WESTINGHOUSE CLASS 3

WCAP-9886

# QUALIFICATION TESTING OF ITT/BARTON TRANSMITTERS PRODUCTION LOT NO. 2

By

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April 1981

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This is revision one of a report prepared by J. B. Lipchak and R. B. Miller and submitted to the NRC by letter NS-TMA-2184, December 21, 1979.

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## ABSTRACT

This report documents the qualification test results of a sample of ITT Barton Model [ ]$^{d,c}$ transmitters from Lot No. 2 production run. The testing consisted of irradiation, seismic and severe environment simulation and demonstrates the adequacy of the instruments to perform required functions under these postulated adverse conditions. The environmental qualification was performed in accordance with IEEE-323, 1971 and the seismic simulation testing was in accordance with IEEE-344, 1975.

## 1.0 INTRODUCTION

The ITT Barton Model 764 differential pressure transmitter and Model 763 pressure transmitter were developed in conjunction with Westinghouse for use in nuclear power plants. These transmitters are used for normal operation and for operation after a high energy line break which results in a high temperature, humidity and pressure condition and possibly a high radiation environment.

Westinghouse had previously tested, qualified and reported the first production run (Lot 1) of these transmitters and the results have been submitted to the NRC (NS-TMA-1950 and NS-TMA-2120). The second production run of transmitters (Lot 2), which is the subject of this report, was also procured under lot control techniques for materials, manufacturing processes and procedures. All transmitters in the lot were required to be manufactured to the same baseline design from the same drawings using identical components and subassemblies by similarly trained people. To verify the qualification of the total lot, which is identified in Table 1-1, sample transmitters were selected from the lot, as identified in Table 1-2, and subjected to a lot verification test consisting of: irradiation, seismic simulation and steam/temperature/pressure/chemical spray testing as outlined in Table 1-3.

The differences between the Barton transmitters in this lot (No. 2) and the transmitters in the earlier lot (No. 1), other than the material procurement and manufacturing period, are identified below.

b,c,e

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TABLE 1-1

ITT/BARTON PRODUCTION LOT NO. 2
SERIAL NUMBERS

Pressure Transmitters-Model 763

318 to 349
352 to 363
370 to 372
384 to 401
413 to 438
442 to 447
459 to 470
474 to 480

Test Units - 370, 371, 372

Differential Pressure Transmitters-Model 764

349 to 438
441 to 505
507 to 560
562 to 633
652 to 750
753 to 775
825 to 827
832 to 843
857 to 866

Test Units 500, 501, 503, 504, 505

TABLE 1-2

PRODUCTION LOT NO. 2 TEST UNITS

| Type | Model No. | Serial No. | Test Facility Designation | Range |
|---|---|---|---|---|
| Pressure | 763 | 371 | BD-1 | 1700-2500 psig |
| Pressure | 763 | 370 | BD-2 | 0-3000 psig |
| Pressure | 763 | 372 | BD-3 | 0-1300 psig |
| Differential Pressure | 764 | 500 | BE-1 | 140-30 in. w.c. |
| Differential Pressure | 764 | 503 | BE-2 | 224-61 in. w.c. |
| Differential Pressure | 764 | 504 | BE-3 | 356-158 in. w.c. |
| Differential Pressure | 764 | 501 | BE-4 | 557-3 in. w.c. |

NOTE: All test units have a 4 mADC to 20 mADC output signal except BD-1 which has a 10 to 50 mADC. These two output spans are obtained by changing the value of a resistor in the output stage of the transmitters.

TABLE 1-3

SENSOR QUALIFICATION PROGRAM TEST SEQUENCE

1. Receive transmitters and inspect
2. Perform 21-point calibration check[a]
3. Perform time response test on certain units[b]
4. Deliver transmitters to radiation test facility
5. Install transmitters in source area
6. Perform 21-point calibration check
7. Irradiate transmitters for 30 minutes
8. Perform 21-point calibration check
9. Irradiate transmitters
10. Perform 21-point calibration check
11. Deliver transmitters to FH site
12. Perform time response test on certain units[b]
13. Perform 21-point calibration check
14. Deliver transmitters to seismic test facility
15. Monitor output of transmitters during seismic test
16. Perform 21-point calibration check
17. Monitor output of transmitters during environmental test
18. Perform 21-point calibration check.

NOTES:

a. All 21-point calibration checks were performed in accordance with SAMA Standard PMC20.1-1973.

b. Pressure transmitter BD-1 and differential pressure transmitter BE-4.

# 2.0 FUNCTIONAL REQUIREMENT AND TEST CRITERIA

## 2.1 GENERAL

The pressure and differential pressure transmitters in this production lot are required to meet the short term (minutes) protective functions (e.g. reactor trip, safety injection) requirement and/or the long term (days) post-accident monitoring functions. Allowable short term and long term accuracy requirements for the various functions, wherein these transmitters are utilized, are identified in Table 2-1. These accuracies are expressed in terms of deviation from the normal accuracy for all functions.

The required test sequence for the program was radiation exposure followed by seismic simulation and adverse environment (high energy line break) simulation as described in the following paragraphs.

## 2.2 RADIATION CONDITIONS

The worst case integrated radiation dose for any transmitter inside the containment is $4 \times 10^4$ Rads for a 40 year service period excluding accident. The accident radiation doses were established based on Total Integrated Dose (TID) source terms with credit taken for shielding based on the location of the transmitters. The resultant accident 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 2-2.

## 2.3 SEISMIC SIMULATION

The seismic simulation test was a biaxial multifrequency test per the response spectra shown in Figure 2.1. Three different input signals (tests) are required to duplicate the total response spectra.

## 2.4 ACCIDENT ENVIRONMENT CONDITIONS

The specified containment temperature profile is intended to envelope the calculated containment temperature conditions associated with a spectrum of postulated steam line break accidents and postulated loss of coolant accident and should be compared with plant specific information.

The environmental test (steam/pressure/temperature/chemical spray) shown in Figure 2.2 was aimed toward a 320°F saturated condition (~75 psig) with a peak at about 370°F of short duration occurring in order to adequately simulate the required rise time of three (3) seconds. The 320°F saturated condition was held for 20 minutes and test conditions were stabilized at 250°F after 24 hours. Chemical spray, consisting of 2750 ppm boric acid dissolved in water and adjusted to a pH of 8.5 at 25°C by sodium hydroxide, was applied for the first 24 hours of the test at a flow rate of approximately six gallons per hour.

Included in the test temperature profile is an accelerated post accident thermal aging simulation at 250°F. The 15 day period at elevated temperature represents a four (4) month post accident monitoring period at a normal average in-containment temperature of 160°F. This profile is calculated by using a conservative activation energy (0.5 ev) in the Arrhenius equation for estimating thermal aging characteristics.

## 2.5 FAILURE CRITERIA

Failure criteria for the verification program are established for the individual seismic test and the environmental portion 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 percent of output span during the seismic simulation. For performance of reactor trip/safety injection functions used to mitigate the consequences of a high energy pipe break, a deviation of ±10 percent of output span is permitted. For plants with model D2 and D3 steam generators this error is limited to +5 percent (feed line break only) on narrow range steam generator level transmitters to preserve operating margin.

The ±10 percent requirement for environmental accuracy is the algebraic sum of the effects on transmitter accuracy due to the containment ambient temperature and radiation at the time of the protective function initiation. This requirement is predicated upon the assumption that, at the time of protective function initiation, the total integrated dose to the transmitter is $\leq 10^6$ rads and the containment temperature environment for the electronics is $\leq$280°F. For post accident monitoring functions (except wide range pressure and steam pressure), the goal is to limit the deviation in accuracy to about ±25 percent for the algebraic combination of the effects due to temperature and radiation from 5 minutes to 4 months following the event. At 5 minutes the assumed combination would be 320°F and $1 \times 10^6$ rads and at 4 months the assumed combination is 160°F and $4 \times 10^7$ rads. For wide range pressure and steam pressure transmitters the goal is to limit the deviation in accuracy to ±10 percent following the postulated steam line break accident. Each transmitter is temperature compensated to ensure these requirements are met (e.g., if no error due to radiation is expected at $1 \times 10^6$ rads the transmitter would be temperature compensated so that its error does not exceed ±10 percent of output span at 280°F even if the ambient temperature remained at 280°F for a long period of time).

The test program will be considered successful if the above criteria are met by all transmitters in the program. However, infrequent failures of a random nature can be expected during the testing of a sample. One failure or two different failures during the test of three similar units will be considered random and the test a success unless the failure(s) investigation reveals potential common mode problems. It should be noted that these are generic error allowances and individual plant evaluations may show that larger instrument errors are acceptable.

TABLE 2-1

ALLOWABLE ACCURACY TOLERANCES FOR IN-CONTAINMENT TRANSMITTERS REQUIRED TO MITIGATE OR MONITOR THE EFFECTS OF POSTULATED ACCIDENTS (RADIATION AND ENVIRONMENT)

| Transmitter Function | *Accuracy (Percent of Span) Short Term | Long Term |
|---|---|---|
| 1. Pressurizer Pressure | +10 | N/A |
| 2. Pressurizer Water Level | N/A | ±25 |
| 3. Steam Generator Pressure** | +10 | ±10 |
| 4. Steam Generator Water Level (Narrow Range) | +10 | ±25 |
| 5. Steam Generator Water Level (Wide Range) | NA | ±25 |
| 6. Steam Flow | -10 | N/A |
| 7. Pressure-Reactor Coolant System (Wide Range) | N/A | ±10 |
| 8. Containment Sump Water Level | ±10 | ±25 |

* Accuracy is the allowable deviation from the normal accuracy.
** Located outside the containment.

TABLE 2-2

RADIATION TEST CONDITION SIMULATION

Calculated* 4 mo dose: $4 \times 10^7$ 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

b,c,e

Acceleration
(g's)

2.5

Frequency (Hz)

FIGURE 2-1
Broad Band Required Response Spectra

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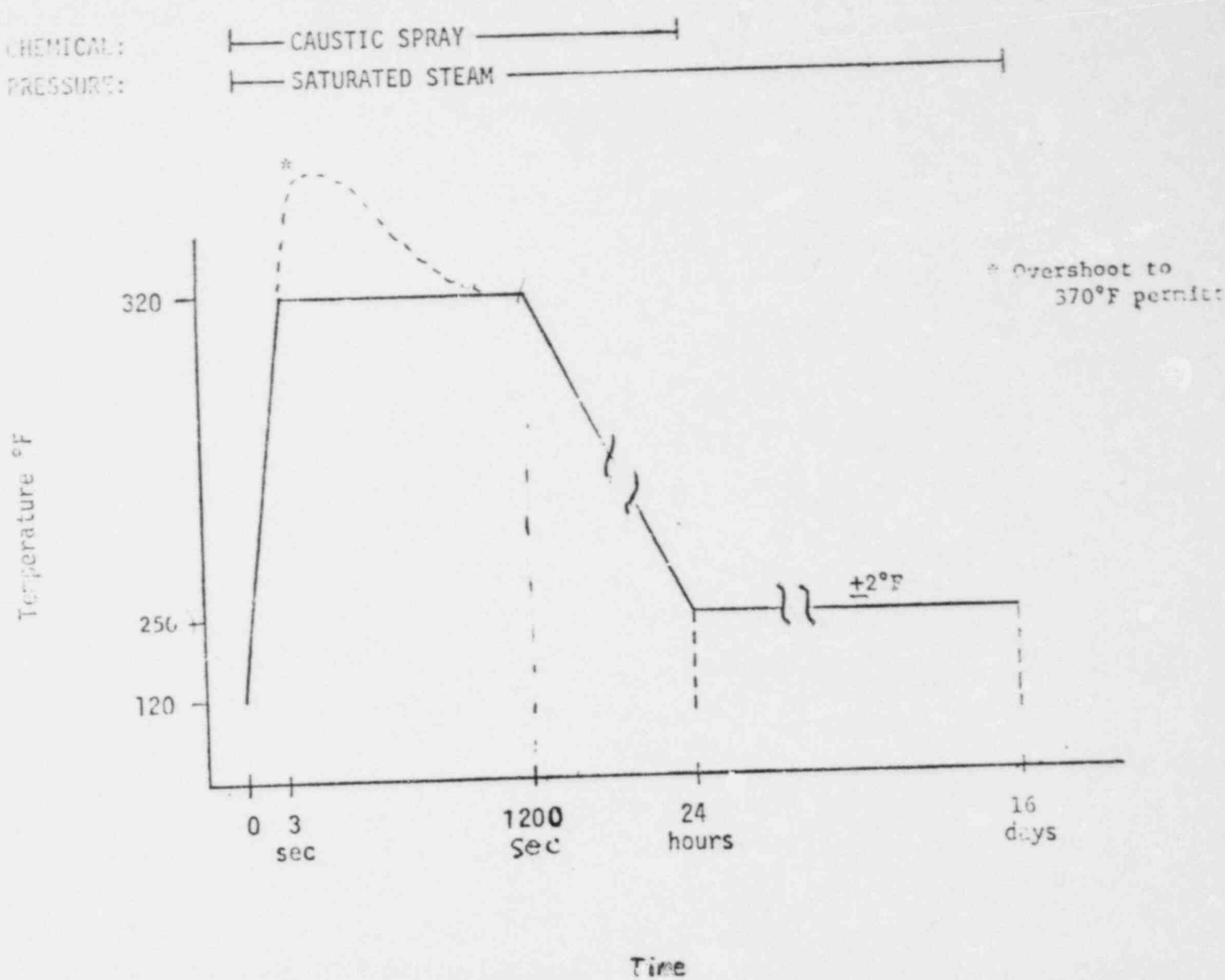


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FIGURE 2.2

TEST CHAMBER ENVIRONMENT

2.6

POOR ORIGINAL

# 3.0 RADIATION TEST

## 3.1 RADIATION TEST FACILITY

The initial phase of testing involved exposure of the process measurement instruments to gamma radiation at rates equivalent to those which would occur in containment during normal life and applicable accident conditions. The irradiation tests were conducted by Westinghouse personnel at the Isomedix, Inc., facility located in Parsippany, New Jersey. The source of gamma radiation at this facility is cobalt-60, whose field strength is approximately 1,500,000 curies. This source consists of metallic cobalt strips arranged on a sliding frame assembly, which is raised and lowered by a hydraulic system from below the cell floor under 18 feet of water. The source strength and radiation field determinations were made by Isomedix, Inc., personnel by placing red Persplex dosimetry in matrix mapping patterns which encompassed the instrument installation area. The determination of the source strength in the designated mapping area was conducted for 30 minutes by the Isomedix personnel; cognizant Westinghouse personnel observed the readout of the dosimetry after the 30-minute exposure period. All irradiation tests were conducted in air at ambient and atmospheric conditions.

## 3.2 RADIATION TEST PROCEDURE

The transmitters were delivered to the Isomedix test facility by Westinghouse personnel for irradiation. Upon delivery the test units were inspected and prepared for test in accordance with Sensor Qualification Program Test Procedures.

Source calibration curves and a radiation map provided by Isomedix were used to position the test units for the selected dose rate of 2.0 to 3.0 M rad/Hour for a Total Integrated Dose (TID) of 50 Megarads. Once the process instruments had been installed, a 21 point reference accuracy measurement was conducted. Reference accuracy meansurements were also obtained after 30 minutes of irradiation and at the completion of the test when the required total integrated dose of at least [ ]$^{b,c,e}$ megarads had been obtained. The test units were oriented as required to obtain a symmetrical overall radiation dose. During the irradiation procedure the test units were normally energized and a simulated pressure signal (dry nitrogen) was used to obtain a signal of approximately 50 percent of calibrated span. The differential pressure test units were pressurized to 2100 psig static pressure.

The dose rate was verified by measuring the total integrated dose during the first 30 minutes of irradiation. The distance from the source to the test units was logged.

When the required exposure time was complete, the test units physical integrity could not be tampered with or altered. Strict material control was enforced to ensure that no transmitter covers could be disturbed or mechanical or electrical adjustments performed. The only operation permitted at this point was the 21-point reference accuracy measurements on each test unit.

Upon completion of the radiation tests, the test units were returned by Westinghouse personnel to the Forest Hills site for pre-seismic test reference accuracy measurements.

Time response tests on two of the test units were performed before and after irradiation.

### 3.3 DATA ACQUISITION

At all times during the irradiation testing (including source up or down condition) the test units were powered by WISD 7300 series 40 volt NLP cards. The total instrument loop resistance was 600 ohms, including the 250 ohm test point resistance associated with the NLP card. The output signal for each test unit was recorded by an analog strip chart recorder and a digital data logger.

Reference accuracy measurements were obtained prior to, during (30 minutes) and after irradiation and are documented in Table 6-1. Calibration of all test units was performed in accordance with SAMA Standard 20.1-1973 by utilizing a 558 step FORTRAN IV computer code designed specifically for calibration data. This code, program DCRGRS, calculates the slope and intercept of the linear regression line best fitting the data. It also computes the error between the actual and calculated ordinates (indicating the maximum such error), the correlation and the span. The routine also determines, as percentages of full calibrated span; the repeatability, hysteresis, and change in slope. The transmitter test summary and results of the irradiation are presented in the Test Results section of the report.

# 4.0 SEISMIC TEST

## 4.1 SEISMIC TEST FACILITY

The seismic test was conducted at the Westinghouse Advanced Energy Systems Division located in Large, Pennsylvania. This facility has capabilities for performing and monitoring random frequency biaxial seismic simulations. The test machine consisted of a 6 by 6 ft test table coupled to a hydraulic piston capable of creating a peak force of 22,000 lbs with a 20 inch peak to peak stroke and a maximum velocity of 100 inches/second. The angle of the piston and the orientation of the test package were such that equal accelerations were produced in the horizontal, front to back, and side to side directions.

The seismic inputs were recorded on a 14 channel FM tape and played back on a Honeywell model 101 recorder. The individual sine beat signals were attenuated, summed and twice integrated prior to feeding into the hydraulic controller. Table acceleration was measured by Kulite model GAD-813-50 accelerometers and recorded by Brush Mark 200 recorders and on 14 channel FM tape. The control accelerometer was also recorded and analyzed by a Spectral Dynamics Model 13231 shock spectrum analyzer. The test response spectrum was then plotted by an Electro Instruments 500 x-y plotter.

Signals from the test and reference transmitters were conditioned by B F model 10-800 amplifiers and recorded on Brush Mark 200 recorders.

## 4.2 SEISMIC TEST PROCEDURE

The test configuration, as indicated in Figure 4.1, results in three equal directional forces by having the table input motion at an angle of 35 degrees from the horizontal and the equipment positioned so that it principal axis is at a 45 degree angle with respect to the horizontal component of the input. This configuration results in equal and simultaneous inputs to all three principal equipment axis. The control accelerometer is mounted on the test table to measure the horizontal

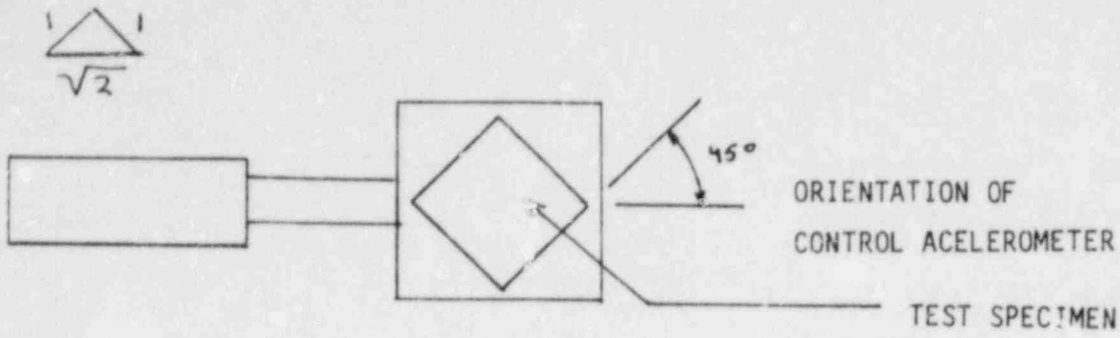
($\sqrt{2}$ times equipment front to back and side to side input) and vertical accelerations. The actual test response spectra has a peak amplitude of ten times gravity, which is $\sqrt{2}$ times the required response spectra as shown in Figure 4.2.

The testing was preceded by a sine sweep of the entire test setup at a level of 0.2 G at frequencies of 1 to 50 Hz then 50 to 1 Hz at a sweep rate of one(1) octave per minute. This was followed by 5 operating basis earthquakes (OBE) level tests in position 1. Safe shutdown earthquake (SSE) level tests were than conducted in four postions (0°, 90°, 180°, 270°) with three tests in each position to envelop the required broad band response spectra.

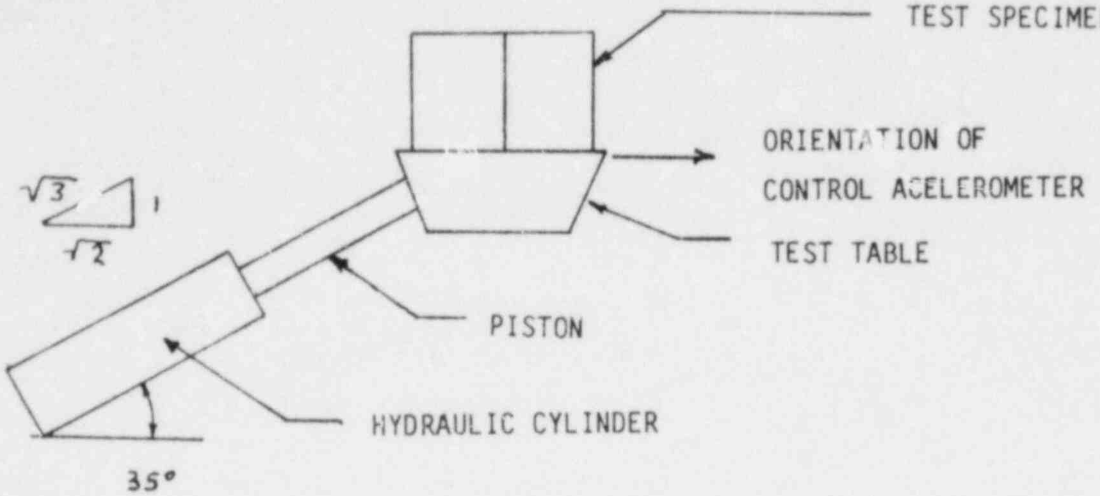
## 4.3 DATA ACQUISTION SYSTEM

The output of all the test units were run to the power supply and data acquisition equipment. Power was supplied from WISD 7300 series NLP cards. The conditioned signals were fed to both strip chart recorders and FM tape recorders.

Accelerometers were mounted on the test table, test fixture and test units. All accelerometer outputs were recorded on strip chart recorders and FM tape recorders. The control accelerometer output was also fed into a shock spectrum analyser. The result of the analysis, which resulted in a acceleration versus frequency correlation was used to determine the success of each test run.




TOP VIEW




SIDE VIEW

FIGURE 4.1

SCHEMATIC OF BIAXIAL TEST SETUP

# 5.0 ENVIRONMENTAL TEST

## 5.1 ENVIRONMENTAL TEST FACILITY

The test facility at Forest Hills, Pittsburgh, Pa., (Figure 5.1) was used for environmental testing of the test units. This comprehensive facility consists of the Trip Test Steam Supply System, Trip Test Chemical Spray System, Test Chemical Spray System, Test Article Environmental Chambers, Severe Environmental Steam Supply System, and High-Pressure Nitrogen Supply System. Data acquisition facilities comprise multipen recorders, digital voltmeters, and a digital data logging system; the digital data logger is the primary system and the analog recorders and digital voltmeters make up the redundant system. Included in the test facility is a diesel-powered emergency power backup system, which comes on line automatically in the event of loss of main site power. Design and construction of the chambers and loop piping complies with the latest ASME Boiler and Pressure Vessel Codes.

The LOCA facility at Forest Hills was constructed to simulate as accurately as possible the in-containment conditions during postulated accidents (for instance, steam-line breaks). The Trip Test Chemical Spray System, an integral part of the test facility, was constructed to simulate the addition of chemical spray during the postulated pipe break. This system consists of an open 1000-gallon stainless steel mixing tank, primary and redundant metering pumps and the required piping, valves, and fittings. The chemical spray consists of 2750 ppm boric acid dissolved in water and adjusted to a pH of 8.5 at 25 C by sodium hydroxide. The solution is premixed and stored in the 1000-gallon mixing tank. A constant displacement metering pump supplies the room-temperature solution to the main inlet steam line at a flow rate of approximately 6 gallons per hour. An option is available for spray injection directly into spray nozzles located in the environmental chamber; however, a distinct advantage is achieved by the injection into the main steam feed, which produces an extremely fast rise time in the chamber during initial transient conditions. Chemical analyses are made periodically to ensure proper chemical makeup.

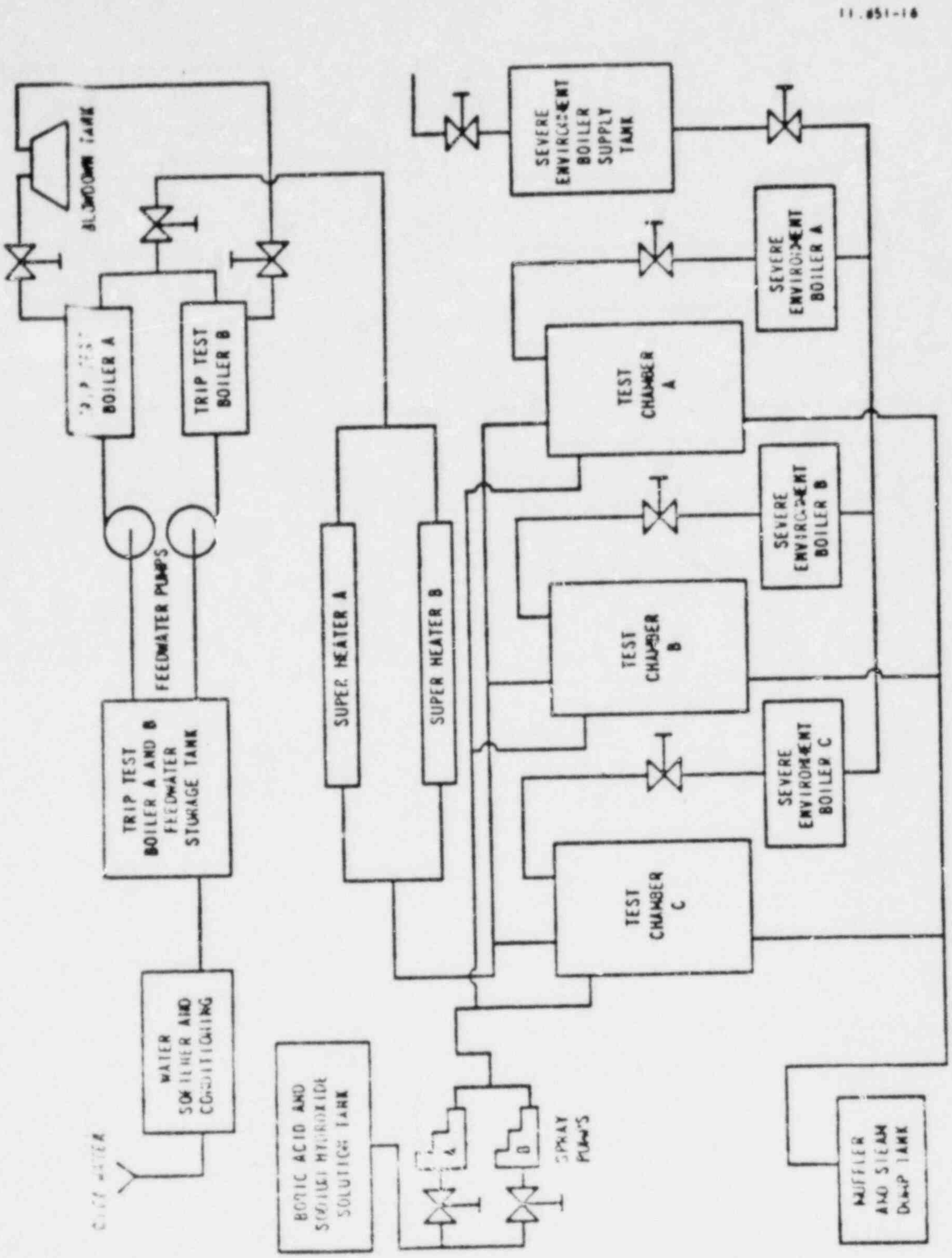



Figure 5-1. Environmental Test Facility Layout

Steam supply for the simulation of a postulated break accident is provide by an arrangement of oil-fired boilers and electrically powered superheaters. Steam leaving the boilers at 212 F and 14.7 psia enters the superheaters; with this heat addition the steam temperature is raised to 540 F saturated. Steam enters the test chamber through two nozzles located on top of the environmental chamber. Air is permitted to discharge from the chamber through a manually operated discharge valve, which is preset to maintain a back-pressure of 75 psig in the test chamber. The discharge of the valve exhausts through a steam muffler and water suppression tank located outside the test area.

## 5.2 ENVIRONMENTAL TEST PROCEDURE

The transmitters were installed in the three test chambers and a 21 point reference accuracy measurement was performed on each test unit. The test units were powered from WISD 7300 series, 40 volt NLP cards during the environment test. The test units were pressurized at approximately 50 percent of calibrated span and differential pressure units were pressurized to 2100 psig static pressure using dry nitrogen as the pressure medium.

The output of the test units were monitored and recorded.

## 5.3 DATA ACQUISITION SYSTEM

During the environment tests, a combination of analog strip chart recorders, a digital data logger (microprocessor), and a digital data logger (minicomputer) constituted the monitoring system for all instruments. The four-channel analog recorders were used as the primary readout for each instrument during the trip portion of the environmental test. A programmable-microprocessor-based data logging system functioned as a redundant recording system during the trip test and as a primary system during the severe environment test. During the severe environment test, a standby system, composed of a general-purpose wide-range minicomputer, was kept on line at all times. Instrument signals were directed via a switching network in which the signal path was directed to the primary data acquistion system and manually switched to the redundant system upon partial or total primary instrument failure.

# 6.0 TEST RESULTS

## 6.1 RADIATION TESTING

The transmitters were exposed via a gamma source at a dose rate of two (2) to three, (3) megarads per hour depending on location. The total integrated dose for the seven (7) transmitters varied from a minimum of 50.4 megarads (BE-2) to a maximum of 55.9 megarads (BD-2), depending on transmitter location. The transmitter calibration checks associated with the radiation test are summarized, in Table 6.1 as test operations 200, 217, and 250 for pre-irradiation, after 30 minutes and post-irradiation respectively.

The maximum output error for the pressure and differential pressure transmitters during the radiation testing is indicated in Table 6.2 along with the errors after 30 minutes of irradiation.

Time response testing which was conducted before and after irradiation on one of each pressure (BD-1) and differential pressure (BE-4) test units indicated [ ]b,c,e in time response due to the radiation.

## 6.2 SEISMIC TESTING

All transmitters remained functional throughout the test and no structural failures or loosening of bolts was observed. The transmitters were subjected to five OBE level seismic simulations and twelve SSE level events (three in each of four positions). The test response spectra (TRS) and the required response spectra (RRS), for each test are shown in Figures 6.1 through 6.17.

The transmitter output deviations for each test run are shown in Table 6-3. The [deviations]b,c,e in the differential pressure transmitters (BE-1, 2, 3, and 4) were also [ ]b,c,e in the reference transmitters, associated with these test units; which are remote from the seismic test table. In some cases these [ ]b,c,e in the reference unit than in the test unit, indicating that most of the [error is due to the system of interconnecting process lines][b,c,e]. Nevertheless, the indicated errors are less than the 10 percent allowance for deviations during a seismic event.

Each transmitter was subjected to seventeen seismic test runs (5 OBE's and 12 SSE's). The transmitters steady state output returned to within its reference steady state value on all pressure transmitters. [~~Three~~][b,c,e] of the four differential pressure transmitters [~~slightly exceeded~~][b,c,e] the reference accuracy in [~~five instances~~][b,c,e] during the 68 calibration checks performed on the four differential pressure units.

The transmitter calibration checks associated with the seismic test are shown in Table 6.1 as test operations 310 (pre-seismic) and 550 (post-seismic).

## 6.3 ENVIRONMENTAL SIMULATION TEST

The transmitters were then subjected to the steam/chemical spray test with maximum pressure corresponding to saturated conditions at 320°F. The chemical composition was 2750 ppm boric acid solution buffered to a pH of 8.5 with sodium hydroxide. The transmitter calibration checks associated with the severe environmental test are shown in Table 6.1 as test operations 550 (before test) and 760 (after test). The temperature profiles for each test along with the transmitter output deviations during the test are shown in Figures 6.18 through 6.29. These graphs show time periods of 5 minutes, 60 minutes, and 24 hours into the test. The results of the stable condition from 24 hours to 16 days are not graphed but maximum errors are shown in Table 6.4. The test facility designation for the transmitter is noted at the bottom of each graph and where more than one transmitter deviation is plotted on the same graph, the first unit is plot A, second is plot B, etc. The maximum deviations during selected time periods are shown in Table 6.4.

TABLE 6-1

TRANSMITTER PRE- AND POST-TEST CALIBRATION CHECK SUMMARY

| Designation | Model | Serial Number | Range | Test Operation[a] | Reference Accuracy | Deadband | Hysteresis | Repeatability |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Results -percent of Span |
| BD-1 | 763 | 371 | 1700-2500 psia | | | | | b,c,e |

a. Test operation code

15 - Initial Calibration (FH)
140 - Post Time Response (FH) (BD-1 and BE-4)
200 - Pre-Irradiation (N.J.)
217 - During Irradiation (30 min) (N.J.)
250 - Post-Irradiation (N.J.)
310 - Pre-Seismic (FH)
440 - Post Time Response (FH) (BD-1 and BE-4)
550 - Post Seismic (FH)

TABLE 6-1 (Continued)

TRANSMITTER PRE- AND POST-TEST CALIBRATION CHECK SUMMARY

| Designation | Model | Serial Number | Range | Results - percent of Span: Test Operation[a] | Reference Accuracy | Deadband | Hysteresis | Repeatability |
|---|---|---|---|---|---|---|---|---|
| BD-2 | 763 | 37[illegible] | 0-3000 psig | | | | | |

b,c,e

TABLE 6-1 (Continued)

TRANSMITTER PRE- AND POST-TEST CALIBRATION CHECK SUMMARY

| Designation | Model | Serial Number | Range | Test Operation[a] | Reference Accuray | Deadband | Hysteresis | Repeatability |
|---|---|---|---|---|---|---|---|---|
| | | | | | Results -percent of Span | | | |
| BD-3 | 763 | 372 | 0-1300 psig | | | | | |

b,c,e

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TABLE 6-1 (Continued)

TRANSMITTER PRE- AND POST-TEST CALIBRATION CHECK SUMMARY

| Designation | Model | Serial Number | Range | Test Operation[a] | Reference Accuray | Deadband | Hysteresis | Repeatabili | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Results -percent of Span | | | | | |
| BE-2 | 764 | 503 | 224-61" w.c. | | | | | | b,c,e |

6-7

TABLE 6-1 (Continued)

TRANSMITTER PRE- AND POST-TEST CALIBRATION CHECK SUMMARY

| | | | | Results -percent of Span | | | | |
|---|---|---|---|---|---|---|---|---|
| Designation | Model | Serial Number | Range | Test Operation[a] | Reference Accuray | Deadband | Hysteresis | Repeatability |
| BE-3 | 764 | 504 | 356-158" w.c. | | | | | |

b,c,e

6-?

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TABLE 6-1 (Continued)

TRANSMITTER PRE- AND POST-TEST CALIBRATION CHECK SUMMARY

| | | | | Results -percent of Span | | | | |
|---|---|---|---|---|---|---|---|---|
| Designation | Model | Serial Number | Range | Test Operation[a] | Reference Accuray | Deadband | Hysteresis | Repeatability |
| BE-4 | 764 | 501 | 557-3" w.c. | | | | | |

b,c,e



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TABLE 6.2

OUTPUT ERROR DUE TO RADIATION EXPOSURE

| Test Unit | Model | Range | Error At $1 \times 10^6$ Rads | Maximum Error (Percent of Span) |
|---|---|---|---|---|
| BD-1 | 763 | 1700-2500 psig | -2.1 | -6.05 |
| BD-2 | 763 | 0-3000 psig | -0.23 | -2.2 |
| BD-3 | 763 | 0-1300 psig | -0.31 | -3.2 |
| BE-1 | 764 | 140-30 in. W. C. | -0.73 | +0.7 |
| BE-2 | 764 | 224-61 in. W. C. | -0.35 | -1.6 |
| BE-3 | 764 | 356-158 in. W. C. | -1.0 | -3.8 |
| BE-4 | 764 | 557-3 in. W. C. | -0.4 | -6.4 |

TABLE 6.3

MAXIMUM DEVIATIONS DURING SEISMIC TEST

(All numbers are in percent of calibrated span)

b,c,e

| Test Run | BD-1 | BD-2 | BD-3 | BE-1 | BE-2 | BE-3 | BE-4 |
|---|---|---|---|---|---|---|---|
| Position 1 | | | | | | | |
| 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 | | | | | | | |

TABLE 6.4

MAXIMUM DEVIATIONS DURING SEVERE ENVIRONMENT

| Test Designation | Model and Range | Maximum Deviations in Percent of Calibrated Span | | |
|---|---|---|---|---|
| | | During First 5 Minutes | During First 24 Hours | From 24 Hours To 16 Days |
| BD 1 | 763<br>1700-2500 psig | +5.1 | +6.6 | +3.88 |
| BD 2 | 763<br>0-3000 psig | -2.6 | -2.6 | +0.9 |
| BD 3* | 763<br>0-1300 psig | -1.5 | -3.0 | -2.9* |
| BE 1 | 764<br>140-30 in. W. C. | +3.4 | -4.2 | +1.6 |
| BE 2 | 764<br>224-61 in. W C. | -17.2 | -17.2 | +1.25 |
| BE 3 | 764<br>356-158 in. W C. | +7.3 | +7.3 | +4.5 |
| BE 4 | 764<br>557-3 in. W C. | -6.0 | -7.4 | -2.3 |

* Lost transmitter output after 164 hours. See Section 7

Figures 6.1 through 6.29 are proprietary in their entirity, therefore, pages 6.13 through 6.41 have been omitted according to criteria covered by codes b,c,e.

## 7.0 SUMMARY AND CONCLUSIONS

As noted in the data in Section 6, a few anomalies occurred during the test program.

1) During the first half of the radiation test two transmiters (BE-3 and BE-4) were inadvertantly valved out for about 9 hours. Therefore no useful data was recorded during this period. However, the calibration check at the midpoint of the test (when the units are turned) indicated that the transmitters were functioning normally and the second half of the radiation test was conducted with the transmitters valved in.

2) At the completion of the radiation test the calibration check of BE-3 and BE-4 revealed [ ]b,c,e as noted in Table 6.1. The next calibration check at Forest Hills [ ]b,c,e. A recheck of the calibration data at the radiation facility showed that [ ]b,c,e. This was determined by comparing the intended input with the actual input as recorded by the reference transducer.

3) The output from test unit BD-3 [ ]b,c,e into the environmental test. After completion of the test, it was discovered that an external lead wire (part of the 8 foot pigtail supplied with the transmitter) had apparently [ ]b,c,e to the insulation, as a result of all the handling necessary to install and transport the test items. The wire was exposed to the environment and had [ ]b,c,e. The transmitter met the accuracy requirements after the [ ]b,c,e

Westinghouse provides these wires external to the transmitter to enable the customer to make a splice or connection in a convenient place near the instrument. After reviewing this occurrence, Westinghouse has concluded that no change to the [ ]b,c,e of production units are not subject to the [ ]b,c,e received by the test units and, furthermore, the production units are subject to stringent inspection procedures prior to installation in the plant.

4) During the final calibration check, S/N 764-504 [ ].b,c,e The [ ]b,c,e disappeared after the unit was tapped with a wrench. This problem has been observed by Barton on a few units during the calibration runs, but only after [ ].b,c,e A shift has never been observed at ambient temperatures or during temperature compensation at [ ].b,c,e When it has occurred Barton has corrected the problem [

]. b,c,e

The problem appears random in nature in that it has occurred on only a limited number of transmitters all subjected to the same compensation conditions. [ ] at these conditions. The temperature compensation runs completed on each production unit are the primary contributors since they typically require [ ].b,c,e The steam test, which is defined to envelope several shorter duration accident conditions, adds only a few additional hours of operation at high temperatures. Therefore, we believe that the temperature compensation runs are the primary source of the [ ]b,c,e problem. Further, the problem can be eliminated by [ ].b,c,e Based on our evaluation, Westinghouse is taking the following actions:



3400 4:1

Inform all Lot No. 1 and Lot No. 2 customers to [ ]b,c,e during the next calibration check.

Ensure that all [ ]b,c,e before leaving Barton on future units.

5) S/N 764-503 exhibited an unusually [ ]b,c,e early in the temperature transient. The magnitude of this [ ]b,c,e far exceeded the [ ]b,c,e of the other three differential pressure units tested. Since this appeared to be a [ ]b,c,e caused by [uneven heat-up of the strain gages and the temperature compensating elements]b,c,e, Westinghouse performed additional tests on an instrumented unit to determine the [ ]b,c,e (Appendix A).

Based on this information, Westinghouse and Barton developed the model in Appendix A to determine the acceptability of the remaining units in Lot 2. This model uses the values of the [ ]b,c,e to calculate the expected [ ]b,c,e temperature difference. Also included is the [ ]b,c,e determined from the final temperature calibration.

Maximum errors for all Lot No. 2 Barton differential pressure transmitters were calculated using the methods described in Appendix A. As noted there, the primary function of concern was steam flow which provides a trip signal following a steam line break and has a -10 percent error limitation. Two serial numbers (569 and 629) must be modified so that excessive temperature compensation is not required. At present, these units have calculated errors of [ ]b,c,e respectively. All other units are well within the trip and/or monitoring accuracy requirements described in Section 2.5.

6) In order to maintain operating margin on plants that have Model D2 or D3 steam generators, an additional requirement to limit the positive error to +5 percent was imposed on the narrow range steam generator level transmitters following a feedline break. As noted in the data summary, serial number 764-504 slightly exceeded this requirement during the first minute. Additional tests were performed (Appendix A) on the same unit using water instead of nitrogen as the process medium. This caused the temperature of the strain gage to track the temperature of the circuit board more closely during the first minute and limited the positive error to less than [ ]b,c,e Table 7.1 contains a summary of total errors.

7) Westinghouse has made every effort to perform tests on transmitters that are representative of actual installations. The units are tested at static pressure and in most cases they are also calibrated to the actual spans for the process being measured. In some cases, particularly with differential pressure units, it is not prudent to test every span so units with the most turn-down (e.g. S/N 500 110 in $H_{2}0$ span) are selected for the test program. Table 7.2 lists those spans tested vs. those supplied from Lot No. 2.

TABLE 7.1

Total Errors

(percent of calibrated span)

| Test Unit | Trip w/rad | Trip w/o rad | Monitoring w/rad | Monitoring w/o rad |
|---|---|---|---|---|
| BD-1 763-371 | +7.2 | +5.1 | +12.6 | +6.6 |
| BD-2 763-370 | -2.8 | -2.6 | +3.1 | -2.6 |
| BD-3 763-372 | -1.8 | -1.5 | -6.2 | -3.0 |
| BE-1 764-500 | +4.1 | +3.4 | -4.9 | -4.2 |
| BE-2 764-503 | -17.5 | -17.2 | -18.8 | -17.2 |
| BE-3 764-504 | +5.0 | +4.0 | +7.8 | +4.0 |
| BE-4 764-501 | -6.4 | -6.0 | -13.8 | -7.4 |

Note: For conservatism, the radiation error is assumed to be the same polarity as the temperature error and since all monitoring errors are well within the allowances using maximum values, no effort was made to reduce the data using errors at each discrete point in time

TABLE 7.2

Test Units

Model 763

1700 - 2500 psig
0 - 3000 psig
0 - 1300 psig

Model 764 (all spans in inches $H_2O$)

140 - 30
224 - 61
356 - 158
557 - 3

Shipped Units

Model 763

1700 - 2500 psig
0 - 3000 psig
0 - 1300 psig
0 - 200 $KG/cm^2$
110 - 175 $KG/cm^2$

Model 764 (all spans in inches $H_2O$)

520 - 200
260 - 40
160 - 0
420 - 140
0 - 1000
0 - 500
600 - 0
600 - 120
138 - 600
214 - 0 - 26
0 - 400
145 - 354
217 - 320
0 - 1300
58 - 322
39 - 137
0 - 1020
29 - 139

# APPENDIX A

# EVALUATION OF DYNAMIC TEMPERATURE EFFECTS

## TABLE OF CONTENTS

APPENDIX A

is proprietary in its entirity
and has been omitted according
to criteria covered by codes a,b,c,e.