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TO: Mr. Edson G. Case

FROM: Indiana & Michigan Power Company
New York, N. Y.
R. S. Hunter

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DESCRIPTION

ENCLOSURE
Consists of additional info. to the supplied info. in 11/23/77 ltr. in support of the use of butt spliced connections for electrical penetrations on the inside of the containment.....

PLANT NAME: Cook
RJL 12/6/77 (2-P) (12-P)
3 ENCL / REPRO BALANCE

FOR ACTION/INFORMATION

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PROJECT MANAGER:	MLYNCZAK		
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INDIANA & MICHIGAN POWER COMPANY
P. O. BOX 18
BOWLING GREEN STATION
NEW YORK, N. Y. 10004

Donald C. Cook Nuclear Plant
Units 1 and 2
Docket Nos. 50-315 and 50-316
DPR No. 58 and CPPR No. 61

November 29, 1977

Mr. Edson G. Case, Acting Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Case:

Attachment A to this letter provides additional information to that supplied in our November 23, 1977 letter, in support of our use of butt spliced connections for electrical penetrations on the inside of the containment. The attachment entitled, Addendum Raychem Report No. 71100, Revision 1 -- Heat Shrinkable Products for Nuclear Power, documents the Raychem post-accident environment qualification of the butt splices that we are using.

A comparison of cable materials used in the Raychem test and those used in the Cook Nuclear Plant splice is shown on Table 5 of the Raychem test report.

The procedures used to fabricate the splices at Cook Nuclear Plant are based on the Raychem procedures.

These Raychem procedures as well as Raychem Report 71100 are to be found in the Raychem Power Distribution Products catalog.

Very truly yours,

R. S. Hunter
Sr. Vice President - Construction
American Electric Power Service Corporation

RSH kb
Attachment

cc: R. C. Callen
P. W. Stekett
R. Walsh
R. J. Vollen
D. V. Shaller - Bridgman
R. W. Jurgensen
G. Charnoff
John Tillinghast

RAYCHEM

To Whom It May Concern:

Subject: Addendum
Raychem Report #71100, Revision 1
Heat Shrinkable Products for Nuclear Power

In order to clarify certain product testing (WCSF), the following notation to subject report should be added:

All WCSF* type parts tested in accordance with Raychem Report No. 71100, Revision 1 were coated type -N adhesive designated by Raychem type S-1024.

Dr. V. Canady
Thermofit Material Development Manager

Al Anderson
Market Manager
Power Distribution Products

*Per our Thermofit Specification #1508 dated May, 1974, Revision 1.

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ABSTRACT

Raychem Corporation is in the process of evaluating many of its products for use in nuclear power plant containments. Using the Institute of Electrical & Electronics Engineers "Proposed Guide for Type Tests of Class I Cables and Connections Installed Inside the Containment of Nuclear Power Generating Stations" as the test basis, 5 and 15KV high voltage terminations (HVT's) and 600-2000 volt in-line splices were found to withstand loss of coolant accident (LOCA) conditions of a design basis event (DBE) either early or late in their anticipated use life. HVT's remain usable, having excellent tensile strengths and elongations, even after 200 Mrads (2×10^8 Rads) of gamma radiation in air. Properly applied HVT's form an environmental seal around the cable protecting it from high pressure steam, moisture, and boric acid spray.

Thermofit Report 71100
Revision 1

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INTRODUCTION

The current energy crisis and increased power consumption have created a demand for more power plants. When these factors are combined with our current ecological awareness and the need to prevent additional damage to the environment, nuclear power plants emerge as viable candidates to satisfy our power needs. As of September 30, 1971, 10,040,800 kilowatts of electricity could be generated in the United States by nuclear power plants; additional capacity of 45,779,000 kilowatts were being built; and 51,571,000 kilowatts of nuclear power were being planned[1]. This growth attests to the increased attention being given to nuclear power as a source of energy. While the ultimate purposes of a nuclear power plant are the same as those of a fossil fuel plant, the requirements and demands placed upon electrical insulating materials are different. In a fossil fuel plant, the engineer needs to know the electrical properties of the insulating materials, how these properties change with time, and the effects of moisture and oxygen upon electrical and physical properties. For nuclear power plant use, in addition to the aforementioned properties, the engineer also needs to know how the materials are affected by nuclear radiation over a 40-year lifetime.

Virtually all organic materials are known to be affected by radiation. In some cases where the radiation can be controlled, the property profiles of many organic materials are improved by exposure to radiation. In these cases, the material is exposed to gamma or electron beam radiation under

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1 "Nuclear Reactors Built, Being Built, or Planned in the United States as of December 31, 1971", National Technical Information Service, Report Number TID-8200 (25th Revision).

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carefully controlled conditions for specific lengths of time and a material with an improved property spectrum results. These improved materials have greater tensile strength, greater stress crack resistance, lower moisture vapor transmission, greater elastic memory, in addition to the other improvements over their non-irradiated counterparts. In a nuclear power plant, the exposure of materials to radiation cannot be fully controlled, nor can the length of exposure be reasonably controlled. The materials installed in a nuclear power plant must have the highest possible resistance to the long-term effects of heat and radiation.

In addition to inherent radiation resistance, the materials used in a nuclear power plant must also provide assurance that in the event of an accident, they will maintain their integrity so that the plant may be safely shutdown. This is true if the accident were to occur during start-up or after the plant had been operating for many years. Consequently, materials designed for use in nuclear power plants must be evaluated under accident conditions before and after their exposure to nuclear radiation.

Raychem Corporation has extensive experience in the irradiation of organic materials. For over 15 years, our principal business has been the irradiation of organic materials to enhance their balance of properties. Some of the products developed in our laboratories and extensively tested in use are our heat recoverable high voltage terminations (HVT) and 600-2000v in-line splices (WCSF). This report describes the evaluation of these products for use in nuclear power plants.

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PROGRAM OUTLINE

HVT and WCSF evaluations were divided into two phases: materials evaluation and systems evaluation. The materials evaluation consisted of an in-depth look at how the materials of construction behaved as a result of nuclear radiation. Systems evaluation consisted of an in-depth analysis of how the completely assembled parts behaved as a result of nuclear radiation and how well it withstood the effects of a loss of coolant accident before and after exposure to nuclear radiation.

The evaluation was based upon the Institute of Electrical and Electronics Engineers "Proposed Guide for Type Tests of Class I Cables and Connections Installed Inside the Containment of Nuclear Power Generating Stations". The test sequence for materials consisted of:

1. Heat aging the materials in a forced air oven at 121° ± 2°C for 168 hours.
2. Irradiation of the materials in a cobalt 60 gamma source at 0.52 Mrads per hour to total doses of 100 and 200 Mrads.

The test sequence for assembled high voltage terminations and in-line low voltage (i.e., 600-2000v) splices consisted of:

1. Heat aging high voltage terminated cables at 121° ± 3°C for 168 hours in a forced air oven.
2. Irradiation of assemblies with cobalt 60 gamma radiation at 0.50 Mrads per hour for HVT's and .27 Mrads per hour for WCSF to total doses of 100 and 200 Mrads.
3. Subjecting irradiated assemblies maintained at maximum rated

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voltage to LOCA tests in a pressurized autoclave according to the following schedule:

a. 5 hours at 360°F, 70 psig steam.

b. 6 hours at 320°F, 70 psig steam.

c. 24 hours at 250°F, 21 psig steam, 0.2% boric acid spray, buffered to pH of 10.

d. 12 days at 221°F, 2.5 psig steam.

e. 100 days @212°F 2.0 psig steam.

TEST RESULTS

Tables 1 and 2 show the results of the materials evaluation of Raychem HVT's and WCSF sleeves. These data show that even after 168 hours at 121°C in a forced air oven and subsequent irradiation to 200 Mrads cobalt 60 gamma radiation in air, the products have maintained a very high degree of mechanical integrity. As an example the outer high voltage tubing and stress grading material have maintained at least 80% and 70% elongations, respectively. This, coupled with the excellent tensile strengths, indicates that these materials have sufficient toughness and radiation resistance to withstand 200 Mrads gamma radiation.

Table 3 shows the electrical performance of 15KV HVT's during LOCA tests. From the data, it is evident that all HVT's, those irradiated to 100 or 200 Mrads, as well as those not irradiated at all, are capable of performing during a loss of coolant accident. Applied voltages for the 15KV HVT's during LOCA tests varied between 8.7 and 15KV, phase to ground.

Table 4 yields similar data for 5KV HVT's. Here again, the Raychem

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HVT's successfully withstand LOCA tests before and after irradiation. The 5KV HVT's were subjected to applied voltages between 5 to 8.6KV phase to ground during the LOCA sequence.

Table 5 shows electrical performance of a series of in-line splices made on 600, 1000 and 2000 volt class cable and subjected to continuous maximum cable rated voltages.

SUMMARY

Data supplied in this report show that when properly assembled, Raychem high voltage terminations and in-line low voltage splices may be recommended for use in nuclear power plants. The assembled terminations and splices have successfully withstood DBE and LOCA tests and remain functional during the accident. They will perform so as to permit a safe and orderly shut-down of equipment in the event of a loss of coolant accident.

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TABLE 1

EFFECTS OF NUCLEAR RADIATION UPON RAYCHEM HVT MATERIALS

	Outer Tubing	Stress Grading
Initial elongation, %	260	236
Elongation after 168 hours at 121°C plus 100 Mrads, %	126	140
Elongation after 168 hours at 121°C plus 200 Mrads, %	80	70
Initial tensile strength, psi	2290	1560
Tensile strength after 168 hours at 121°C plus 100 Mrads, psi	3025	2015
Tensile strength after 168 hours at 121°C plus 200 Mrads, psi	3020	1665
Initial hardness, Shore D	43	37
Hardness after 168 hours at 121°C plus 100 Mrads, Shore D	57	50
Hardness after 168 hours at 121°C plus 200 Mrads, Shore D	60	50

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TABLE 2

EFFECTS OF NUCLEAR RADIATION UPON RAYCHEM WCSF MATERIALS

	WCSF Tubing Samples	WCSF Slab Sample @.125" Thickness
Initial elongation, %	565	440
Elongation after 168 hours at 121°C plus 100 Mrads, %	--	145
*Elongation after 168 hours at 121°C plus 200 Mrads, %	100	70
Initial tensile strength, psi	2180	1600
Tensile strength after 168 hours at 121°C plus 100 Mrads, psi	--	1745
Tensile strength after 168 hours at 121°C plus 200 Mrads, psi	1500	1685
Initial hardness, Shore D	37	43
Hardness after 168 hours at 121°C plus 100 Mrads, Shore D	--	46
Hardness after 168 hours at 121°C plus 200 Mrads, Shore D	42	52

*Tubing samples were exposed to simultaneous heat aging and irradiation

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TABLE 3

PERFORMANCE CHARACTERISTICS (CORONA EXTINCTION VOLTAGE) OF RAYCHEM 15KV HIGH VOLTAGE TERMINATIONS DURING DBE/LOCA TESTING[1]

	HVT #1	HVT #2	HVT #3	HVT #4	HVT #5	HVT #6
Initial CEV, KV	20	17.5	20	19.5	21.5	21
CEV after 168 hours at 121°C	30	25	25	24	31	19
CEV after 168 hours at 121°C plus 100 Mrads[2]	--	--	14	15.5	--	--
CEV after 168 hours at 121°C plus 200 Mrads[2]	--	--	--	--	19.5	16
CEV after 35 hours DBE[3]	17	15	20.5	21	16	16

Notes

1. Crosslinked polyethylene cable, copper tape shield, extruded semiconductive layer.
2. Cobalt 60 gamma radiation, dose rate of 0.50 Mrads per hour.
3. 5 hours at 360°F, 70 psig steam; 6 hours at 320°F, 70 psig steam, 24 hours at 250°F, 21 psig steam, 0.2% boric acid spray at pH of 10, 12 days at 221°F, 2.5 psig steam, 100 days at 212°F 2.0 psig steam.

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TABLE 4

PERFORMANCE CHARACTERISTICS (CORONA EXTINCTION VOLTAGE) OF RAYCHEM 5KV HIGH VOLTAGE TERMINATIONS DURING DBE/LOCA TESTING[1]

	HVT #1	HVT #2	HVT #3	HVT #4	HVT #5	HVT #6
Initial CEV, Kv	4.8	4.2	5.5	5.5	5.8	5.8
CEV after 168 hours at 121°C	4.5	4.3	4.6	4.0	4.8	4.4
CEV after 168 hours at 121°C plus 100 Mrads[2]	---	---	5.2	4.3	---	---
CEV after 168 hours at 121°C plus 200 Mrads[2]	---	---	---	---	4.2	5.0
CEV after 35 hours DBE[3]	4.5	4.1	4.7	4.5	4.8	(4)

Notes

1. EPR cable, copper tape shield, tape semiconductive layer.
2. Cobalt 60 gamma radiation, dose rate of 0.50 Mrads per hour.
3. 5 hours at 360°F, 70 psig steam; 6 hours at 320°F, 70 psig steam; 24 hours at 250°F, 21 psig steam, 0.2% boric acid spray at pH of 10, 12 days at 221°F, 2.5 psig steam, 100 days at 212°F 2.0 psig steam.
4. Specimen mechanically damaged before being placed in autoclave.

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TABLE 5

PERFORMANCE CHARACTERISTICS OF RAYCHEM 600-2000 VOLTS IN-LINE SPLICES TYPE WCSF DURING DBE/LOCA TESTING

	New Material	Per Table 2 Aged 168 Hours @121°C & 200 Mrads
Electrical Strength 5 Samples - Volts/Mil		
Minimum	312	318
Maximum	491	355
$\overline{X}$	380	334
Wall Thickness	.084"	.086"
Volume Resistivity OHM-CMS	2.5×10^{13}	1.2×10^{14}
Flammability Per A.S.T.M. D-2863 Oxygen Index Note Slab Data Only	35.0	37.0

Notes

1. Cable types for testing
   - A. 600 volt Flamtrol™
   - B. 2000 volt EPR/Neoprene

Cable types for Cook Nuclear Plant splices

600 v Kapton
600 v Hypalon

2. All samples were continuously operated at maximum current and voltage per cable class. Current levels per I.P.C.E.A.
3. Cobalt 60 gamma radiation, dose rate of 0.27 Mrads per hour.
4. 5 hours at 360°F, 70 psig steam; 6 hours at 320°F, 70 psig steam; 24 hours at 250°F, 21 psig steam, 0.2% boric acid spray at pH of 10, 12 days at 221°F, 2.5 psig steam, 100 days at 212°F 2.0 psig steam.
5. All samples passed. No electrical or mechanical failures.

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