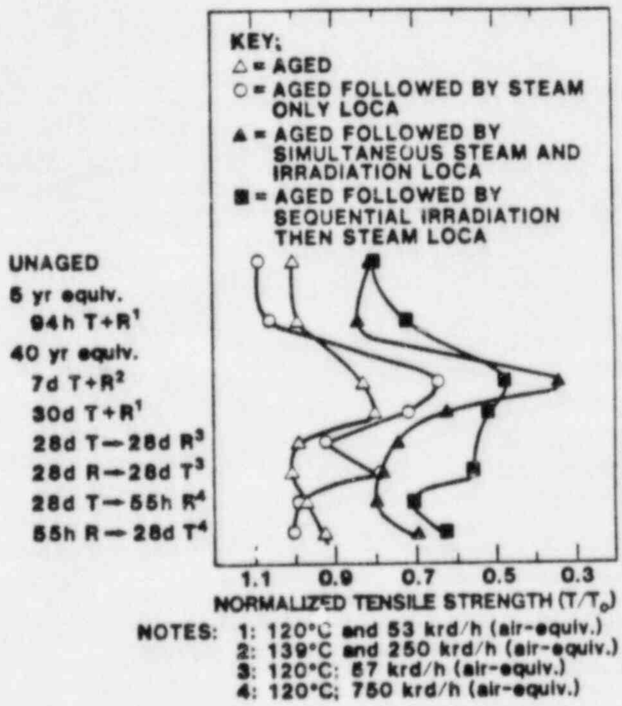


Fig. 4. Effect of Aging and Accident Techniques on Normalized Tensile Strength of EPR-1483

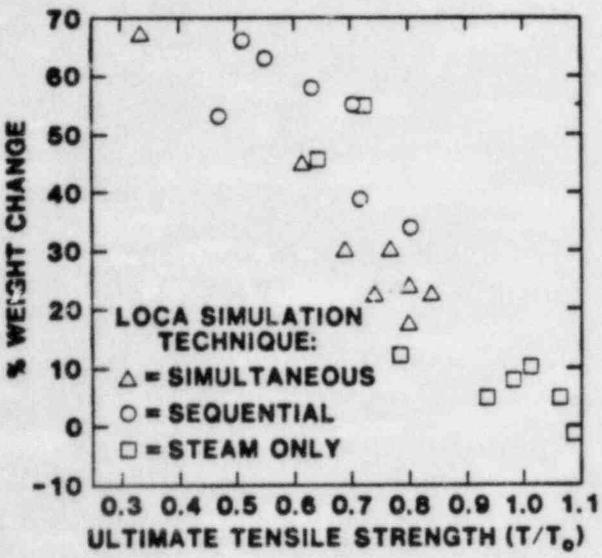
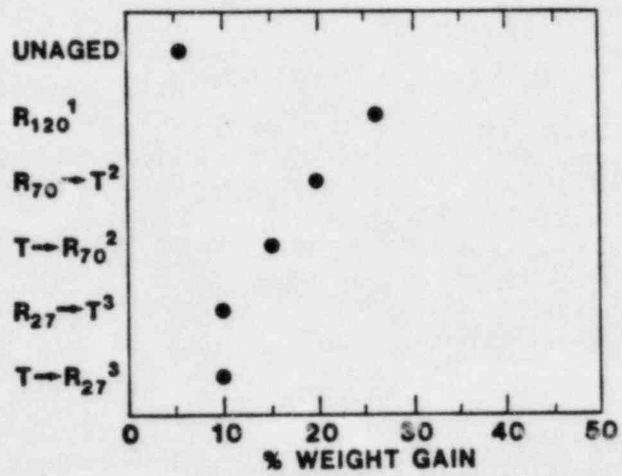


Fig. 5. Relationship Between Weight Changes (Moisture Absorption) for EPR-1483 and the Normalized Ultimate Tensile Strength at the Completion of the Accident



NOTES: 1: 16d 120°C and ~65 krd/h (air-equiv.)
2: 16d 70°C, ~65 krd/h (air-equiv.) and 16d 120°C
3: 16d 27°C, ~65 krd/h (air-equiv.) and 16d 120°C

Fig. 6. Effect of Aging Techniques on Moisture Absorption (% Weight Gain) of EPR During Simulataneous 60 Mrd and Steam (w/o Air) Exposure.