UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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MEMORANDUM FOR: Carlyle Michelson, Director
Office for Analysis and Evaluation
of Operational Data

THRU: Stuart Rubin
Office for Analysis and Evaluation
of Operational Data

FROM: Medhat El-Zeftawy
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SUBJECT: SITE VISIT/MEETING NOTES - BRUNSWICK STEAM ELECTRIC PLANT - MARCH 24, 1982

1.0 SUMMARY

1.1 Objectives

At the request of the Office for Analysis and Evaluation of Operational Data, S. Rubin, M. El-Zeftawy, and T. Wolf met with personnel from Carolina Power and Light (CP&L) at their Brunswick Steam Electric Plant (BSEP) located in Southport, North Carolina on March 24, 1982. The major objectives of this site meeting were:

a. Gather firsthand experience information on moisture intrusion in purportedly environmentally qualified electrical equipment;

b. Discuss operational experience concerning non-marine growth fouling of small diameter pipes with particular attention focused on those lines in systems associated with the raw water supply of the ultimate heater sink; and

c. Provide M. El-Zeftawy and T. Wolf their first opportunity to examine in person an operational boiling water reactor facility including structural and equipment layouts and equipment and personnel operating conditions.

1.2 Findings

The principal findings of this site visit were:

a. Moisture induced failures of supposedly qualified electrical equipment at BSEP have been caused by three main pathways:

(1) Moisture entering the equipment through unsealed conduit, i.e., conduit serves as a conducting pipe line;

(2) Moisture entering the equipment at sealed but not water-tight conduit fittings; and

(3) Moisture entering the equipment passed poorly re-sealed equipment cover plates or doors following maintenance or testing activities.

b. BSEP personnel have undertaken several corrective and preventive measures to help eliminate the moisture intrusion problems including:

(1) Additional personnel training;

(2) Revised maintenance practices;

(3) Additional equipment sealing particularly internal and external to equipment penetrations; and

(4) Contracted with their Architect/Engineer (A/E) to study the problem further and recommend additional or alternative preventive measures.

c. BSEP personnel believe IE Bulletin 79-01B covered only initial equipment qualification and installation. They felt it did not address the need for, importance of, or adequacy of equipment maintenance surveillance controls.

d. Non-marine growth blockage of small diameter lines at BSEP has never been a problem. As a precaution against such an occurrence, however, BSEP has taken several steps to minimize the potential for sediment buildup. Included are:

(1) To the extent possible, all small lines tap off of the top of the process pipe;

(2) Instrumentation is located at the top of a vertical run of pipe with drain valves and lines located at the bottom of these vertical runs;

(3) For pump seal protection, cyclone separators are provided in the seal injection lines of the raw service water pumps and the circulating water pumps.

1.3 Actions

Engineering evaluations of several recent BSEP submitted licensee event reports (LERs) which involved equipment environmental qualification and small line blockage are being prepared. It is anticipated that these evaluations will contain several points which will be suitable for transmittal to both NRR and IE for their information and utilization in ongoing equipment qualification and small line blockage studies.

2.0 DETAILED DESCRIPTION

2.1 Background

Over the years that CP&L has been operating commercial nuclear power stations, they have reported to the NRC numerous occurrences of safety-related equipment failures resulting from moisture intrusion. Primarily involved are electrical components located in high humidity/high temperature areas of the reactor building outside primary containment. During this period, intensive independent NRC staff reviews covering the importance of equipment qualification have been occurring. The results of these studies have included the issuance of IE Bulletin 79-01B concerning the environmental qualification of electrical equipment and the formalization of a position covering the continued operation of nuclear units while further qualification review progressed. AEOD is concerned as to whether or not these staff reviews are adequately addressing, on both a plant specific and a generic basis, the lessons which may be learned from the Brunswick experiences.

Another point of concern within the NRC, including AEOD, is the generic implications of flow blockage of prime heat removal systems due to either marine growth or water source transmitted fouling. Extensive studies have been completed and are continuing on marine growth fouling, especially in relation to oyster and Asiatic clam infestations of essential service water piping systems. A search of the available data base, however, indicates that substantial numbers of LERs have been submitted which cover equipment problems associated with service water (SW) systems caused by sedimentation rather than marine growth. This is especially true for small bore piping. A recent LER from BSEP attributed a total loss of the RHR service water system to such fouling of instrument lines. AEOD is concerned that such fouling is adequately addressed by both the NRC and the plant licensees since a common mode failure mechanism, similar to that associated with contaminated air systems, may exist and not be treated appropriately.

As a consequence of these concerns and because of the experiences which BSEP has had with both environmentally qualified equipment and service water line fouling, it was felt that a site visit and meeting with

cognizant BSEP personnel was warranted and desirable. Additionally, a major side benefit of such a visit would be the essential training and experience given to M. El-Zeftawy and T. Wolf. Neither had previously visited and studied on site an operating boiling water reactor of the BSEP type.

2.2 Meeting Arrangements and Participants

After contacting both the NRC BSEP project manager and the region, direct site visit arrangements were made through BSEP personnel. On March 24, 1982, S. Rubin, M. El-Zeftawy, and T. Wolf (all from AEOD Reactor Operations Analysis Branch, Reactor Systems 4 - BWR Technology) met with personnel from CP&L at the BSEP site in Southport, North Carolina. The participants directly involved with this visit are listed in Figure 1.

Prior to the meeting date, AEOD drafted and sent to CP&L a letter outlining specific informational needs. Some forty six items were noted but due to travel schedule deadlines, a few of these items were not addressed during the visit. A follow-up telecon was held on April 9, 1982 to resolve the unaddressed topics.

2.3 Site Tour

As requested in the AEOD letter, a site tour was included in the visit. The areas covered during this tour included the Unit 1 reactor building (excluding primary containment since the unit was operating), the common control building (including the shared main control room), one diesel bay in the common diesel generator building, the common intake structure, and miscellaneous yard structures. Prime items viewed and studied included: (a) the mechanical, electrical, and instrumentation components in the high pressure coolant injection (HPCI), low pressure coolant injection (LPCI), and combined residual heat removal (RHR) and reactor core isolation cooling (RCIC) pump rooms; (b) the RHRSW pumps, piping and instrumentation; (c) the diesel generator SW piping and instrumentation; and (d) the SW and circulating water pumps, piping and instrumentation. Also observed were the scram system piping arrangements and the cask handling equipment loading and lifting components, layout, and travel paths.

2.4 Meeting Details

After the plant tour, an informal meeting was held to discuss the items listed in the AEOD information request letter. This meeting was broken into two basic areas: (a) moisture intrusion into purportedly environmentally qualified equipment with particular emphasis on instrumentation and (b) sediment collection in process piping systems, especially small bore piping associated with the raw service water systems.

a. Moisture Intrusion

Numerous moisture intrusion related equipment problems have occurred at BSEP. The equipment involved includes, but is not limited to, electrical wiring termination boxes and pressure switch instrumentation. The equipment affected is primarily located outside of primary containment in the reactor building basement (-17 foot elevation) HPCI, LPCI, and RHR/RCIC pump rooms. These pump rooms normally experience an operational environment of about 95°F and 90% relative humidity. Due to system leakage and sump overflow problems, these rooms may also experience some water accumulation on their floors. This water can have a temperature of up to 130°F.

Recently, LERs 81-108/03L and 81-139/03T were received which described moisture intrusion-related contact corrosion failures of pressure switches associated with the RHR and RCIC systems. These switches were located in the -17 foot elevation pump rooms and were purchased to withstand an environment of 290°F, 16.2 psia, 100% relative humidity and 1.0×10^7 rads. Thus, from an environmental qualification standpoint, these switches should have been able to perform correctly in the environment where they were located.

Investigation by BSEP personnel into the cause of these failures, along with similar failures noted in the past, has led BSEP personnel to conclude that several mechanisms for such equipment problems are most likely. These are (see figure 2):

(1) Moisture entering into unsealed conduit connections at cable trays. These cable trays are located throughout the reactor building. The moisture subsequently condenses within the conduit and uses the conduit as a piped pathway to connecting equipment such as termination boxes and instrumentation;

(2) Moisture in the local environment entering the equipment at moisture resistant but not moisture tight conduit connections; and

(3) Moisture intrusion at improperly sealed equipment enclosure covers.

In both mechanisms 2 and 3, moisture may condense and enter the connecting conduit where, as in mechanism 1, other equipment may be affected. Also, BSEP personnel believe that mechanism 3 is a result of inadequate maintenance practices and lack of attention to details during resealing of equipment after calibration rather than from design or manufacturing problems. This conclusion was based on post maintenance/calibration equipment walkdowns which revealed enclosure or cover plate retaining screws loose and/or missing.

In an attempt to resolve these problems, BSEP personnel have decided to undertake several corrective and preventive measures. Included are:

(1) Training - Affected personnel are required to take a four-week course which covers electronics and instrumentation and the associated installation techniques and problems. This course is taught by experienced CP&L personnel and includes hands-on training.

(2) Maintenance Practices - Plant maintenance practices were revised to ensure proper sealing of applicable plant instrumentation housing and/or gaskets by a dedicated plant group. Figure 3 contains pertinent excerpts from the BSEP Maintenance Procedure Manual which address these revised practices.

(3) Additional Sealing - All conduit-to-component junction points, both internally and externally, were sealed on the affected instrumentation. This was also done to all equipment on the seven instrument racks located on the reactor building outside containment -17 foot elevation which are subjected to the same environmental conditions as the failed equipment (Note: The instrumentation in the core spray rooms on -17 foot elevation was not included.) The sealing compound being used is Dow-Corning 732 RTV, a silicon-rubber compound. To date, no sealing problems, including wear-out or end-of-life aspects, have been experienced with this material. Figure 4 is a sample request and authorization form for this work.

(4) Additional Study - The Architect/Engineer is working on a possible generic permanent fix to prevent wetting the racks and associated equipment.

(5) Manufacturing Changes - Since the equipment failures do not appear to be attributable to manufacturing defects or problems, the manufacturer (Barksdale) has not been contacted.

During the investigation, cognizant BSEP personnel also considered whether the problems identified would have been addressed by IE Bulletin 79-01B "Environmental Qualification of Class IE Equipment." Their conclusions were that the IE bulletin only requested licensees to examine the pertinent equipment once and verify that it had been installed as required in the installation procedure. They felt that the IE bulletin did not address the need for, importance of, or adequacy of subsequent equipment maintenance controls to assure that the equipment meets all original installation requirements. They recognized on their own that proper and sufficient maintenance controls are essential to assure continued equipment qualification, operability, and performance.

With respect to the consequences of the failures noted in LERs 81-108/03L and 81-139/03T, the BSEP personnel felt that neither case jeopardized the plant safety. Involved were pressure switches which had redundant back-ups. Affected were one train of each of the (a) RHR pump discharge pressure permissive interlocks to the automatic depressurization system (ADS) logic and (b) RCIC system discharge steam line rupture diaphragm pressure sensors. Due to the redundancy in circuitry design, neither sensor associated function (i.e., permits ADS initiation and isolate RCIC, respectively) was lost.

b. Sedimentation Fouling of Small Lines

Serious common cause systems interactions failures may result as a consequence of equipment fouling due to sedimentation of materials carried in essential service systems such as the instrument air system and the

service water system. The nature of the sediment, however, is of prime importance insofar as the potential for fouling is concerned. The sediment which is contained in the service water at BSEP appears to be fine, sand-like material. This fine structure has the characteristics of remaining loose and disassociated and, even upon settlement, minimal disturbances such as small flow rates will stir the sediment up and mix it with the fluid.

Displaying a sample of the normal service water, BSEP personnel noted to date that while considerable sediment appears to be contained in the service water, BSEP has not experienced any sediment collection which has caused equipment problems. The prime equipment fouling source at BSEP is oyster infestation. (This problem of marine growth fouling has been addressed in a previous AEOD report.)

Even though no operational problems have been experienced to date, BSEP has incorporated several design and operational items into the systems which could most be affected by sediment buildup. Some of these are:

(1) To the extent possible, all small lines tap off the top of the main process line. This arrangement helps minimize heavy particle carry-over into small diameter lines.

(2) Where possible, all instrumentation connected to the small lines is located at the top of a vertical run of pipe. Low point drain lines are included at the bottom of this vertical run primarily for use in calibration since the sensor lines are occasionally purged prior to calibration. This purging tends to prevent major buildups of sediment in such lines.

(3) Cyclone separators are provided on a few pumps such as the service water pumps. These separators are supplied expressly to filter out small debris which could be injected into the seals of the pumps and, as a consequence, could cause seal damage and equipment failure. In cases where heavy sedimentation may be expected, such as in the circulating water pumps, redundant separators are supplied. These separators are piped up in parallel and help assure that if blockage of one separator does occur, another separator is available. To date, the cyclone separators appear to be performing satisfactorily. Blockage of one separator has occurred. This blockage was at the drain discharge nozzle and was due to oyster shell fragments which were easily removed by inserting a screwdriver blade into the nozzle and rotating the blade.

(4) To help protect the small lines associated with the RHRSW pumps from the effects of the salty service water, the pumps and the associated small piping are purged of the normal salty service after pump testing with demineralized water. They are subsequently laid up in their standby mode with demineralized water.

The statement that no equipment or system failures had been experienced at BSEP conflicted directly with LER 82-005/01T which was submitted in January 1982. In this report, a total loss of RHR shutdown cooling and suppression pool cooling was experienced when the RHRSW pumps would not respond to a start signal. This refusal to start was attributed to the loss of essential suction header pressure switches which produce pump start lockout signals. The pressure switch failures were believed to have been caused by sensor-line sedimentation plugging. During the meeting, however, BSEP personnel noted that subsequent to the issuance of the information upon which the LER was based, further study revealed that this was not the case. When the sensing lines were flushed, sediment was released but its consistency and quantity were not sufficient to cause problems. The actual causes were an open power supply circuit breaker to one pressure switch and a lack of operating fluid in the diaphragm housing of the other pressure switch. A revised LER is being prepared to reflect these findings.

When queried on whether the sediment quality, and thereby the resultant problem potential, was seasonal or weather-condition dependent, BSEP personnel responded that their experience has been that while the quantity of sediment reaching the service water pumps is dependent on seasonal and weather conditions, the quality does not seem to vary. To date, this variance has not caused any noticeable problems. As an example they noted that no problems had occurred after heavy sediment producing seasonal rains caused by the passing of a tropical storm.

In summary, BSEP personnel believe that the programs and actions which they have implemented, along with the sediment quality mitigate the concern of small line fouling due to sedimentation.

2.5 Further Actions

Combining the information gathered during the site visit with other research material will lead to engineering evaluations of the recently reported events at BSEP involving equipment environmental qualification problems and RHR loss due to RHRSW difficulties. Included in the RHR report will be the results of a follow-up telecon of April 9, 1982.

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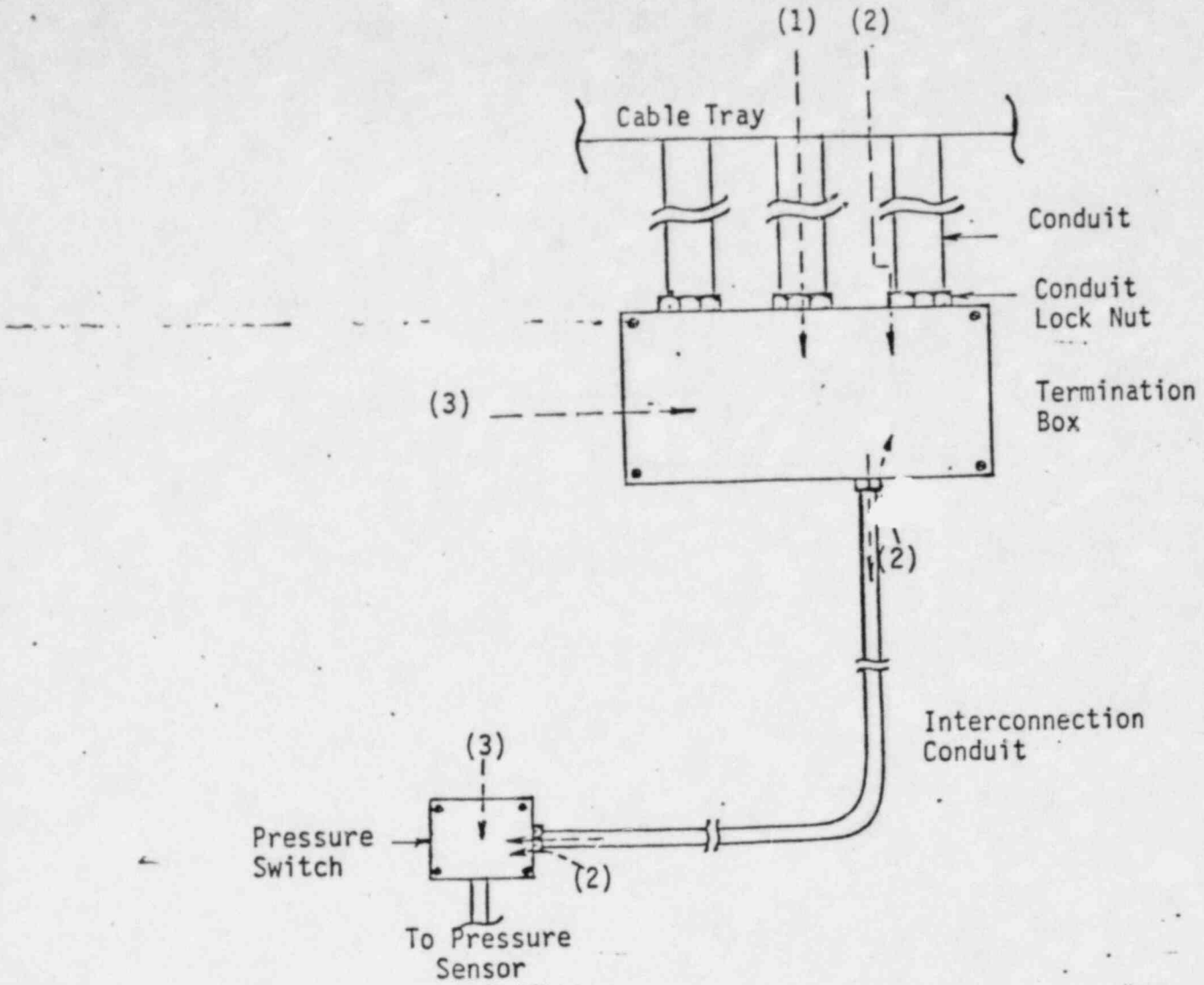
* Part time

Figure 1 Brunswick Steam Electric Plant
Site Visit/Meeting Participants



Pathway Notation

(1) Cable Tray/Conduit/Equipment
(2) Environment/Connectors/Equipment
(3) Environment/Enclosure Covers/Equ

Figure 2: Brunswick Steam Electric Plant
Representative Moisture Intrusion Pathways

X. Environmental Qualification

In general, Maintenance actions should be performed to such an acceptance criteria that the capability of the equipment will not be degraded from the plant construction specifications. The proper materials to ensure this criteria are procured and controlled under Stores and Quality Assurance procedures. The proper maintenance practices to ensure attainment of this criteria are guided by maintenance procedures, maintenance instructions, and personnel training. The general criteria is given in the environmental qualification rules given in this section and further specific criteria may be provided in other Maintenance documents such as Maintenance Instructions and Work Authorization.

A. All Maintenance actions must maintain the specification for environmental qualification on Class 1E equipment as committed to in Appendix M to the FSAR. As an example, the conditions that must be met inside the primary containment are:

1. Pressure - each component must be maintained such that it will function properly under normal and accident ambient pressures ranging from -2 to 56 psig.

2. Temperature - each component must be maintained such that it will function properly under normal and accident temperatures as high as 340°F.

3. Humidity - each component must be maintained such that it will function properly under normal and accident humidity as high as 100 percent.

4. Integrated Radiation Dose Levels - frequently repair materials must be certified for high radiation environment.

5. Spray - each component must be maintained such that it will function properly under normal and accident conditions of 200°F spray.

Detailed conditions that must be met in other plant buildings/areas are provided in Figure M.7.9-1 of the FSAR.

B. To preserve the environmental qualifications discussed above, some general maintenance practices that must be adhered to are:

1. The proper "Q" list consumables listed in plant Operating Manual, Vol. XI, Bk. 2, Supplement 1, the "Q" list must be used. This list is duplicated in Paragraph C.

2. All gaskets and seating surfaces including protective covers must be inspected prior to reassembly. Any deficiency must be corrected or documented.

3. All fasteners must be installed. The environmental quality of each component is violated if any fastener is missing.

Figure 3: Brunswick Steam Electric Plant
Maintenance Procedure Manual
Environmental Qualification Excerpt

25-52-677

CP&L

WORK REQUEST & AUTHORIZATION FORM

Instrument Racks

IWO

H21-P037

H22-B3T60529-03P

1-4-82

8240

81

T. Gore

1110

Water & Moisture are getting into Instruments ELEV-17

1-4-82

T Gore	4					20	IC	220	2	

Open Cover at instrument and seal Conduit with Dow Corning 732 Silicon Rubber also open termination Box on Rack and seal all conduits. If a splice box is inline, remove cover and seal conduits. Seal around all bolt-nuts on boxes and instruments. Replace all covers and ensure proper tightness of covers, screws and bolts.

2-8-82

sealed conduits and Flex inside and outside of Boxes
Did not seal inside of instrument. Left in satisfactory condition

RWP 21-2C2

Donald Norris				Darrial Place							
ID — YCC 568				ID — YCC 594				ID — YCC 1868			
DATE	START	STOP	TOTAL	DATE	START	STOP	TOTAL	DATE	START	STOP	TOTAL
2-11-82	0730	0900	1.5	2-11-82	0730	0900	1.5	2-11	0730	0900	1½

Figure 4: Brunswick Steam Electric Plant
Instrumentation Water and Moisture Intrusion
Sample Work Request and Authorization Form