

U. S. NUCLEAR REGULATORY COMMISSION
REGION IV

June 17, 1982

Docket No.: 99900902/82-05

Environmental Qualification Program: Duke Power Company Verification Test for D. G. O'Brien Electrical Penetration Assembly (EPA) Including Mating Connector and Cable Assemblies, Report No. 4.

1. LOCA/HELB Environmental Qualification Test - Post Analysis
2. LOCA/HELB Environmental Qualification Extended Accident Test - Documentation Review.
3. LOCA/HELB Environmental Qualification Extended Accident Test - Post Analysis.

Equipment Identification:

Test Specimen: EPA and Mating Connector/Cable Assemblies

Type: C, D, E, F, K, and L Modules

Equipment Spec. No.: MCS-1393 01-00-0003, Rev. 5, April 9, 1982, Duke Power Company

Qualification Test Procedure No.: 543/6124-2/DK, Rev. C, April 26, 1982, Wyle Laboratories

Serial No: See Table 1

Test Organization: Wyle Laboratories (Eastern Operations), Scientific Services and Systems, 7800 Governors Drive West, Huntsville, Alabama 35807

Contract No.: Purchase Order No. 8828.05-3PM, Job No. 45869

Inspections Conducted: April 28-30, 1982*
May 11-13, 1982
May 17-20, 1982*

*Accompanying Mr. A. R. Johnson, team leader, in the April 28-30, 1982, inspection were Mr. W. S. Farmer of NRC, Nuclear Regulatory Research, and Messrs. W. H. Buckalew and F. V. Thome, NRC Consultants, Sandia National Laboratories; and the May 17-20, 1982, inspection were Mr. G. T. Hubbard, NRC, Region IV, and Mr. J. Benson, NRC Consultant, Sandia National Laboratories.

NRC Inspector: Alva L. Smith 8/13/82
 for A. R. Johnson, Equipment Qualification Section, Date
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Summary: The purpose of these inspections was to observe and review the results of both post analyses; and witness, verify, and review documented test records, for the above testing, for the safety-related D. G. O'Brien Electrical Penetration Assemblies (including mating connector and cable assemblies) to qualify this class IE equipment to Category II requirements of NUREG-0588, Revision 1 (IEEE-std 323-1971) for McGuire Nuclear Station Units 1 and 2. These inspections were a continuation of the inspection performed by the NRC-RIV inspector on March 29-April 1, 1982 (IE Inspection Report No. 99900902/82-03).

Results: The inspection performed during this period indicated:

1. EPA Modules C, F, and K, specified for electrical service during and following a postulated accident, met the prescribed margins set by the licensee outlined in its specification. This includes the margin necessary for his notification during test, as well as the prescribed margins for acceptance.
2. EPA Modules D and L, not specified for electrical service during and following a postulated accident, also met the prescribed margins set by the licensee outlined in its specification (prescribed margin for licensee notification and acceptance).

3. EPA Module E, not specified for electrical service during and following a postulated accident, did not meet the prescribed margin necessary for his notification during test. It could not be determined by the NRC-RIV inspector that this module met the prescribed acceptance criteria.
4. It should be noted that all EPA's undergoing tests were required to be safety-related with respect to maintaining the integrity of the containment pressure boundary. The pressure boundary integrity was not included in this environmental test but was proven at an earlier date on prototype equipment.

DETAILS SECTION

Prepared by A. R. Johnson

A. Persons Contacted

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B. General

On July 6, 1981, the I & C staff met with representatives from Duke Power Company, D. G. O'Brien Inc., and Life Cycle Engineering (Consultant of Duke Power) in Bethesda, Maryland, to discuss various environmental qualification tests conducted on D. G. O'Brien EPA's for the McGuire Nuclear Station 1 and 2, including failures which occurred during the NRC-sponsored independent verification tests at Sandia National Laboratories on May 19-June 21, 1981.

The qualification tests performed by Sandia National Laboratories indicated the shorting of conductor leads caused by extrusion of the grommet through the wire holes in the back of the sleeve, resulting in stripping of the insulation. The grommet extrusion was attributed to differential expansion between the sleeve and grommet during accelerated thermal aging.

Duke Power Company was requested by the NRC staff to provide either the details of their proposed testing program in their July 15, 1981 environmental qualification submittal, or to detail their plans for further testing of the EPA's. Duke Power Company indicated that additional tests, in lieu of analysis, would be performed to substantiate that their initial qualification tests and documentation (McGuire tests by D. G. O'Brien, 1974-1975, and D. G. O'Brien test for V. C. Summer plant, 1978) were still valid and the EPA's environmentally qualified. Duke Power Company's position was that the failures that occurred during the Sandia tests would not occur under postulated accident conditions, but rather were a result of the artificiality of the accelerated thermal aging process.

An independent confirmatory test was developed by Duke Power Company (specification No MCS-1393.01-00-0003, Rev. 4) and implemented by Wyle Laboratories, as developed by their approved test plan No. 543/6124-2/DK, Rev. B, dated March 17, 1982. The LOCA/HELB Environmental Qualification Test was run on March 24 through March 26, 1982. Due to the erratic behavior observed of five conductors in three EPA's during this test, Duke Power Company elected to extend the test program and rerun the LOCA/HELB test profile commencing at the 250° F plateau and continuing for a test duration of 168 hours. Duke Power Company's specification No. MCS-1393 01-00-0003 was revised to Revision 5 to include the extended testing, and Wyle Laboratories developed their approved test plan No. 543/6124-2/DK to Revision C, April 26, 1982. The LOCA/HELB Environmental Qualification Extended Accident Test was run on May 11 through May 17, 1982.

All D. G. O'Brien EPA's undergoing the above tests are required to be safety-related with respect to maintaining the integrity of the containment pressure boundary, regardless of the required electrical functional capability of the connectors.

Duke Power Company's penetration layout Drawing No. MC 1921-03 Rev. 18, May 13, 1982, identifies those electrical penetration assemblies (EPA's) which are specified to be electrically functional during and following a postulated accident, for McGuire Nuclear Station Units 1 and 2, to meet the licensing commitments of the FSAR. Table 1 of this report identifies this disposition.

Duke Power Company's technical specification MCS 1361.00-3 Rev. 10, March 8, 1978, specifies the requirements for testing of instrument and control penetrations as procured from D. G. O'Brien for McGuire Nuclear Station Units 1 and 2. (Ref para. 5.2.3 for EPA Module K, requiring full LOCA testing, and para. 5.2.4 for EPA Module L, requiring normal environmental testing only.)

Duke Power Company's technical specification MCS 1361.00-2, Rev. 11, March 8, 1978, specifies the requirements for testing of power penetrations, as procured from D. G. O'Brien for McGuire Nuclear Station Units 1 and 2 (Ref - EPA Modules C, D, E, & F requires full LOCA/HELB testing).

All EPA modules have had the seals torqued to specified load after thermal aging and irradiation test, but prior to LOCA/HELB testing.

C. Objectives

The objectives of the NRC RIV inspections conducted during these periods, were to observe and review the results of both postanalyses for the LOCA/HELB and LOCA/HELB Extended Tests, and to witness, verify, and review documented test records of the LOCA/HELB Extended Test, to assure that the above EPA modules have met the Duke Power Company specification requirements as follows:

1. To verify test results were well within the prescribed margins of acceptance.
2. To observe and identify test results outside of the margins necessary for licensee notification.
3. To verify that test results meet the Commission's requirements of NUREG-0588, Rev. 1, Category II (IEEE-323-1971).
4. To verify that the tests and inspection activities performed were in accordance with detailed test procedures.
5. To review the test procedures for conformity to the environmental qualification specification.
6. To verify all necessary information and data were collected to allow evaluation of test results in relation to the licensee notification/acceptance criteria.
7. To witness installation and checkout of test specimens in the environmental test chamber.
8. To determine that Notices of Anomalies (NOA), where required, are prepared in a timely manner.

D. LOCA/HELB Environmental Qualification Test - Postanalysis

The purpose of the postanalysis inspection, at the completion of the LOCA/HELB Environmental Qualification Test, was to disassemble, to the extent necessary, the EPA module assemblies and associated cables, to evaluate and observe evidence of water intrusion, grommet extrusion, material distortion, deformation or separation, excessive thermal expansion of insulating materials, breaches in the conductor insulating jackets, and other evidence of degradation due to steam condensate intrusion, as a result of the LOCA/HELB Environmental Qualification Test of March 24-31, 1982.

1. Evaluation of D. G. O'Brien EPA Modules C, D, E, F, and L.

Due to the change in program by Duke Power Co., to rerun and extend the LOCA/HELB testing using the above EPA modules, the EPA modules were not disassembled at this time. Disassembly and/or dissection were performed during the LOCA/HELB Extended Accident Test - Post Analysis (refer to Section F of this report). The above EPA modules were not removed from the simulated containment structure assembly (integral part of the LOCA test chamber). However, this assembly, as a whole unit, was removed from the LOCA test chamber and apparatus and visually inspected. No apparent water intrusion was observed during this visual inspection.

2. Evaluation of D. G. O'Brien EPA Module K

EPA Module K (M10), specified for electrical service during and following a postulated accident, was disassembled to the extent necessary and dissected (cut in half), then examined for evidence of distortion, extrusion, or other evidence of excessive thermal expansion. There was no evidence of grommet extrusion nor conductor insulation damage. The grommet thickness measured 230 mils as compared to a 250-mil thickness of a new grommet. No distortion of the grommet was observed (e.g. . . . uniformly filled the brass plug sleeve cavity). Moisture intrusion was not evident.

The EPA Module K (M10) plug on the annulus side was then reinserted into the simulated containment structure on the chamber side. A new plug sleeve, cable grommet, plug sleeve insulator, leads and contact sockets were then installed on the annulus side, prior to conducting the LOCA/HELB Extended Accident Test of May 11-18, 1982 (Refer to Sections E and F).

3. Evaluation of Associated Cables of EPA Modules

The associated cable conductors to each of the six EPA modules (listed in Table 1) were tested to ascertain whether the borated steam condensate had breached the cable insulation and jacket. Indications as to the direction and location of water intrusion of the cable conductors were also to be ascertained by test. Each associated cable conductor (six feet long) was pressurized to 5 psig at one end and connected (sealed with epoxy) to a distilled water test vessel. Water samples of leaks were obtained for analysis to search for the presence of boron and sodium, to ascertain quantity

comparisons at the two ends of the cables. This analysis would substantiate the quantity of borated steam condensate and respective traceable paths that would have occurred during the LOCA/HELB Environmental Qualification Test of March 24-31, 1982. Water samples would be sent to Micron Inc., Delaware (utilizing electron microscopy techniques for boron/sodium analysis) and University of Alabama (utilizing atomic absorption techniques for boron chemical analysis) at a later date.

During the above testing, two breaks in the cable conductor insulation and jacketing to EPA Module C (M02) were observed. All cable conductors exhibited leakage through the conductor ends.

The associated cable conductors to each of the six EPA modules were then tested for current leakage to ground by making I/R measurements. The test was accomplished by placing each conductor in water with bare ends out to serve as an electrode and measure the insulation resistance between the conductor and water. All hi-pot measurements ranged from 125-170 microamps at 1000 VAC.

E. LOCA/HELB Environmental Qualification Extended Accident Test - Documentation Review

The NRC-RIV inspector reviewed the documented test records on May 11-13, 1982, for the above test, to assure that the EPA modules have met the Duke Power Company specification requirements.

1. Findings

- a. D. G. O'Brien EPA Module E (M13); Mating Connectors C32P1015G01 and C32P1015G02; 12C# 2AWG EP Hypalon Insulation with Interlocked Armor (Samuel Moore)

This EPA is not specified for electrical service during and following a postulated accident. On May 10, 1982, 7 hours into the saturated soak plateau of 250° F, the protective 0.5 amp fuse (indicating a deficiency) was blown to the above EPA Module E. Indications identified the deficiency in channels No. 9 & 10. I/R measurements indicated 15.7×10^4 ohms, well below the 100 megohms margin set by the licensee necessary for his notification during test. On May 11, 1982, 28 hours into the test at the 250° F plateau, channels No. 9 & 10 indicated re-establishment of its circuit integrity by maintaining the required voltage through the penetrator at 120 VAC in lieu of the Duke specification requirement of 600 VAC. At 52 hours into the test, now at the 228° F plateau, channels No. 9 & 10 were clearly reestablished by maintaining the Duke specification requirement of 600 VAC.

b. D. G. O'Brien EPA Modules C, F, and K; Mating Connectors and Cable Assemblies as listed in Table 1

These EPA's are specified for electrical service during and following a postulated accident. No deficiencies were identified, on the above EPA modules, during the LOCA/HELB Environmental Qualification Extended Accident Test. All I/R measurements were well within the prescribed margins set by the licensee necessary for his notification during test.

c. D. G. O'Brien EPA Modules D and L; Mating Connectors and Cable Assemblies as listed in Table 1

These EPA's are not specified for electrical service during and following a postulated accident. No deficiencies were identified, on the above EPA modules, during the LOCA/HELB Environmental Qualification Extended Accident Test. All I/R measurements were well within the prescribed margins set by the licensee necessary for his notification during test.

F. LOCA/HELB Extended Accident Test - Post Analysis

The purpose of the post analysis inspection, at the completion of the LOCA/HELB Extended Accident Test, was to disassemble completely or dissect the EPA module assemblies and associated cables, to evaluate and observe evidence of water intrusion, grommet extrusion, material distortion, deformation or separation, thermal expansion of insulation materials, breaches in the conductor insulation or jacket, and other evidence of degradation.

Two methods of detection were planned for posttest analysis to demonstrate the effectiveness of seals, grommets, etc., in preventing borated steam condensate from intruding into the EPA modules during the LOCA/HELB Extended Testing. One method of detection will employ the x-ray spectroscopy of micro probe analysis of the EPA module at the conclusion of the posttest analysis at Wyle. The other method utilized a fluorescent dye which was put into the boron solution during the test which would fluoresce during the post analysis by means of an ultraviolet light (black lamp). The later method above did not present meaningful results during the postanalysis inspection, as the EPA module materials equally fluoresced, not having been exposed to the boron solution. The first method above will be done by Duke Power Company direction at a later date.

One of the purposes of the postanalysis inspection focused on observation and inspection of EPA modules C and E. Water was observed to be coming out of the cable fitting to the test chamber, as observed by Duke Power Company during the LOCA/HELB Environmental Qualification Test on March 24-31, 1982. Water was also observed coming out of splices to the conductor for pins No. 3 of EPA module C, and No. 6 of EPA module E.

1. Evaluation of D. G. O'Brien EPA Modules C, E, and L

The post analysis on the above EPA modules was performed by disassembly for evidence of steam condensate inside the seal assembly, and at the plug sleeve insulator and pin interface. The above EPA modules were those which exhibited erratic behavior during the LOCA/HELB testing on March 24-31, 1982. The visual examination also consisted of observing the surfaces of the components for evidence of tracks/channels of electric current paths. Grommet extrusion, material distortion, deformation, separation, and thermal expansion of materials, was also to be observed. All of the EPA modules above did not exhibit any of the above deficiencies, and the distortion, deformation, expansion, and separation was minimal. One exception to the above was observed on EPA module E, in which water intrusion on the interface (pin to socket) of pins 9 and 12 was observed. Evidence of a pronounced current path between pins was visually observed. Also, evidence of the cable clamp pinching against the conductor to pin 12, observed the conductor insulation broken. The above EPA modules were then packaged for Duke Power Company for future x-ray spectroscopy or micro probe analysis for traces of boron. The two laboratories designated by Duke Power were Micron Inc., Delaware, and University of Alabama.

2. Evaluation of D. G. O'Brien EPA Modules D, F, and K

The post analysis on the above EPA modules was performed by dissection (cut in half). The above EPA modules were those which successfully passed the LOCA/HELB Environmental Test on March 16-24, 1982. The dissected EPA modules were examined for evidence of distortion, extrusion, or other evidence of excessive thermal expansion. There was no evidence of grommet extrusion or conductor insulation damage. Moisture intrusion was not evident. It was observed by the NRC-RIV inspector, particularly in EPA module D (M03-1), that grommet contraction (although minimal) could be questioned at the silicone interfacial seal. This was evidenced by the slight bow of the grommet section as it sealed into the plug sleeve cavity. The above EPA modules were then packaged to be returned to Duke Power Company for further analysis.

3. Evaluation of Associated Cables of EPA Modules

The associated cable conductors to each of the six EPA modules were then tested for current leakage to ground by taking I/R measurements. The test was accomplished by placing each conductor in water with bare ends out to serve as an electrode and measure the insulation resistance between the conductor and water. All hi-pot measurements ranged from 125-170 microamps at 1000 VAC.

G. Summary

Within the scope of these inspections, as conducted during these tests covered in this report, the NRC-RIV inspector determined that:

1. EPA Modules C (M02), F (M12), and K (M10), met the prescribed margins set by the licensee necessary for his notification during test, and met the Duke Power Co. acceptance criteria outlined in their specification. The NRC-RIV inspector found no instances where the licensee failed to qualify this class IE equipment for McGuire Nuclear Station Units 1 and 2 to Category II requirements of NUREG-0588, Revision 1 (IEEE Std 323-1971).
2. EPA Modules D (M03-1) and L (M09), not specified for electrical service during and following a postulated accident, met the prescribed margins set by the licensee necessary for his notification during test, and met the Duke Power Company acceptance criteria outlined in their specification.
3. EPA Module E (M13), not specified for electrical service during and following a postulated accident, did not meet the prescribed margins set by the licensee necessary for his notification during test. The NRC-RIV inspector could not determine that EPA Module E (M13) met the Duke Power Company acceptance criteria.
4. It should be noted, that even though six EPA module configurations were tested, and only three EPA modules were to be used for electrical service during and following a postulated accident, all six EPA modules had the same basic generic design configuration.
5. Again it should be noted that all six EPA modules undergoing tests were required to be safety-related with respect to maintaining the integrity of the containment pressure boundary. The pressure boundary integrity was not included in this environmental testing, but was proven at an earlier date on prototype equipment.

6. NOA's were properly documented and corrective actions approved.
7. All test inspection activities were performed in accordance with Wyle Laboratories' test procedures.
8. Test procedures were reviewed and verified to conform to the Duke Power Company specification.
9. All information and data were collected to allow evaluation of test results.
10. The installation and checkout of test specimens in the environmental test chamber was verified to be correct in accordance with the test specifications.

Table 1
LIST OF SPECIMENS

Module	Plug Kit	Mark No.	Cable Description
* C (M02)	C32P1002G07	3X2G2	3/C #2 AWG, EP/Hypalon Insulation interlocked armor, Anaconda
	C32P1002G08	3X2G2	
D (M03-1)	C32P1003G01	SP140X	4/C #8 AWG, 2/C #4 AWG EP/Hypalon insulation, hypalon jacket.
	C32P1003G02	SP140X	SS braid Okonite
E (M13)	C32P1015G01	12X12G1	12/C #12 AWG, EP/Hypalon insulation, interlocked armor. Samuel Moore
	C32P1015G02	12X12G1	
* F (M12)	C32P1004G07	3X10G2	3/C #10 AWG, insulation interlocked armor Anaconda
	C32P1004G08	3X10G2	
* K (M10)	C32P1009G01	8X16G6	8/C #16 AWG, XLPE insulation interlocked armor, Brand Rex
	C32P1009G06	8X16G6	
L (M09)	C32P1010G01	12X12G1	12/C #12 AWG, EP insulation interlocked armor, Okonite
	C32P1010G02	12X12G1	

*EPA specified to be Safety-Related (electrically functional during and following a postulated accident)

DESIGNATED ORIGINAL
Certified By *Rheanne Jouts*