Supplemental Qualification Testing of Barton Lot 1
Pressure and Differential Pressure Transmitters

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1.0 INTRODUCTION

1.1 BACKGROUND

In the late 1960's Westinghouse performed a series of environmental qualification tests on transmitters to demonstrate the ability of the instruments to carry out their applicable safety function under postulated loss of coolant accident environmental conditions. The testing performed was documented in WCAP-7410-L, Volume 1 (Proprietary) and WCAP-7744, Volume 1 (Non-Proprietary), "Topical Report-Environmental Testing of Engineered Safety Features Related Equipment (NSSS-Standard Scope)" and submitted to the Atomic Energy Commission for review.

The review of the topical report by the Atomic Energy Commission (now Nuclear Regulatory Commission) resulted in several questions regarding test methods and acceptance criteria. To respond to the Nuclear Regulatory Commission's (NRC) concerns regarding instrument qualification Westinghouse committed to provide accuracy requirements, by plant type, for Westinghouse supplied sensors located inside containment that initiate short term automatic protective functions to mitigate the consequences of postulated accidents. Additionally Westinghouse agreed to provide an experimental basis for demonstrating the capability of instruments utilized in long term post accident monitoring applications to function throughout their duty cycle in the accident environment. These commitments were included in Westinghouse letter NS-CE-692, C. Eicheldinger (Westinghouse) to D. B. Vassallo (NRC), dated July 10, 1975. The programs outlined above are applicable to those Westinghouse plants which were in the Operating License review stage in July, 1975 and future plants not committed to IEEE-323-1974. Table 1-1 identifies the plants to which the programs are applicable.

Allowable short term environmental accuracy tolerances for in-containment transmitters that initiate automatic protective functions to mitigate the consequences of postulated accidents were established and submitted under NS-CE-743, C. Eicheldinger (Westinghouse) to D. B. Vassallo

(NRC), dated August 8 1975 and NS-CE-792, C. Eicheldinger (Westinghouse) to D. B. Vassallo (NRC), dated October 1, 1975. These environmental accuracy tolerances are included as Table 1-2. Additional investigation since the submittal of the above letters (NS-CE-743 and NS-CE-792) has shown that the steam generator water level (narrow range) allowable error can be increased from +0% span and the change is included in Table 1-2. It should be noted that while the allowable tolerances identified in Table 1-2 are applicable to a group of plants, individual plant evaluations would, in general, result in the capability to accept larger accuracy tolerances than those listed in Table 1-2.

Upon receipt of the Nuclear Regulatory Commission's letter of November 19, 1975, D. B. Vassallo (NRC) to C. Eicheldinger (Westinghouse), accepting the Westinghouse programs as meeting IEEE-323-1971, Westinghouse initiated development of a detailed test program and procurement of instruments for test. The test program included irradiation of the instrument followed by simultaneous testing of the instrument under steam, temperature, pressure and chemical spray conditions. At the time in which the program was being developed (late 1975 early 1976) calculated containment temperature conditions resulting from postulated steam line break accidents were exceeding those calculated temperature conditions resulting from a postulated loss of coolant accident. Consequently an effort was undertaken to establish environmental conditions to be used in the test program that would envelope both the postulated loss of coolant accident and the postulated steam line break accident.

The result of this effort resulted in the establishment of the test envelope shown in Figure 1-1. The temperature profile exceeds that previously used in transmitter testing, particularly during the early portion of the test. For testing simplicity, Westinghouse decided to require the test pressure conditions to be equal to the saturation pressure corresponding to the temperature envelope. This results in a conservative test whose pressure conditions exceed plant design conditions. The conservatism of this testing with respect to the more recent (and higher) calculated containment temperature conditions following a postulated steamline break is documented in WCAP-8936 (Proprietary) and WCAP-8937 (Non-Proprietary), "Environmental Qualification-Instrument Transmitter Temperature Transient Analysis." Included in the temperature test envelope is an extended post accident duty period at elevated temperature conditions. This extended duty period represents long term post accident monitoring and is simulated by higher than expected temperatures. The $10^{o}C$ rule was chosen as an approximation for accelerated aging. Successful operation under these environmental conditions provides confidence in the ability of the instrument to function under prolonged post accident conditions.

While the calculated steam line break containment conditions established the temperature conditions, the radiation doses were established based on TID source terms with credit taken for shielding base on the location of the transmitters. The resultant doses are conservative with respect to both the postulated loss of coolant accident and the postulated steam line break accident. The instrument radiation test conditions are given in Table 1-3.

In summary the test conditions chosen were worst case conditions enveloping different accidents. The high temperature conditions were based on the postulated steam line break and the high radiation conditions were based on the postulated loss of coolant accident. One test envelope was developed to eliminate the need for separate testing to steam line break conditions (high temperature, low radiation) and loss of coolant accident conditions (lower temperature, high radiation).

1.2 INITIAL TESTING

After the establishment of the environmental test conditions an autoclave facility was built at the Westinghouse Forest Hills Test Facility in Pittsburgh, Pennsylvania. Irradiation testing was contracted with Isomedix in Parsippany, New Jersey. A description of these facilities is included in Section 3.2 of the original test report (NS-TMA-1950). Testing was initiated in early 1976. Transmitters tested for short term

These modifications for the Barton [ ][a,c] pressure transmitter included [

][a,c,e] The Barton [ ][a,c] differential pressure transmitter was also modified by [

][a,c,e]

To confirm the adequacy of the above modifications, Westinghouse tested three prototype models of each of the modified Barton pressure and differential pressure transmitters to the steam/temperature/pressure/chemical spray conditions identified in Figure 1-1. The prototype units tested were not subjected to the radiation portion of the program since the electronics had not been changed and [

][b,c,e] Results of this prototype testing were successful and demonstrated the ability of the modified instruments to satisfactorily function throughout the initial (trip) portion and the long term monitoring phase of the test. The test results were submitted to the NRC via Westinghouse letter NS-CE-1384, C. Eicheldinger (Westinghouse) to J. F. Stolz (NRC), dated March 23, 1977.

1.4 PRODUCTION RUN BARTON (LOT 1) TRANSMITTERS

Based on the successful prototype testing an order was placed with Barton for supply of transmitters. The modified differential pressure transmitter was designated as the model [ ][a,c] and the modified pressure transmitter was designated as the model [ ].[a,c] As a requirement of the purchase order the supplier was to procure material and manufacture the instruments under lot control techniques thereby reducing the variables affecting qualification of the instrument. The transmitters in a lot were required to be manufactured to the same baseline design from the same drawings using identical components and automatic protective function initiation or post accident long term monitoring or both short term and long term functions are listed in Table 1-4.

Testing of these instruments (3 of each model) was completed in mid 1976. Test results showed that all RTD models successfully met their test requirements and survived throughout the initial portion and post accident monitoring phase of the accident. The Fischer and Porter Transmitter (item E) and the Foxboro Transmitter (item F) were both tested for initial automatic protective function initiation and were deemed to have successfully met their test requirements. Results of the testing for the Rosemount RTD's (item H), Sostman RTD's (item I), Fischer and Porter Transmitters (item E) and Foxboro (item F) have been separately reported in WCAP-9157, "Environmental Qualification of Safety Related Class 1E Process Instrumentation" and are not discussed in this report.

While the results of the testing for the Barton, Veritrak and Foxboro [ ]^{a,c} indicated that the transmitters could provide automatic short term protective functions (e.g. reactor trip, safety injection), none of the transmitters met the [ ]^{a,c,e} requirement established by Westinghouse for long term post accident monitoring. The results of this testing were provided to the NRC in August, 1976 under Westinghouse letter NS-CE-1179, C. Eicheldinger to J. F. Stolz (NRC), dated August 26, 1976. Subsequent investigation identified the cause of the unsuccessful long term Barton results to be [ ].^{b,c,e}

1.3 BARTON TRANSMITTER DEVELOPMENT

To resolve the identified cause of the unfavorable transmitter test results Westinghouse, in conjunction with Barton, modified the Barton design to prevent [ ].^{b,c,e}

subassemblies by similarly trained people. To verify the qualification of the lot, samples would be selected from the lot and subjected to a lot verification test consisting of irradiation, seismic simulation and steam/temperature/pressure/chemical spray testing.

The lot 1 test results were submitted to the NRC via Westinghouse letter NS-TMA-1950, T. M. Anderson (Westinghouse) to J. F. Stolz (NRC), dated September 29, 1978. The instruments included in those tests are identified in Table 1-5 by serial number, facility designation and range. The test report showed that during the long term phase of the testing the three differential pressure transmitters and the narrow range transmitter [ ]b,c,e their accuracy requirement of ±25% for a period of [ ]b,c,e and then stabilized to within [ ]b,c,e span. The wide-range pressure transmitters also [ ]b,c,e their accuracy requirement of ±10% during the long term test phase then stabilized to within [ ]b,c,e by the end of the test.

To assess the [ ]b,c,e experienced at the beginning of the long term monitoring phase of the autoclave testing, Westinghouse completed additional testing to determine the cause of the [ ]b,c,e and to demonstrate that, under specific steam line break and loss of coolant accident conditions, the instruments would perform within specification. The results of these additional tests, as reported in NS-TMA-1950, and supporting information from Barton which showed that the [ ]b,c,e essentially disappeared after removal of the transmitter cover ('burping') it was concluded that a gas may be generated in the electronic housing during radiation which becomes conductive at elevated temperatures. Further radiation and temperature threshold tests confirmed that under either the high temperature/lower radiation environment of the steam line break or the lower temperature/high radiation environment of the LOCA, the [ ]b,c,e did not occur and therefore the long term performance capability of the transmitters is assured.

1.5 SUPPLEMENTAL TESTING OF BARTON LOT 1 TRANSMITTERS

The NRC evaluation of the Westinghouse testing of the Barton Lot 1 production run of transmitters (NS-TMA-1950) is contained in a letter dated May 15, 1979 from J. F. Stolz (NRC) to T. M. Anderson (Westinghouse). The evaluation concluded that while the tests described in NS-TMA-1950 provided additional assurance that the transmitters would initiate short-term protection system actions within acceptable instrument accuracies, the tests do not provide an adequate basis to support the use of these transmitters as instruments required for operator actions during long-term post-accident cooling. As a consequence the staff requested additional justification to demonstrate the requisite long term capability.

In letter NS-TMA-2103 dated June 21, 1979 from T. M. Anderson (Westinghouse) to J. F. Stolz (NRC), Westinghouse proposed a supplemental test program which would consist of demonstrating the capability of the Lot 1 units under separate simulations of the LOCA and steam line break employing a complete test sequence (i.e. irradiation, seismic, accident, post accident). These supplemental tests are described in this report.

TABLE 1-1

NS-CE-692 INSTRUMENT PROGRAM APPLICABILITY

Indiant Point 3	D. C. Cook 1 & 2*
Beaver Valley 1 & 2	Watts Bar 1* & 2
Trojan	Virgil C. Summer
Diablo Canyon 1* & 2*	Catawba 1 & 2
Salem 1 & 2*	Shearon Harris 1 - 4
Sequoyah 1* & 2	Alvin W. Vogtle 1 & 2
McGuire 1* & 2	Millstone 3
North Anna 1* & 2*	Jamesport 1 & 2
Farley 1* & 2	

*Plants employing Barton Lot 1 transmitters.

TABLE 1-2

FUNCTIONAL REQUIREMENTS FOR INCONTAINMENT TRANSMITTERS THAT INITIATE PROTECTIVE FUNCTIONS AND/OR PROVIDE POST ACCIDENT MONITORING CAPABILITY

	Required Duration of Function	Pressurizer Level	Pressurizer Pressure	Steam Line Flow	Steam Generator Level (NR)	Reactor Coolant System Pressure (WR)
Transmitter Model	-	[$]^{a,c}$	[$]^{a,c}$	[$]^{a,c}$	[$]^{a,c}$	[$]^{a,c}$
Short Term Trip Accuracy[1]	≤ 5 mins.	(5)	±10%	-10%[3]	+10%[2][4]	-
Long Term Monitoring Accuracy[1]	≤ 4 months	±25%	-	-	±25%	±10%

(1) Accuracy is specified as % of span and does not include steady state errors.

(2) No negative accuracy tolerance is assigned to the Pressurizer Level and Steam Generator Level Transmitters since negative errors during postulated accidents that result in containment environmental transients are in the conservative direction and would result in early protective function initiation.

(3) No positive accuracy tolerance is assigned to Steam Line Flow Transmitter for the same reason as in note 2 except for positive errors.

(4) For those plants employing split flow preheat steam generators, this requirement has recently been revised to +5% for improved operational flexibility.

(5) The requirement for coincident trip from pressurizer level in conjunction with pressurizer pressure has been deleted.

TABLE 1-3

RADIATION TEST CONDITION SIMULATION

Calculated* 4 mo dose: 4×10^7 rads total integrated dose; dose rate varies between $\sim 2.5 \times 10^6$ R/hr to $< 10^4$ R/hr

Test Conditions: [

]b,c,e

*Based on postulated loss of coolant accident assuming TID-14844 and shielding.

TABLE 1-4

INSTRUMENTS TESTED

Instrument	Function
A. Barton [ ]a,c	S/L
B. Barton [ ]a,c	S
C. Veritrak [ ]a,c	S
D. Veritrak [ ]a,c	L
E. Fischer and Porter [ ]a,c	S
F. Foxboro [ ]a,c	S
G. Foxboro [ ]a,c	S/L
H. Rosemont RTD [ ]a,c	S/L
I. Sostman RTD [ ]a,c	SL
J. Burns RTD [ ]a,c	S/L
K. RdF RTD [ ]a,c	S/L

S = Short Term
L = Long Term

TABLE 1-5

ORIGINAL QUALIFICATION UNITS

Type	Serial Number	Test Facility Designation	Range
Pressure	[ ]a,c - 142	AQ-2	[ ]a,c
Pressure	- 124	AQ-3	
Pressure	- 119	AQ-4	
Differential Pressure	- 229	AR-1	
Differential Pressure	- 165	AR-2	
Differential	- 275	AR-3	

TROUBLE SHOOTING UNITS

Type	Serial Number	Test Facility Designation	Range
Pressure	[ ]a,c - 139	AQ-5	[ ]a,c
Differential Pressure	- 274	AS-1	
Differential Pressure	- 276	AS-2	
Differential Pressure	- 347	AS-3	

b,c,e

TEMPERATURE (°F)

11.851-14

Figure 1-1 Sensor Environmental Qualification Program
Temperature Profile – Transmitters

2.0 SUPPLEMENTAL TEST PROGRAM PLAN

2.1 OBJECTIVE

To demonstrate that the Barton Lot 1 transmitters will meet specified performance requirements when subjected to separately simulated LOCA and Steam Line Break environments and thereby provide the NRC with the requested additional assurance that the Lot 1 units will meet their design specification in the long-term post accident environment.

2.2 ACCEPTANCE CRITERIA

The tests are considered acceptable if the specified functional requirements identified in Table 1-2 are successfully demonstrated when the transmitters are exposed to either the LOCA or Steam Line Break Environments specified in Section 2.4.

Acceptance criteria for the verification program are separately established for the seismic and environmental portions of the test program. Since the high energy lines inside containment are designed for seismic effects, the in-containment instruments are not assumed to be subjected to simultaneous seismic and environmental effects. Consequently errors due to these events are evaluated separately. The seismic error criterion allows for a variation of ±10% of output span during the seismic simulation. For performance of short term reactor trip/safety injection functions used to mitigate the consequences of a high energy pipe break the environmental error criteria are as specified in Table 1-2.

The measured environmental error is obtained by summating the maximum errors obtained during the separately completed radiation and steam tests. For example, a conservative estimate of the LOCA conditions at the maximum time permitted for initiation of the short-term protective function (i.e., 5 min) is a containment atmosphere temperature of [ ]^{a,b,c}°F and an integrated dose of [ ]^{a,b,c} rads.

Consequently, to derive the measured LOCA error, the maximum transmitter error measured during the steam test transient up to [ ][a,b,c]°F is added to the maximum error obtained during the separate irradiation tests up to [ ][a,b,c] rads. The resulting summated error is then compared for acceptability to the specified short term trip accuracy requirements identified in Table 1-2. For post accident monitoring functions (except wide range pressure), the goal is to limit the deviation in accuracy to about +25% for the arithimetic sum of the effects due to temperature and radiation from [ ][a,b,c] following the event. For example, for LOCA at [ ][a,b,c] the assumed environmental combination is [ ][a,b,c] rads and at [ ][a,b,c] the assumed combination is [ ][a,b,c] rads. For the wide range pressure transmitter the goal is to limit the deviation in accuracy to +10% following the postulated steam line break accident. Each transmitter is temperature compensated to ensure these requirements are met (e.g., since no error due to radiation is expected at [ ][a,b,c] rads the transmitter is temperature compensated so that its error does not exceed [ ][a,b,c] of output span at [ ][a,b,c] even if the ambient temperature remained at [ ][a,b,c] for a long period of time).

2.3 FAILURE CRITERIA

The primary purpose of equipment qualification is to reduce the potential for common mode failures due to anticipated environmental conditions. A test unit will therefore be considered to have failed the test if the functional requirements identified in Table 2-1 cannot be met, unless an investigation can establish that the failure mechanism is not of common mode origin or that plant specific analyses can demonstrate that the additional inaccuracy is acceptable.

2.4 TEST PLAN

The sequence of testing for the transmitters in these supplemental tests was radiation, seismic and a steam/temperature/pressure/chemical spray simulation.

2.4.1 RADIATION

The total specified integrated radiation dose is based upon a 40 year normal operating dose of $4x10^4$ rads plus a 4 month post accident dose. Calculations of dose for both LOCA and Steam Line Break are based on the assumptions, methods and results defined in Section 6.8.4 of Reference 1. The LOCA calculation (based on TID 14844 source terms and a 2.7 factor taken as credit for shielding) yields a specified integrated dose of $4x10^7$ rads at the transmitter. The Steam Line Break calculation (based on 1% clad damage and a 2.7 factor taken as credit for shielding) yields a specified integrated dose of $3.9x10^4$ rads at the transmitter.

2.4.2 SEISMIC

The required response spectra for generic testing of transmitters under this program is provided in Figure 2-1.

2.4.3 HIGH ENERGY LINE BREAK SIMULATION

The environmental test (steam/pressure/temperature/chemical spray) is aimed to achieve a [ ]^{a,b,c} ^oF saturated condition (~ [ ]^{a,b,c} psig) for Steam Line Break with a peak at about [ ]^{a,b,c} ^oF overshoot beyond the specific saturation condition of short duration in order to adequately simulate the required rise time. A [ ]^{a,b,c} ^oF peak temperature stabilizing at [ ]^{a,b,c} ^oF saturated conditions is specified for the LOCA simulation. For both Steam Line Break and LOCA tests a chemical spray of 1.14 weight percent boric acid and 0.17 weight percent sodium hydroxide is specified to be initiated at the beginning of the test and terminated after [ ]^{a,b,c} hours. A post accident monitoring period of [ ]^{a,b,c} months is specified to be simulated by holding the test chamber conditions at [ ]^{a,b,c} ^oF for [ ]^{a,b,c} more days.

References:

1. Butterworth G. and Miller R. B., "Methodology for Qualifying Westinghouse WRD Supplied NSSS Safety Related Electrical Equipment", WCAP 8587 Revision 2, February 1979.

b,c,e

Acceleration
(g's)

Frequency (Hz)

FIGURE 2-1
Broad Band Required Response Spectra

3.0 LOT I SUPPLEMENTAL TEST RESULTS

3.1 TEST FACILITY DESCRIPTION

The test facility is described in Section 3.2 of the original report. (NS-TMA-1950).

3.2 TEST UNITS

3.2.1 SUPPLEMENTAL LOCA TEST

In order to conclusively demonstrate the finding of the threshold testing reported in NS-TMA-1950, namely that the LOT 1 units would perform to specification when subjected to either the high temperature/low radiation of the steam line break or the lower temperature/high radiation environment of LOCA, a decision was made to carry out further testing using a transmitter that had previously been subjected to the severe test environment (Fig. 1-1). As a result, a previously tested differential pressure unit (AR-2, Table 1-5) was selected to be subjected to a further lower temperature test simulating a LOCA without being recalibrated or "burped" (i.e. cover removed and r laced) in the interim. Thus the overall test sequence to be complet by this unit was radiation (LOCA)/seismic/steamline break simulati /LOCA simulation. Since this sequence is in total more severe than any postulated conditions, successful performance of the selected unit would not only conclusively verify the findings of the threshold tests (NS-TMA-1950) but would demonstrate additional margin in the capability of the Lot 1 units with respect to their performance specification.

3.2.2 SUPPLEMENTAL STEAM LINE BREAK TEST

Two previously tested units were selected for the high temperature/low radiation steam line break test sequence. Again, by using transmitters that had previously been subjected to radiation and severe temperature environments, successful performance of the selected units would provide assurance of additional margin in the capability of the Lot 1 units. Pressure transmitter AQ-4 (Table 1-5) and differential pressure transmitter AS-2 were subjected to a further radiation dose approximately [ ]a,b,c R prior to seismic testing and a steam/chemical spray test simulation of the steam line break (Sectin 2.4.3). Since AQ-4 was an original qualification unit and AS-2 was used in the trouble shooting effort (Table 1-5) both of these units were "burped" before beginning this additional test sequence. The calibration and temperature compensation of these units remained unchanged.

3.3 TEST RESULTS

3.3.1 LOCA SIMULATION

The results of the additional LOCA simulation test on AR-2 are presented in Figure 3-1. The autoclave temperature peaked at 280°F a,b,c and was stabilized at [ ]a,b,c after about [ ]a,b,c minutes. The transmitter output had a peak negative error of [ ] a,b,c thus demonstrating that the [ ]a,b,c does not occur after [ ]a,b,c Rads total integrated dose during LOCA temperatures. The test was terminated when it was determined that the output had recovered and was not going to show the [ ]b,c,e previously observed. This test was completed August 1, 1978 shortly after the original qualification program reported in NS-TMA-1950.

3.3.2 STEAM LINE BREAK SIMULATION

Radiation Test

After being "burped", transmitters AQ-4 and AS-2 were exposed to a gamma source at a dose rates of [ ]a,b,c rads/hr to a total integrated dose of [ ]a,b,c rads. The maximum errors in percent of calibrated span noted during this test were [ ]a,b,c for AQ-4 and [ ]a,b,c for AS-2.

Seismic Test

The seismic testing of the irradiated transmitters consisted of multi-frequency biaxial seismic simulation with a broad band response spectra of [ ]^{b,c} times gravity (Fig. 2-1). Following five OBE's in position 1, SSE tests were conducted in four positions with three tests in each position required to envelope the broad band response spectra. The test response spectra are shown in Figure 3-2 through 3-18. The transmitter output deviations for each test are shown in Table 3-1. The transmitter returned to within their original reference accuracy following each seismic test run. The deviations in AS-2 were also present in the reference transmitter which is remote from the seismic table. In some cases these deviations were larger in the reference unit than in the test unit, indicating that most of the error is due to the system of interconnecting process lines employed during the test. Nevertheless, the indicated errors are significantly less than the 10% allowance for deviations during a seismic event.

Steam/Pressure/Chemical Spray Test

The transmitters were then subjected to the steam/chemical spray test with maximum pressure corresponding to saturated condition at [ ]^{a,b,c}. The chemical composition was [ ]^{a,b,c} ppm boric acid solution buffered to a pH of [ ]^{a,b,c} with sodium hydroxide. The temperature profiles for each transmitter are shown in Figures 3-19 thru 3-22 along with the transmitter output deviations. As noted there, the peak temperature in the autoclave was [ ]^{a,b,c} for the test on AQ-4 and [ ]^{a,b,c} for AS-2 before stabilizing at [ ]^{a,b,c}. The long term test temperature was held at approximately [ ]^{a,b,c} in both tests. All actual test parameters are therefore conservative with respect to the specification contained in Section 2.4.3.

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The maximum deviations, in percent of calibrated span, were less than [ ]^{a,b,c} for the first [ ]^{a,b,c} of the steam test for both transmitters and the maximum negative error during the complete test was approximately [ ]^{a,b,c} for both units. The maximum long term

term positive error of [ ]^{a,b,c} on the output of AS-2 occurred at about [ ]^{a,b,c}, which is the switch-in point for the temperature compensation network for Barton Lot 1 transmitters. This large positive error has been reported to the Commission (NS-TMA-2098 June 11, 1979, Anderson to Davis) and as a result of the corrective action described in that transmittal none of the units installed will exceed the positive error requirement specified in Table 1-2.

The magnitude of the error of AS-2 remained at approximately [ ]^{a,b,c} for the remainder of the [ ]^{a,b,c}. The deviation of AQ-4 had returned to less than [ ]^{a,b,c} as the temperature reached [ ]^{a,b,c} and remained stable thoughout the remainder of the test.

3.3.3 Summary of Test Results

The test results presented in this supplement provide data following an additional test sequence of radiation, seismic and steam/chemical spray that demonstrates the absence of a [ ]^{a,b,c} in the output of the Barton Lot 1 transmitters if the LOCA and steam line break tests are conducted separately and, furthermore, that the established test criteria are met.

TABLE 3-1

MAXIMUM DEVIATIONS DURING SEISMIC TEST
(All numbers are in percent of calibrated span
of the transmitter)

	AQ-4	AS-2
Position 1	a,c	a,c
Run 2		
Run 3		
Run 4		
Run 5		
Run 6		
Run 7		
Run 8		
Run 9		
Position 2		
Run 2		
Run 3		
Run 4		
Position 3		
Run 1		
Run 2		
Run 3		
Position 4		
Run 1		
Run 2		
Run 3		

b,c,e

Figures 3-1
to 3-22

are proprietary and
would appeare as
bordered on this
page

4.0 SUMMARY OF BARTON LOT 1 TESTS AND CONCLUSIONS

4.1 PRODUCTION RUN (LOT 1) BARTON TRANSMITTER TESTS

The initial production run tests on six Barton Lot 1 transmitter units reported in Section 3 of NS-TMA-1950 consisted of a full sequence of irradiation, seismic and steam/temperature/pressure/chemical spray. In an attempt to establish the required qualification with a single test, the test parameters were selected to envelope all anticipated applications. In particular, the specified accident irradiation dose is applicable to 4 months operation post-LOCA and the specified peak steam temperature is applicable to the Steam Line Break.

While these initial tests demonstrated the capability of the Lot 1 units to survive the applied test sequence and meet the established accuracy requirements under radiation, seismic and long-term post accident conditions, the tests failed to demonstrate the capability of the units to meet all specified accuracy requirements in the short term (< 2 hours) following the initiation of the steam test. In particular:

1. The narrow range pressure transmitter, to be used to monitor pressurizer pressure for trip/safety injection function initiation, exhibited a maximum positive error of [ ]^{b,c} span that was out of specification (+10% span) for the first [ ]^{b,c} of the test.

2. The wide range pressure transmitters, used to monitor reactor coolant system pressure, also exceeded their post accident monitoring specification of -10% for approximately [ ]^{b,c} into the test, but did not go beyond approximately [ ]^{b,c,e} span at any point.

3. The differential pressure transmitters, used for pressurizer level and steam generator level applications exceeded their post accident monitoring specification of -25% for approximately [ ]^{b,c} into the test.

The acceptability of the .tive error of [ ]b,c exhibited by the Barton Model [ ]a,c narrow range pressure transmitter is being evaluated on a case by case basis for those plants employing this unit in the pressurizer pressure function for short term automatic protective function initiation. The cause of the [ ]b,c,e exhibited by the wide range pressure and the differential pressure transmitters was the subject of additional testing described below.

4.2 CONCURRENT TESTING

Additional testing reported in Section 4 of NS-TMA-1950, was completed on three new transmitters to establish whether the [ ]b,c,e would be affected by simultaneous application of temperature and radiation and whether the results were dependent on the test sequence of irradiation and temperature. These tests showed that the [ ]b,c,e was only exhibited after or during radiation at temperatures above [ ]b,c,e and with the transmitter sealed. As a result of these tests and supporting information from Barton which showed that the [ ]b,c,e essentially disappeared after removal of the transmitter cover, it was concluded that a gas may be generated in the electronic housing during radiation which becomes conductive at elevated temperatures. While further investigation and gas sampling has still not to date identified the specific cause of this phenomenon, the conductive gas theory is still supported and 'burping' of the transmitter (i.e. lifting the cover) always causes the [ ]b,c,e to disappear.

4.3 THRESHOLD TESTING

Additional testing; reported in Section 5 of NS-TMA-1950, was completed on one previously tested and one new unit to establish the threshold of the appearance of the [ ]b,c,e to radiation and temperature. The tests showed that the [ ]b,c,e is not induced when either the temperature is below [ ]b,c,e or the applied dose rate is below [ ]b,c,e R/hr. Since during LOCA the peak temperature is no greater than [ ]b,c,e and during the

Steam Line Break the maximum dose rate does not exceed [ ]^{b,c,e} R/hr the threshold tests show that the transmitters will not exhibit the [ ]^{b,c,e} under separately simulated LOCA and Steam Line Break conditions.

4.4 SUPPLEMENTAL TESTING

The additional supplemental tests described in this report employed three previously tested Lot 1 units. The test results confirm the conclusions derived from the threshold tests that the Lot 1 units do not exhibit the [ ]^{b,c,e} and perform within the long term monitoring performance goals when tested under correctly simulated LOCA or Steam Line Break conditions.

4.5 OVERALL PROGRAM CONCLUSION

The overall test program has incorporated some 10 transmitters from the total Lot 1 production of 253 units. Short term trip capability has been demonstrated subject to a plant specific verification that a [ ]^{b,c} error is acceptable for the pressurizer pressure function. While the exact mechanism causing the [ ]^{b,c,e} observed in the original Lot 1 verification tests has not been identified, the range of conditions under which it occurs have been clearly defined and verified. Since the required combination of temperature [ ]^{b,c,e} and dose rate [ ]^{b,c,e} to generate the [ ]^{b,c,e} does not arise under either LOCA (280°F) of Steam Line Break (<7x10^{4} R/hr) conditions, the Lot 1 units are not subject to this phenomenon under applicable design basis event environments. The supplemental tests presented in this report have demonstrated this to be a fact and have provided the Commission with the requested additional confirmation that the Lot 1 units will perform within specification under applicable post accident monitoring conditions. Furthermore, since the units employed in these supplemental test have been previously tested, the successful results indicate that the Lot 1 transmitters have endurance capabilities in excess of the design specification.