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Director
Office of Nuclear Reactor Regulation
U S Nuclear Regulatory Commission
Washington, DC 20555

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Docket Nos. 50-282 License Nos. DPR-42
50-306 DPR-60

Safety Evaluation for Environmental Qualification of
Safety-Related Electrical Equipment; Ten-Day Response

The following is submitted in response to a letter dated April 25, 1983 from Robert A Clark (NRC) to D M Musolf (NSP) transmitting the Safety Evaluation for the Environmental Qualification of Safety-Related Electrical Equipment for the Prairie Island Nuclear Generating Plant.

The Franklin Research Center (FRC) in their Technical Evaluation Report (TER) placed Rosemount 1153 Series A transmitters in qualification Category II.B on the basis of transmitter testing to IEEE Standard 323-1974 in which O-ring failure occurred during accelerated thermal aging testing. Our consultant, EDS Nuclear, has evaluated 1153 Series A transmitters for Prairie Island's specific environment and has determined that environmental qualification for postulated accident conditions following the criteria set forth in the DOR Guidelines has been established. This evaluation, which is summarized in Enclosure One to this letter, is based on type testing of 1153 Series A transmitters by Rosemount and Westinghouse, discussions with the equipment vendor, and evaluation of FRC's basis for placing this equipment in Category II.B.

NSP will commit to re-evaulating the previously stated qualified lives utilizing recently completed testing on the Rosemount 1153 Series B and 1153 Series D transmitters. Until this evaluation is complete, the transmitters will experience an insignificant amount of thermal degradation because of their recent installation date (operational January 1982, and purchased December 1979).

On the basis of the discussion summarized above and presented in detail in Enclosure One, we respectively request that Rosemount 1153 Series A transmitters installed at Prairie Island be reclassified as Category II.C equipment items. Following the completion of the thermal aging evaluation in which our previously stated replacement interval is re-evaluated, these equipment items will be placed in qualification Category I.A.

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We have reviewed the TER and identified no material requiring proprietary protection.

Please contact us if you have any questions related to our response.

David Musolf
Manager - Nuclear Support Services

DMM/bd

cc: Regional Administrator-III, NRC
NRR Project Manager, NRC
Resident Inspector, NRC
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Attachment

NORTHERN STATES POWER COMPANY
Prairie Island Nuclear Generating Plant

Enclosure One

Technical Evaluation of the Environmental Qualification
of Rosemount 1153 Series A Transmitters
Installed at Prairie Island Units 1 and 2

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1.0 INTRODUCTION

Rosemount 1153 Series A transmitters installed in safety-related applications at Prairie Island are used as Main Steam steam flow transmitters in Unit 2 and Reactor Coolant System wide range pressure transmitters in Unit 1. The environmental and functional requirements for these transmitters are described below:

Main Steam Steam Flow Transmitters: Rosemount 1153HA6

Plant ID Numbers:	23017, 23018, 23019, 23020
FRC Equipment Item Number:	40
Required Operating Time:	30 minutes
Required Radiation Dose:	1×10^6 rads gamma (TID) @ 2.67×10^6 rads/hr* 2×10^8 rads beta**
Required Temperature/Pressure:	See Figure 1
Required Chemical Solution:	Boric Acid (H_3BO_3) buffered with Sodium Hydroxide (N_aOH) such that the pH varies from 7.0-10.5.
Accident Functional Requirements:	Initial accident assessment and HELB outside containment.

* Based on containment centerline dose at time t=0. A dose rate decay curve is provided in Figure 2.

** Based on generic values provided in the DOR Guidelines.

RCS Wide Range Pressure Transmitters: Rosemount 1153GA9

Plant ID Numbers:	1-PT-709, 1-PT-710
FRC Item Number:	44 - See Note Below
Required Operating Time:	30 days
Required Radiation Dose:	2.2×10^6 rads gamma (TID) @ 1.2×10^5 rads/hr* 2×10^8 rads beta**
Required Temperature/Pressure:	See Figure 1
Required Chemical Solution:	Boric Acid (H_3BO_3) buffered with Sodium Hydroxide (N_aOH) such that the pH varies from 7.0-10.5.

Accident Functional Requirements:	Reactor Coolant System wide range pressure indication. Required for both a LOCA and HELB.

* Based on analysis at transmitter locations

** Based on generic values provided in the DOR Guidelines.

NOTE: FRC equipment item number 44 incorrectly states the Plant ID Number for RCS wide range pressure transmitters as 21102 and 21159. These two components have been deleted from the safety-related equipment list. A new system was installed to monitor RCS wide range pressure. The 1153 Series A transmitters installed are identified with plant ID numbers 1-PT-709 and 1-PT-710. FRC equipment item number 47, Plant ID numbers 1-PT-729 and 2-PT-729 (reactor vessel head vent leak detection pressure transmitters), has been deleted from the safety-related equipment list. These changes were noted in our SER response dated April 30, 1982 [1].

Environmental qualification testing has been performed by both the equipment vendor, Rosemount [2], and the NSSS vendor, Westinghouse [3]. Because failures were experienced in the Westinghouse test, Rosemount performed a post-test analysis of the tested transmitters [4] to ascertain why the failures occurred. The results of this testing and subsequent analyses are described in Sections 2.0 and 3.0 of this enclosure. A thermal aging analysis was performed by EDS Nuclear [5] in an effort to establish a qualified life for the component using the Arrhenius methodology. This analysis is summarized in Section 4.0 of this enclosure. All equipment qualification analyses and evaluations performed for the Prairie Island Nuclear Generating Plant were done in accordance with the DOR Guidelines. These guidelines specifically state, "The objective of the evaluations using these guidelines is to identify Class 1E equipment whose documentation does not provide reasonable assurance of environmental qualification." The DOR Guidelines go further, to state that "The intent of this document is not to provide guidelines for implementing either version of IEEE Std. 323 for operating reactors."

Each of the test reports and evaluations described herein was provided to the Franklin Research Center (FRC) for their review. The results of this review are documented in the Technical Evaluation Report (TER) [6]. As a result of their review, several questions were raised regarding the environmental qualification of Rosemount 1153 Series A transmitters ultimately leading to their classification as a Category II.B item - equipment not qualified. The specific questions raised by the FRC are addressed and discussed with respect to the installed application at Prairie Island in Section 5.0 of this enclosure.

On the basis of the technical evaluations performed and summarized herein, we believe that the environmental qualification of Rosemount 1153 Series A

transmitters to postulated accident conditions at Prairie Island has been established. As noted later in this enclosure, NSP is willing to commit to reevaluating the stated qualified life of the transmitters based on recently completed testing of similar transmitters (1153 Series B and 1153 Series D). Therefore, we request that all Rosemount 1153 Series A transmitters installed at Prairie Island be reclassified in Category II.C - equipment satisfies all requirements except qualified life or replacement schedule justified.

2.0 ROSEMOUNT QUALIFICATION TESTING OF 1153 SERIES A TRANSMITTERS

Rosemount performed environmental qualification testing on three 1153DA5 transmitters following the guidelines of IEEE 323-1971 and IEEE 344-1971. Rosemount Report 3788[2] presents the results of the qualification testing and documents the applicability of the qualification test to the entire line of Series A transmitters. The only difference in the Series A model line is the spring constant (thickness) of the sensing diaphragm and by the process pressure level. Therefore, the testing documented in this report is applicable to the 1153HA6 and 1153GA9 transmitters installed at Prairie Island.

The test program consisted of irradiation, seismic testing, and steam/chemical spray (LOCA) testing. All output signals were continously monitored throughout the three tests. The electronics cover was not loosened, no adjustment pots were changed, and O-ring seals were not changed throughout the qualification testing. Acceptance criteria established by Rosemount for this testing included structural integrity and accuracy to specified values. Specifically, accuracy shall be within $\pm 5\%$ of upper range limit during irradiation, within $\pm 5\%$ of span during seismic testing, and within $\pm 8\%$ of upper range during the LOCA testing.

The test specimens were irradiated to a Total Integrated Dose (TID) of 4.4×10^7 rads gamma at 5×10^5 rads/hr. The radiation qualification requirements for the installed transmitters were specified in Section 1.0 of this enclosure. Worst case output signals for the three transmitters during irradiation were: -0.6%, +3.7% and +1.5% of span, which is well within the specified $\pm 5\%$ of upper range limit. The test units were continously powered throughout the entire test with process pressure applied from 0-11 Mrads and from 19.2 - 44 Mrads.

Thus, the test TID completely envelops the required gamma TID for both the steam flow and RCS wide range pressure transmitters with adequate conservatism (46.7% for the 1153GA9 transmitters and 4,300% for the 1153HA6 transmitters). Although the tested dose rate of 5×10^5 rads/hr was less than the required maximum dose rate of 2.67×10^6 rads/hr, we feel that the conservatisms in the TID, coupled with acceptable transmitter performance throughout the radiation testing, give confidence to the ability of the transmitters to function when subject to the higher dose rate. Figure 2 shows that the dose rate decays to the tested dose rate after approximately 4-1/2 hours. Beta radiation qualification was addressed separately

and is documented in EDS Report 04-0910-21 [7]. Following the criteria presented in the DOR Guidelines, it was shown that the transmitter housing shields adequate beta radiation so that the dose to sensitive equipment internals is less than 10% of the qualified gamma dose.

Although seismic qualification was not evaluated as part of the IE Bulletin 79-01B effort, it should be noted that acceptable transmitter performance was observed during seismic testing when test specimens were subjected to a peak acceleration of 3.5 g's in frequency ranges of 0-40 Hz.

LOCA testing was also performed with the performance of the transmitters well within the stated acceptance criteria. Figure 3 presents the test profile with the postulated Prairie Island containment accident profile superimposed upon it. The maximum error noted was +6.95%, which is less than the upper range limit of ±8%. This error occurred during the 10-minute spike at 350°F. Post-test examination of the test units included removal of the electronics housing covers and examination for moisture and corrosion. No evidence of housing leakage was found.

Review of Figure 3 shows the conservatism of the test conditions compared to the postulated accident conditions at Prairie Island. The test completely envelops the required profile, with the following exceptions:

1. The peak accident temperature of 290°F is reached within 10 seconds, while the peak test temperature of 350°F was not reached until 3 minutes. Conservatively assuming a linear rise in temperature, this implies that 290°F was not achieved in the test until approximately 138 seconds. Considering that two transients were performed on the test specimens and that the peak temperature, when attained, was 60°F over the required value, the slower transient is judged to be insignificant.

2. The required operating time for the 1153GA9 RCS wide range pressure transmitters is 30 days. The test was slightly longer than 64 hours (ignoring the first temperature spike). The duration of the required operating time after 64 hours (656 hours) is at a temperature of 150°F. The DOR Guidelines specifically state that tests of shorter duration may be acceptable if analyses are performed to demonstrate that the materials involved will not experience significant accelerated thermal aging during the period not tested. Our analyses, using the Arrhenius Method, have shown that significant thermal aging will not occur during the 30-day post-accident operating time, and that the total thermal input to the test specimens exceeds that which would occur during 30-day post-accident operation. These analyses are documented in Reference 5.

   The 1153HA6 steam flow transmitters have a 30-minute required operating time which is completely enveloped by the Rosemount testing.

The conclusion reached by Rosemount is that the 1153 Series A transmitters are qualified for Class 1E Service by virtue of the testing performed in accordance with IEEE 323-1971 and IEEE 344-1971. These test conditions satisfy all requirements for environmental qualification in accordance with the DOR Guidelines for the Prairie Island Nuclear Generating Plant, with the exception of beta radiation qualification, thermal aging qualification, and the establishment of a maintenance/replacement interval. As discussed earlier, beta radiation was analytically established by showing that the transmitter's steel housing adequately shields the sensitive equipment internals from the effects of beta radiation. Thermal aging qualification and establishment of a maintenance/replacement interval are discussed in Section 4.0 of this enclosure.

The results of FRC's review of this qualification report concur with Rosemount's and our conclusions as documented in the TER. Specifically, the TER states "All units successfully passed test in accordance with acceptance criteria. Testing was under IEEE-323(71) standard. Qualification program satisfies all applicable criteria of the DOR Guidelines except that aging degradation and qualified life or replacement schedule has not been addressed."

3.0 WESTINGHOUSE QUALIFICATION TESTING OF ROSEMOUNT 1153 SERIES A TRANSMITTERS, AND ROSEMOUNT'S POST-TEST ANALYSIS.

Westinghouse PWR Systems Division performed qualification testing of the Rosemount 1153 Series A transmitters to test levels exceeding those described in Rosemount Report 3788 [2] as documented in Reference 3. The testing included irradiation, seismic simulation, and high temperature steam/chemical spray (LOCA) testing. Four test specimens designated AW-1 (1153GA9), AW-2 (1153GA9), AX-1 (1153DA5), and AX-2 (1153DA5) were used. A Conax electric conductor seal assembly (ECSA) was used to seal the conduit port on the transmitter, and RTV was applied to the inside and outside of the connection. The transmitters installed at Prairie Island also use Conax ECSAs. The test was performed in the following sequence: inspection, calibration check, time response check, irradiation, calibration check, time response check, seismic simulation, calibration check, LOCA simulation, final calibration check.

Prairie Island utilizes the 1153 Series A transmitters in two applications: RCS wide range pressure and Main Steam steam flow. The Westinghouse test states that test unit AW-2 (0-3000 psig) would be used in the RCS wide range application, and either AX-1 or AX-2 would be used in steam flow applications. The performance of the test samples during the Westinghouse testing is discussed below. Because failures were noted during the Westinghouse testing, Rosemount performed a post-test analysis [4]. The results of this analysis are also described below.

Test Sample AX-1

This unit was exposed to a TID of 5.0×10^7 rads gamma at 2.5×10^6 rads/hr. The test TID completely envelops the installed transmitters' maximum required TID of 1×10^6 rads gamma. The tested dose rate of 2.5×10^6 rads/hr is very close to the t=0 containment centerline dose rate of 2.67×10^6 rads/hr and envelops the 2.46×10^6 rads/hr containment edge dose rate. The worst case error of the test unit was 8.7% of upper range limit.

The test unit was subjected to both operating basis earthquakes (OBEs) and safe shutdown earthquakes (SSEs) utilizing biaxial random testing at peak accelerations of 3.5 g's and 7.0 g's, respectively, in the frequency range of 0-35 Hz. The worst case error during seismic testing was 3.3% of span.

LOCA testing was performed following the profile shown in Figure 4. Superimposed upon this test profile is the required Prairie Island containment accident profile. The conservatism of the Westinghouse test is clearly shown. The worst case error was 4.3% of upper range limit. The output signal went high after 8 days of post-accident monitoring, returned to normal periodically until after 12 days, when it remained high (25.8 mA) for the rest of the test.

Rosemount performed a post-test analysis of the AX-1 performance during the Westinghouse testing. They have concluded that the constant high output signal was caused by a defective output-stage operational amplifier. The failure was of a random type and was most likely caused by intrusion of contaminants into the die cavity via a defective or degraded seal. Intrusion of contaminants may have been aided by the significantly higher test parameters (temperature/pressure) than would be expected at Prairie Island.

As noted above, this sample simulates the installed steam flow transmitters with a required accuracy (as specified by Westinghouse) of $\pm 10\%$ during a steam-line break accident. The required operating time for the steam flow transmitters is 30 minutes, and the accident functional requirements are for high energy line breaks only. Both the Westinghouse test and the Rosemount post-test analysis conclude that the tested unit is acceptable for steam flow applications, based on the Westinghouse testing. Therefore, with the exception of aging requirements, the requirements of the DOR Guidelines have been satisfied. Thermal aging qualification is discussed in Section 4.0 of this enclosure.

Test Sample AX-2

This unit was also exposed to a TID of 5.0×10^7 rads gamma at 2.5×10^6 rads/hr. The discussion provided for AX-1 regarding enveloping of the Prairie Island radiation requirements is also applicable here. The worst case error was -5.6% of upper range limit. The maximum error during seismic testing was 6.5% of span at test levels identical to those for test sample AX-1.

During the LOCA test, the worst case error was as high as 9.9% of upper range limit. The test LOCA profile is shown in Figure 4. It was discovered that the Conax ECSA had leaked, allowing caustic spray solution to enter the terminal side of the electronics housing.

In Rosemount's post-test analysis, it was determined that the transmitter failure was caused by a short between the primary and feedback winding of the oscillator transformer. These failures were a result of one or more of the following workmanship defects: excessively long termination leads running across adjacent pins, termination leads twisted together, and solder balls along with solder flux residue in the lead termination area. The high output signal was determined to be occurring between the terminal block positive signal terminal and the electronics housing. The cause of this leakage was most likely due to spray solution being trapped behind the terminal block as a result of the Conax fitting leak during the test. This is judged to be a failure of the Conax seal and not a generic problem with the transmitters. Furthermore, the conservatism in the test temperature and pressure likely contributed to the breakdown of the Conax ECSA, leading to intrusion of caustic solution into the transmitter.

Similar to the AX-1 test sample, the AX-2 sample is representative of transmitters installed at Prairie Island in steam flow applications with a 30-minute operating time. Both Westinghouse and Rosemount conclude that the results of this testing document acceptable performance of the 1153 Series A transmitters for steam flow applications. Thus, with the exception of thermal aging, all required qualification parameters of the DOR Guidelines are satisfied. Thermal aging will be discussed in Section 4.0 of this enclosure.

<u>Test Sample AW-1</u>

This unit was also exposed to a TID of 5.0×10^7 rads gamma and experienced the largest error of the four transmitters tested, 13.5% of upper range limit. The maximum error occurring during seismic simulation was 3.8% of span. During the LOCA test, the maximum error -3.5% of upper range limit. This transmitter sample performed through the entire duration of the LOCA test and was within 1.2% of upper range limit accuracy after completion of the test. The LOCA test profile is provided in Figure 5.

Although this unit was not returned to Rosemount for post-test examination, Rosemount attributed the high error experienced during irradiation to the dose rate as opposed to the TID. Radiation errors are caused predominantly by a change in the input offset voltage of the integrated circuit operational amplifier. The large error experienced by the high dose rate is attributed to one of three op-amps. However, Rosemount has concluded that the erratic performance during irradiation is not typical of the entire 1153 Series A transmitter line, as evidenced by the performance of the other three test transmitters.

This test sample is not representative in application to either the steam flow or RCS wide range pressure transmitters installed at Prairie Island, although, for qualification purposes, it is representative of the entire 1153 Series A transmitter line.

Test Sample AW-2

This test sample was irradiated to a TID of 5.0×10^7 rads gamma, with the worst case error being 4.0% of upper range limit. The LOCA profile is shown in Figure 5. The transmitter output was monitored at the set point of 2100 psig, with high erratic output occurring until the final day of testing (15 days), at which point the output went to a constant low of 2.19 mA.

Rosemount's post-test analysis isolated the cause of the constant low output to be a short between the feedback windings of the oscillator transformer. Similar to test sample AX-2, this failure was determined to be a workmanship defect and is not representative of all 1153 Series A transmitters. Erratic sensor behavior was attributed to an intermittent short between the sensor's center diaphragm and the deposited film capacitor plate on the low pressure side of the DP cell. Rosemount concluded that this failure was not caused by the environmental testing and is a random-type failure.

Inside the covers of the electronics housings of all four test samples, a gray-black residue was present. An Auger Electron Spectrographic analysis was performed at the University of Minnesota on the residue from the terminal side cover of test sample AW-2. This technique is capable of detecting all elements except hydrogen and helium.

The results of the analysis conclude that the residue definitely contained silicon, sulfur, and oxygen. Carbon may have been present, but because the residue was mixed with graphite, the carbon could not be detected. Only trace quantities of boron were present. The conclusions that can be reached from this analysis are:

1. The residue was not a corrosion product of the stainless steel covers. If it were, elements such as iron, nickel, and chromium would have been detected.

2. Since only traces of boron, and no sodium, were detected, this indicates that the residue was not produced from the chemicals in the steam chemical test, indicating that the steam did not leak into the unit.

3. The source of the silicon was probably the General Electric Red RTV used to seal the Conax fitting. The source of the sulfur could be residual machining lubricants.

Although Westinghouse states that the results of testing show the 1153 Series A to be unacceptable for RCS wide range pressure applications, Rosemount disagrees, based on the failure analyses described above.

To summarize the Westinghouse testing and the Rosemount post-test analysis: both Westinghouse and Rosemount agree that the 1153 Series A transmitter is qualified for steam flow applications, based on the testing performed by Westinghouse. Westinghouse believes that test results show the unacceptability of the 1153 Series A transmitter for RCS wide range pressure applications; however, Rosemount attributes the unacceptable performance to random failures and severe overtesting (temperature/pressure).

The results of this testing were not reviewed by FRC in the Prairie Island TER. However, in their review of the environmental qualification of 1153 Series A transmitters for other plants, FRC has concluded that the results are acceptable in satisfying the requirements of the DOR Guidelines, with the exception of aging qualification, providing test anomalies are adequately addressed and Conax fittings are installed on the transmitters. The discussion provided above, coupled with the Rosemount post-test analysis, has adequately addressed all test anomalies. In addition, Conax fittings are installed on all RCS wide range pressure and Main Steam steam flow transmitters at Prairie Island.

4.0 THERMAL AGING QUALIFICATION

NRC IE Bulletin 79-01B established the DOR Guidelines as the criteria for evaluating the qualification and associated documentation of safety-related electrical equipment. The objective of these guidelines is to identify Class IE equipment whose documentation does not provide reasonable assurance of environmental qualification.

The DOR Guidelines are not intended to provide for the implementation of either the 1971 or 1974 version of IEEE Standard 323 for operating reactors. The intent of the Guidelines is to provide a basis for judgements required to confirm that operating reactors are in compliance with General Design Criterion 4, specified in Appendix A of 10CFR50. General Design Criterion 4 states in part that "structures, systems, and components important to safety shall be designed to accommodate the affects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents." Thus it is clear that aging qualification using methods other than strict application of data obtained from type testing in accordance with either IEEE 323-1971 or 323-1974, and in particular accelerated thermal aging testing of 323-1974, does not necessarily imply that the equipment is unqualified to the DOR Guidelines.

The DOR Guidelines state that type testing of equipment identical in design and construction to the installed component is the preferred qualification method, although alternatives are acceptable provided justification is presented. Appendix C of the DOR Guidelines contains a partial

listing of materials which may be found in nuclear power plants, along with an indication of the material susceptability to thermal and radiation aging. Other data sources may be used by the licensee in evaluating the radiation and thermal aging qualification of equipment and materials.

Appendix C of the DOR Guidelines shows the generic nature of materials categories. Categories include nylon, silicone rubber, polyethylene, EPR, cross-linked polyethylene, etc. It is clear that, by providing these generic categories, the NRC is indicating the level of detail by which qualification can be established, and that a more detailed review is at the licensee's discretion.

The calculation file referenced in our April 30, 1982, SER response provides documentation of the detailed analysis used to establish the qualified (thermal aging) life for Rosemount Series A transmitters. The methodology and sequence used to assess thermal aging qualification and establish a qualified life are outlined below.

1. Identify the specific component materials susceptible to degradation from thermal aging. A non-metallic materials list for the 1153 Series A transmitters was obtained from Rosemount which identified the material of construction for the various subcomponents. Metallic components were assumed not susceptible to degradation from thermal aging.

2. Identify thermal aging properties of the susceptible materials. Data sources included:

   a. Appendix C of the DOR Guidelines

   b. Material Manufacturer Information

   c. EPRI Report NP-1558

   d. Test Lab Data

   e. Other Sources

   In each case, the most applicable data available was used with respect to both the tested geometry (bulk, thin film, O-ring, etc.) and the physical property of the material pertinent to the function of the component. For example, the critical physical property for a diaphragm would be retention of elongation, flexure strength, or tensile strength, as appropriate. The aging data utilized incorporate conservative definitions of material failure relative to retention of the critical property.

3. Determine a qualified life for thermal aging. In general, safety-related equipment at Prairie Island can be classified into two categories, based on the availability test data:

Category A: Equipment tested under LOCA/HELB conditions with pre-aging included in the test program.

Category B: Equipment tested under LOCA/HELB conditions without pre-aging in the test program.

For equipment in Category A, qualified thermal aging lives are based on the thermal aging tests, activation energies for the materials of construction, and the critical physical property for these materials.

For equipment in Category B, such as the Rosemount 1153 Series A transmitters, pre-aging was not performed as part of the test sequence. Since significant margins often exist between the required environmental profiles and the tested environmental profiles, the "overtesting" can be used to account for in-service aging using the Arrhenius Method.

In the absence of a pre-accident aging test for an equipment item, the accident "overtesting" provides the next best measurement of a qualified thermal aging life. This conclusion is based on the following considerations:

- The materials used in the test specimen provide the most accurate indication of how the materials in the installed equipment will age. The materials used in the test specimen are in most cases identical to the materials used in the installed equipment. Where differences exist, the tested materials usually meet the same functional design specifications.

- The atmosphere in the test chamber is acceptably similar to normal plant conditions to simulate normal aging. No accelerated aging test environment can accurately simulate all aspects of normal plant aging. Air oven aging is the most widely used accelerated aging method. However, this method results in an extremely dry environment which excludes the aging effects of moisture. The test chamber atmosphere during LOCA/HELB accident testing also has disadvantages, in that it has a lower-than-normal concentration of oxygen. Oxygen is present in the chamber in some quantities at the start of testing and, as chamber temperature rises, gases (including oxygen) are driven out of solution from water present in the chamber in the form of spray solution or a vapor source pool. This oxygen is available to participate in aging reactions. Thus, test chamber conditions are adequate to provide reasonable assurance of the thermal aging capability of the equipment being tested.

- The Arrhenius method predicts the effects of normal aging mechanisms by modeling them as chemical reactions. The most rapid reaction rate produces the most significant aging mechanism and therefore the lowest activation energy. Since most activation energies are experimentally derived from air oven aging tests, they predict the most rapid degradation reaction rate exhibited by the material being tested (usually

oxidation). Use of this activation energy to extrapolate accident simulation testing yields inherent conservatism. If oxidation is the controlling aging mechanism, then life estimates extrapolated from accident test data are biased towards this mechanism by use of the lower activation energy associated with oxidation. However, if a moisture-induced aging mechanism is predominant, the test data will reflect resulting failures. In either case, use of accident test data leads to conservative estimates of equipment aging capability because such testing does not usually take the equipment to failure.

Additional conservatism is included in all Arrhenius calculations in the following manner:

a. The lowest listed apparent activation energy for a material was used unless a justification for a higher value was provided.

b. A conservatively high normal operating temperature was used to calculate a qualified life.

c. A conservative activation energy of 0.5 eV was assumed for materials where adequate aging data was unavailable.

d. A conservatively high material temperature was assumed when evaluating equipment items that generate heat, such as energized solenoids and running motors.

4. Evaluate effect of material degradation. When the qualified life for a component material was less than required, the effect of the material failure was evaluated. If it was determined that failure of this material or subcomponent would not affect the operability of the equipment, this material was no longer considered the limiting material and the next most limiting material was used to establish the qualified life for the equipment item. An example of this situation would be a cover gasket on a component not subject to harsh temperature, pressure, or relative humidity conditions. In this situation, failure of the cover gasket due to age-related degradation would not have a deleterious effect on the component's functionability.

For equipment exposed to small accident temperature transients and/or durations, the normal age-related degradation will not be significantly accelerated during post-accident conditions. Therefore, catastrophic failure due to thermal aging under these circumstances is very unlikely.

This same methodology was used by other plants and identified in their various responses to IE Bulletin 79-01B and the associated SER responses. This methodology was reviewed by FRC and their conclusion was "that the Licensee has provided a satisfactory response" to aging concerns.

The application of this methodology in the determination of a qualified thermal aging life for the Rosemount 1153 Series A transmitters is described below. This discussion is basically a summary of the evaluation presented in Reference 5.

The non-metallic materials present in the 1153 Series A transmitters have been identified by Rosemount and are listed in Table 1. Also identified on Table 1 are the continuous service temperatures and the appropriate activation energies used in the thermal aging evaluation. Many of the activation energies and continuous service temperatures are based on the environmental qualification testing on 1153 Series D transmitters. In cases where identical materials, and components exist in the two transmitters, the activation energies and continuous service temperatures used in the Series D transmitter qualification program are applied to the Series A transmitters. It should be noted that this does revise some of the values presented in the calculation file referenced above. Many of these materials are shown in IE Bulletin 79-01B to be not susceptible to thermal degradation.

The thermal aging calculation was based on the epoxy-glass laminated circuit board as the limiting material. Using the methodology described earlier, the Westinghouse test was used to establish a thermal aging life. The Westinghouse test was selected because of its severity of test conditions. Test results on Sample AX-1 were used as the basis for calculations, as this was determined to be the most conservative for the following reasons:

1. Failure of sample AX-2 was due to failure of the Conax fitting rather than the transmitter itself.

2. Sample AW-1 performed throughout the test but it would be unconservative to use this as representative of all test samples.

3. Sample AW-2 failed in the 15th day of testing from the same op-amp failure that occurred in the 12th day of testing on AX-1. Therefore, use of AX-1 will be conservative.

Although AX-1 did not actually fail until the 12th day of testing, erratic output occurred after the 8th day of testing. For conservatism, the thermal aging life was based on only the first eight days of operation. This calculation resulted in a qualified thermal aging life of 43.9 years for the Main Steam steam flow transmitters (30-min. operating time) and 35.9 years for the RCS wide range pressure transmitters (30-day operating time).

While it may be true that this is a somewhat long qualified thermal aging life, it is based on NRC accepted methodology. NSP will commit to reevaluating this qualified life to incorporate newly available test data on similar transmitters, specifically Rosemount 1153 Series B and 1153 Series D transmitters. In this testing, the accelerated aging programs included operational cycling, power and pressure fluctuations, temperature and

humidity fluctuations, and other aging mechanisms. NSP will use this information to determine if the stated qualified life should be modified. It should be clear from this evaluation, however, that, based upon the activation energies and service temperatures listed in Table 1 for the various components, the installed ambient environment of approximately 95°F has imposed an insignificant amount of thermal aging on the transmitters since their operational date of January 1982 (purchase date December 1979).

5.0 DISCUSSION OF THE FRC'S EVALUATION

FRC has evaluated the environmental qualification of Rosemount 1153 Series A transmitters installed at Prairie Island and identified in the TER [6] as equipment items 40, 44, and 47. We have noted in Section 1.0 the fact that equipment item 47 was deleted from the safety-related equipment masterlist, and that the correct Plant ID numbers for equipment item 44 are 1-PT-709 and 1-PT-710, rather than 21102 and 21159 as listed in the TER. FRC's evaluation was organized as follows:

1. Evaluation of Rosemount Report 3788 (FRC Reference 1764) and conclusions,

2. Evaluation of Rosemount Report 37821 (FRC Reference 4423) and conclusions,

3. Overall conclusions.

FRC's conclusion regarding the adequacy of Rosemount Report 3788 [2] in satisfying the requirements of te DOR Guidelines is as follows: "All units successfully passed test in accordance with acceptance criteria. Testing was under IEEE-323(71) standard. Qualification program satisfies all applicable criteria of the DOR Guidelines except that aging degradation and qualified life or replacement schedule has not been addressed."

Although Rosemount Report 37821 was not used by NSP in establishing qualification of the Series A transmitters, the FRC performed an evaluation of the test report. The objective of this test program was to determine the equipment accuracy at three different temperatures: 350°F, 303°F, and 250°F. THe environmental profile for this testing was as follows: 350°F / 120 psig / 100% RH for 10 minutes; 303°F / 55 psig / 100% RH for 2 hours; and 250°F / 15 psig / 100% RH for 1.5 hours. 15,000 ppm boric acid was used as the chemical spray solution. FRC's conclusion regarding the adequacy of Rosemount Report 37821 is as follows: "The Model 1153 Series A (1153GA9) Gauge Pressure transmitter has been shown that it can operate within the acceptance criteria ± 8% of upper range during and after exposure to the environment noted herein."

At this point, it would appear that all requirements of the DOR Guidelines for accident qualificaton have been estabished. The Westinghouse qualification testing and Rosemount post-test analysis were not evaluated by the

FRC in Prairie Island's TER, but were evaluated in TERs for other plants. The conclusion reached by the FRC in these evaluations was the the test is acceptable with the exception of radiation qualification, test failures and accuracies, and aging and qualified life assessment. We believe the Rosemount post-test analysis resolves these deficiencies, with the exception of thermal aging qualification.

The overall conclusion reached by the FRC is as follows: "We note the following information abstracted from applicable and available qualification documentation associated with the overall NRC equipment environmental qualification review program: 'Rosemount testing to qualify a transmitter to meet IEEE 323-1974 requirements has resulted in failure. A combination of thermal aging, irradiation, and chemical spray test specification parameters has resulted in failed components. The initial failed element was an O-ring comprised of sulphur-cured polyethylene rubber. This allowed steam/chemical spray to affect electronic components. The O-ring mode of failure is attributed to high temperature vs. time necessary for the Arrhenius curve time compression to satisfy aging test requirements.'" Unfortunately, the FRC did not reference this information to any qualification report so that this issue could not be clarified. Discussions with the NRC in Bethesda also resulted in some confusion over the source of this test data. The confusion was eliminated after consultation with Rosemount, the equipment vendor.

The referenced failures refer to initial environmental qualification testing on the 1153 Series B transmitters. Reference 9 describes this testing in detail and is summarized below. 1153 Series B transmitters classified as "Group A" were thermally aged at 254°F for 47 days to simulate ten years of operation at 120°F. The limiting component in the aging analysis which led to the selection of test times and temperatures is the integrated circuit, with an activation energy of 0.7 eV. The temperature of 125°C (257°F) was arbitrarily chosen because most electronic components have this value as their upper temperature limit. Using this temperature, a 38-day aging period was required. The 10% margin required by IEEE 323-1974 and an additional 10% safety factor were added, ultimately resulting in a 47-day aging period at 123°C (254°F). The O-rings which failed the thermal aging tests were actually sulphur-cured ethylene propylene and have an activation energy of 1.02 eV based on manufacturer's testing. The required aging time to simulate 10-year operation for the O-rings is 34 hours. Thus, because the limiting material had a significantly lower activation energy, severe overaging of the O-rings occurred; 47 days at 123°C simulates approximately 125 years at 120°F.

Subsequent retesting for aging requirements was performed after reevaluating the aging criteria. Thermal aging testing on "Group B" transmitters was performed at 203°F for 47 days, which reflects both an increase in the activation energy and a decrease in the aging temperature. The pertinent changes made to the Group B transmitters were the material of the cover O-rings on the zero and span adjustment shafts being changed from sulphur-cured ethylene propylene to peroxide-cured ethylene propylene. This

change was made to improve the humidity resistance during steam testing and to allow successful performance during the high temperature accelerated aging program. However, testing by Rosemount showed that both elastomers exhibit similar characteristics under non-accident conditions. In addition, the process O-rings were changed to 316SS to improve pressure and temperature resistance. While several other minor changes were also made prior to retesting, the overall conclusion reached by Rosemount is that the combination of high process pressure (4500 psig) and high thermal aging temperatures (254°F) imposed unnecessary and unrealistic stresses on the transmitter, leading to failure of the O-rings. Following these changes, the transmitters successfully passed the environmental qualification program.

NSP believes that the testing described above does not constitute the technical basis necessary to establish non-qualification of Rosemount 1153 Series A transmitter to postulated accident conditions at Prairie Island. The failures which occurred were due to imposing unrealistic stresses in the form of temperature and pressure on the transmitters. The aging temperature of 254°F was unreasonably high for the O-rings. Furthermore, we do not believe that failures occurring as a result of thermal aging prove unacceptable performance during accident conditions, thereby invalidating the previous accident testing by Rosemount and Westinghouse.

6.0 CONCLUSIONS

This enclosure has presented a summary of Rosemount testing on the 1153 Series A transmitter [2], Westinghouse testing on different specimens in the same model line [3] and Rosemount's post-test analysis of the Westinghouse testing [4], discussion of the thermal aging evaluation [5], and discussion of FRC's evaluation. Environmental qualification issues and, specifically, questions raised by FRC can be broken into two basic categories: accident qualification and thermal aging qualification.

We believe that environmental qualification to postulated containment accident conditions at Prairie Island has been established on the basis of type testing. The Rosemount test conditions adequately envelop the service conditions for the installed environment, and functionality of the transmitter was documented to be within the stated acceptance criteria. FRC has concurred with the adequacy of this test in establishing qualification to postulated accident conditions. As a result of subsequent testing to more severe environmental conditions, Westinghouse has concluded that the 1153 Series A transmitters are qualified for accident conditions in steam flow applications. Although Westinghouse concludes that the 1153 Series A transmitters are not qualified for RCS wide range pressure applications, Rosemount disputes this in their post-test analysis and states that the failures which occurred were due to overtesting and random failure.

FRC has also evaluated a steam/temperature test performed by Rosemount on 1153GA9 transmitters, Rosemount Report 37821, Rev. B [8]. Rosemount's

purpose in performing this test was to assess the accuracy of the test specimen at temperatures of 350°F, 303°F, and 250°F. The intent of this test was not to establish environmental qualification, and it was not used in establishing environmental qualification at Prairie Island. Despite this, FRC's conclusion regarding this report was "The Model 1153 Series A (1153GA9) Gauge Pressure transmitter has been shown that it can operate within the acceptance criteria of +8% of upper range during and after exposure to the environment noted herein." FRC's inclusion of this report in the environmental evaluation does support the conclusions reached regarding the environmental qualification of the 1153 Series A transmitters.

With respect to thermal aging qualification, our evaluation has produced qualified thermal aging lives of 43.9 years for Main Steam steam flow transmitters and 35.9 years for RCS wide range pressure transmitters. These qualified lives are based on a materials evaluation to identify the limiting component with respect to thermal aging, and on the use of the Arrhenius Method in extrapolating overly conservative LOCA test data. NSP is willing to commit to reevaluating the qualified life of the transmitters to consider recently completed testing on the 1153 Series B and 1153 Series D transmitters. Specifically, other aging parameters such as operational cycling, power and pressure fluctuations, temperature and humidity fluctuations, and other aging mechanisms, as known, will be incorporated into the aging evaluation to revise, as necessary, the presently stated qualified lives. Until this aging evaluation is completed, however, the transmitter material list and associated service temperatures indicate that the materials are generally designed for high temperature applications and that relatively little thermal aging has occurred since installation (purchased December, 1979 and operational January, 1982) in the ambient environment of 95°F. In addition, the vendor has stated that identical O-rings have been used in 1151 Series transmitters for many years in industrial applications with no degradation problems. We therefore request that Rosemount 1153 Series A transmitters be removed from qualification Category II.B and reclassified in qualification Category II.C.

7.0 REFERENCES

1. Prairie Island Nuclear Generating Plant Response to IE Bulletin 79-01B Safety Evaluation Report, April 30, 1982.

2. Qualification Test Report for Rosemount 1153 Series A, RMT Report 3788, Rev. A, March 1978.

3. Westinghouse Qualification Testing of Rosemount 1153 Series A Electronic Transmitter, December 1970.

4. Rosemount Post-Test Analysis of 1153 Series A Pressure Transmitters for Westinghouse PWR Systems Division, RMT Report No. 17912A, January 1979.

5. EDS Nuclear Calculation File 0910-002-EQF-02, Rev. 1, June 1981.

6. Franklin Research Center Technical Evaluation Report, Northern States Power Company, Prairie Island Nuclear Generating Plant Units 1 and 2, March 29, 1983.

7. EDS Nuclear Calculation File 0910-204-EQ-01, Rev. 1, April 1982.

8. Rosemount Report 37821, Rev. B.

9. Rosemount Pressure Transmitter Model 1153 Series B for Nuclear Service. Qualification Report 108025, Type Test Report 108026 (Test Results), and Type Test Report 108026 (Appendices).

TABLE 1

Component	Material	Activation Energy (eV)	Maximum continuous service temperature or maximum operating temperature
Terminal Block	Phenolic	1.02	150°C
O-ring	Ethylene-Propylene	1.23	148°C
Resistor	Wire Wound	0.87	130°C
Resistor	Cermet	1.64	275°C
Diode	Silicone	1.13	150°C
Potentiometer	Cermet	0.87	95°C
Capacitor	Tantalum	1.27	85°C
Capacitor	Ceramic	1.14	125°C
Thermistor	Ceramic	0.87	125°C
Diode	Silicone	1.41	175°C
Transistor	Silicone	1.02	150°C
Thermal Compound	Silicone Oil, Zinc Oxide	1.82	215°C
Mounting Pad	Glass-Filled Diallyl Phthalate	2.17	204°C
Op. Amp	Silicone	1.0	95°C
Grease	Silicone	Not Available	176°C
Potting Compound	Epoxy Resin	1.48	260°C
Tubing	Irradiated Polyethylene	1.29	135°C
Tubing	Polyolefin	1.29	135°C
Oil	Trisiloxene	1.82	187°C
Dye	N/A	Not Required for Transmitter Operation	

TABLE 1
(continued)

Component	Material	Activation Energy (eV)	Maximum continuous service temperature or maximum operating temperature
Coating	Epoxy	1.48	125°C
Transformer	Alkyd-limiting component is pottery shell	1.14	180°C
Thread Sealant	Loctite proprietary	Not Available	149°C
Washer	Nylon	1.14	93°C (lowest)
Wire Insulation	Kapton	1.06	greater than 200°C
Capacitor	Nylon	1.14	93°C (lowest)
Capacitor	Porcelain	Not Age-Susceptible	
Circuit Board	Epoxy-Glass Laminate	0.98	105°C

FIGURE 1

Containment Accident Profile

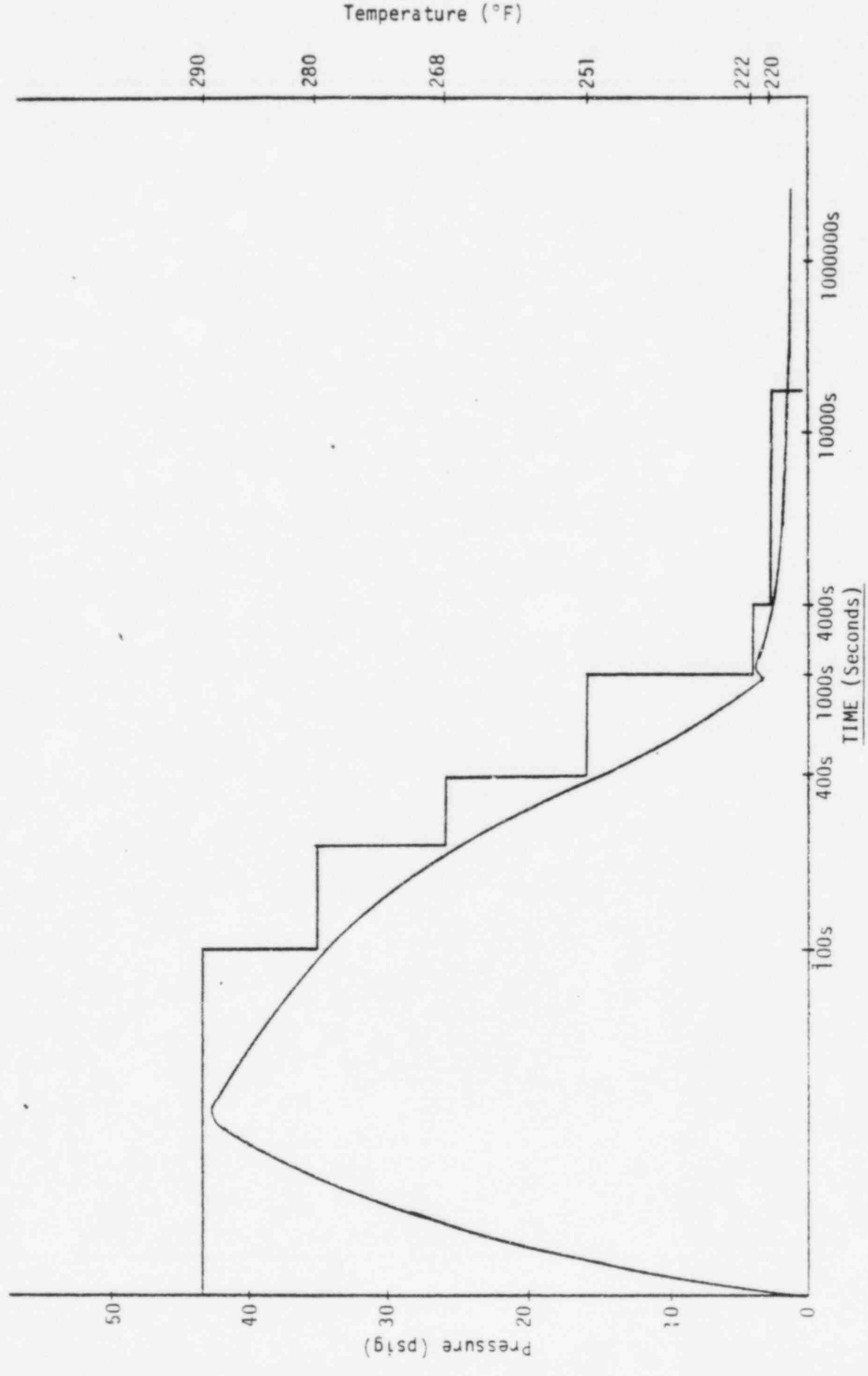

FIGURE 2

Dose Rate Decay Curve - Containment

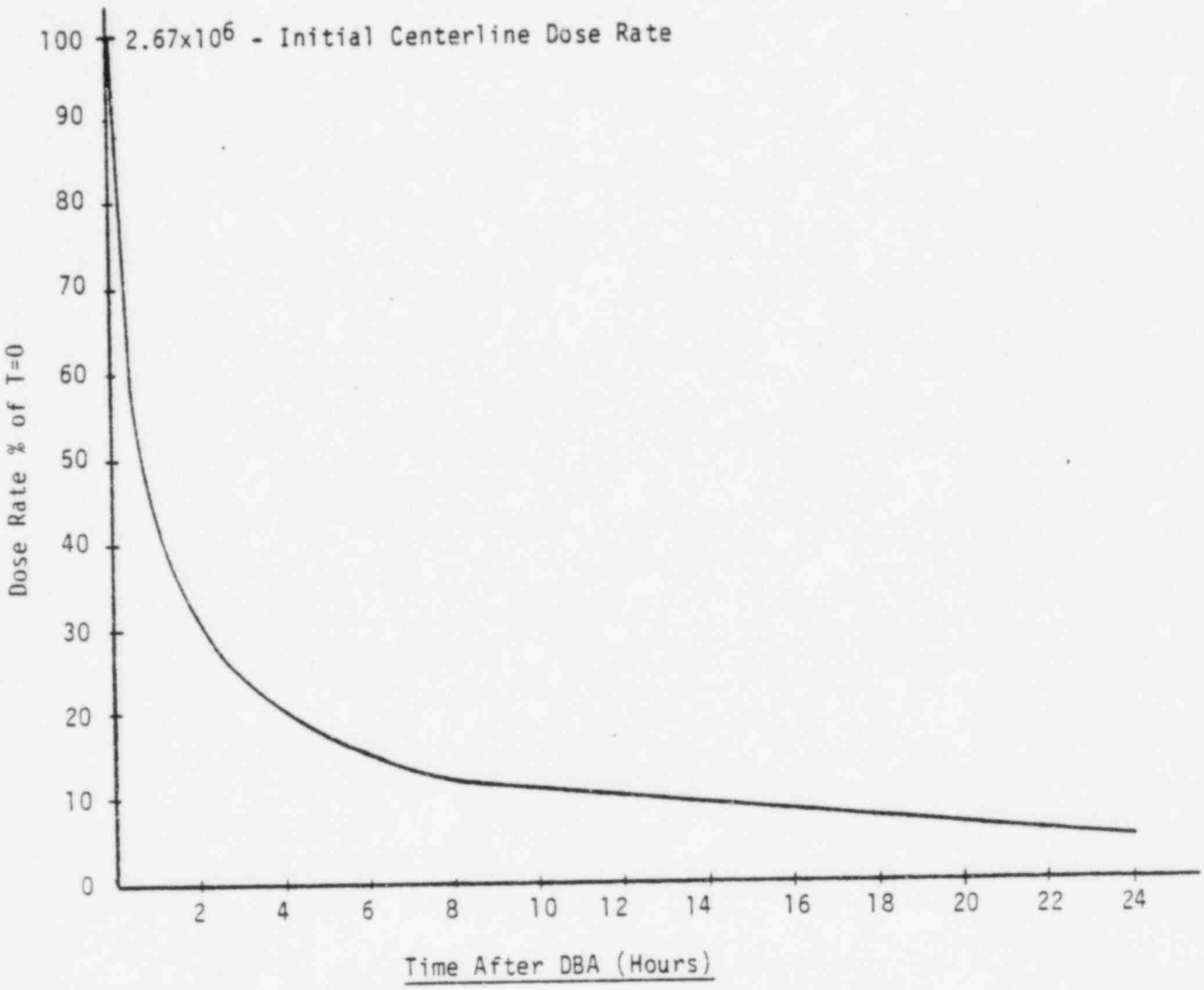

FIGURE 3

Rosemount Report 3788

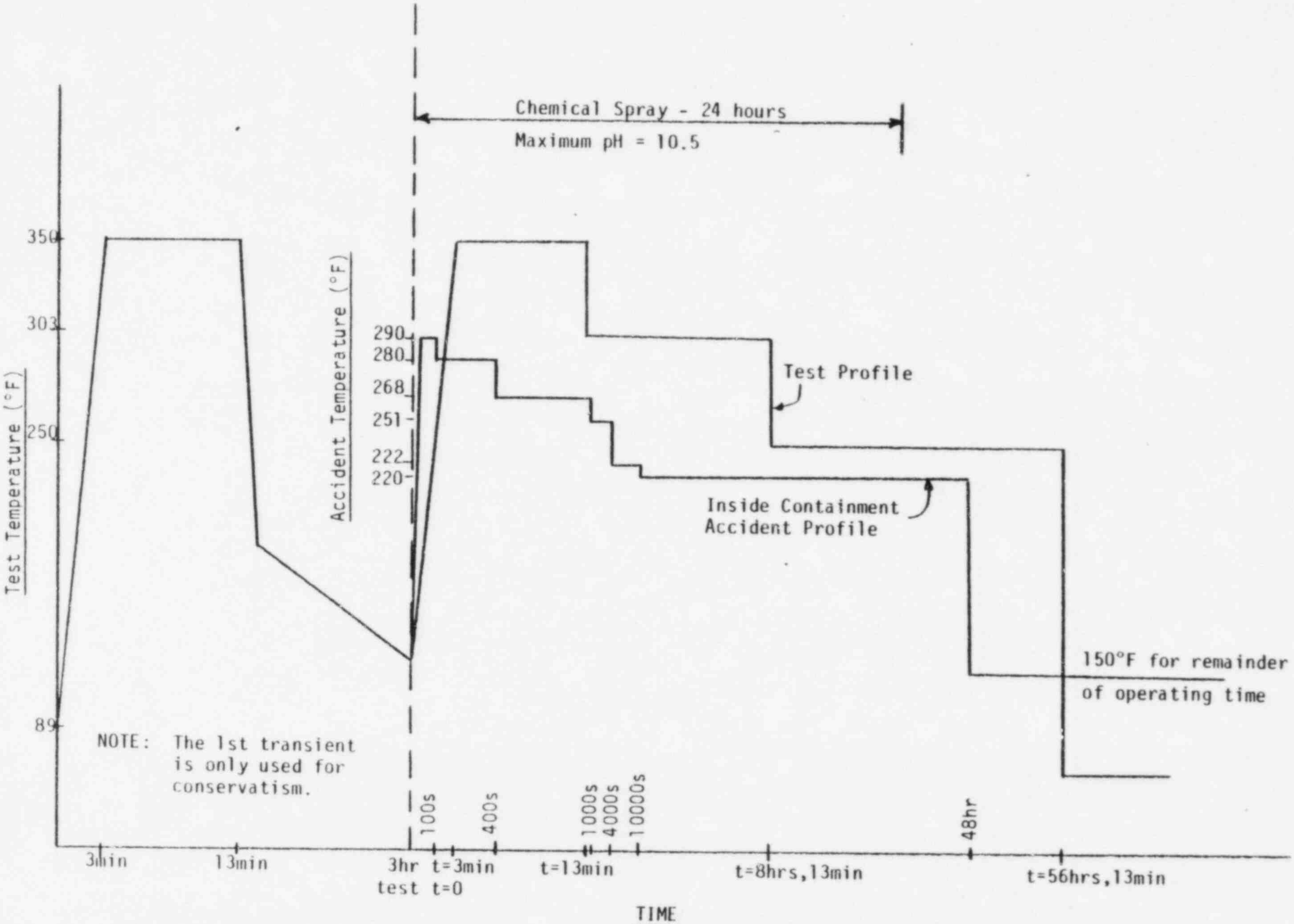

FIGURE 4

AX-1, AX-2 Temperature Profile

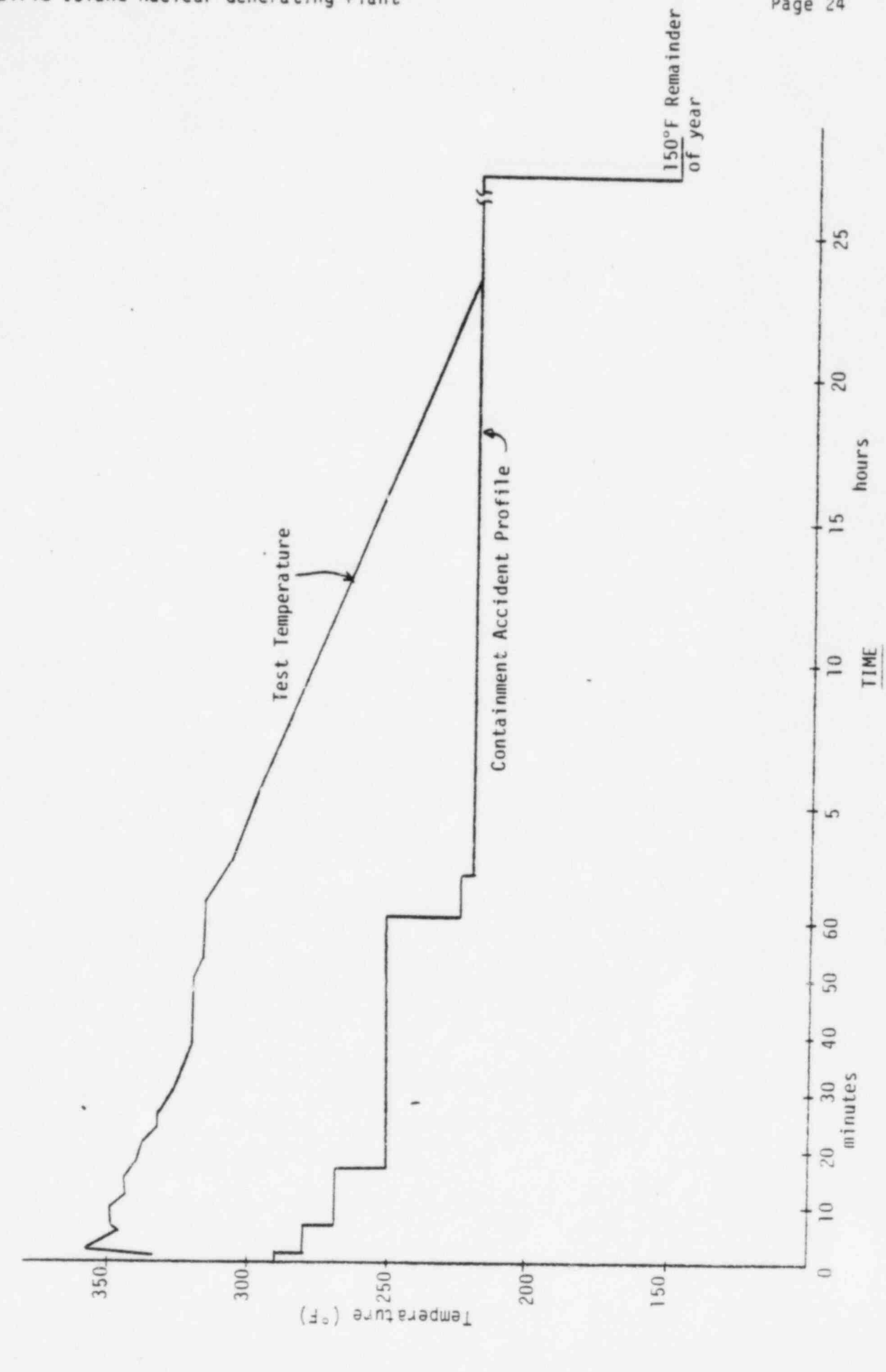

FIGURE 5

AW-1, AW-2 Temperature Profile