WESTINGHOUSE

QUALIFICATION TESTING OF
ROSEMOUNT MODEL 1153 SERIES A
ELECTRONIC TRANSMITTERS

PREPARED BY R.A. Bitting 1/4/79
R.A. Bitting, Process & Control Board Group

REVIEWED BY R.B. Miller 1/5/79
R.B. Miller, Process & Control Board Group

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1.0 INTRODUCTION

Rosemount Model 1153 Series A transmitters were tested to learn their operating characteristics during a Westinghouse PWRSD level A qualification test. The test consisted of a sequential series in which the transmitters were irradiated, put through a seismic simulation and subjected to a high temperature steam environment. Details of each of these sub-tests appear in this report.

2.0 TEST UNITS

The test units were Rosemount Model 1153 series A transmitters which are manufactured specifically for nuclear power application. A listing of the identification numbers, serial numbers and ranges appear in Table 2.1. An outline and dimensional drawing appears in figure 2.1.

The test units were manufactured under standard Rosemount production procedures for nuclear grade equipment. They were purchased by Westinghouse purchase order 546-CLC-290475-MN. Each transmitter was supplied with a data package listing final calibration data, material certifications for all pressure boundry parts and certification of hydrostatic testing and nuclear grade cleaning.

WPWRSD normally specifies a sealed transmitter with pig-tail leads for electrical connection. Since Rosemount does not supply this, it was necessary to obtain a seal from another source. The seal used was a Conax fitting, part number PL-18-BZ-P, purchased by WPWRSD purchase order 546-TSR-290477-MN. The seal consisted of 5 feet of # 18 AWG solid copper wire with kapton insulation, installed in a conax gland seal with a poly-solfane gland. The connector has a 1/2" NPT male thread on both ends. The connector was threaded into the conduit port on the transmitter and an RTV sealant was applied to the inside and outside of the connection.

3.0 TEST DESCRIPTION

3.1 Material Control

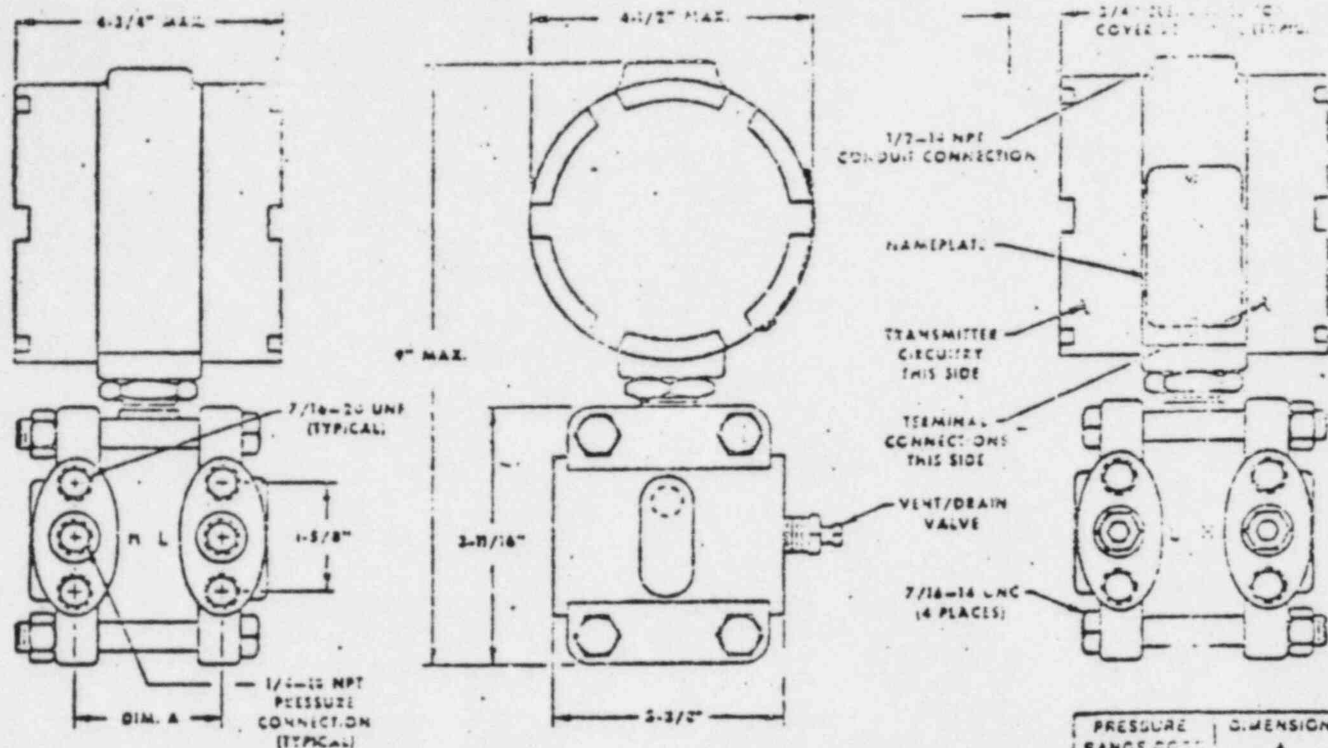
Prior to the start of testing, the transmitters were subjected to an incoming inspection and assignment of an individual route card. The route card is retained as a permanent record of each step in the test with the signature of the responsible party appearing after completion of each step.

TABLE 2.1

TEST UNITS

DESIGNATION	MODEL	TYPE	CALIBRATED SPAN	ELEC. OUTPUT (ma)	SERIAL NUMBER
AW-1	1153GA9	Gage Pressure	1700-2500 PSIG	4-20	135947
AW-2	1153GA9	Gage Pressure	0-3000 PSIG	4-20	135948
AX-1	1153DA5	Diff. Pressure	138-500 in. W.C.	4-20	135945
AX-2	1153DA5	Diff. Pressure	475-210 in. W.C.	4-20	135946

DIMENSIONAL DRAWINGS
MODEL 1153DA



PRESSURE RANGE CODE	DIMENSION A
3, 4, 5	2-1/8"
6, 7	2-3/16"
8	2-1/4"
9	2-9/32"

DIMENSIONAL DRAWINGS
MODEL 1153AA

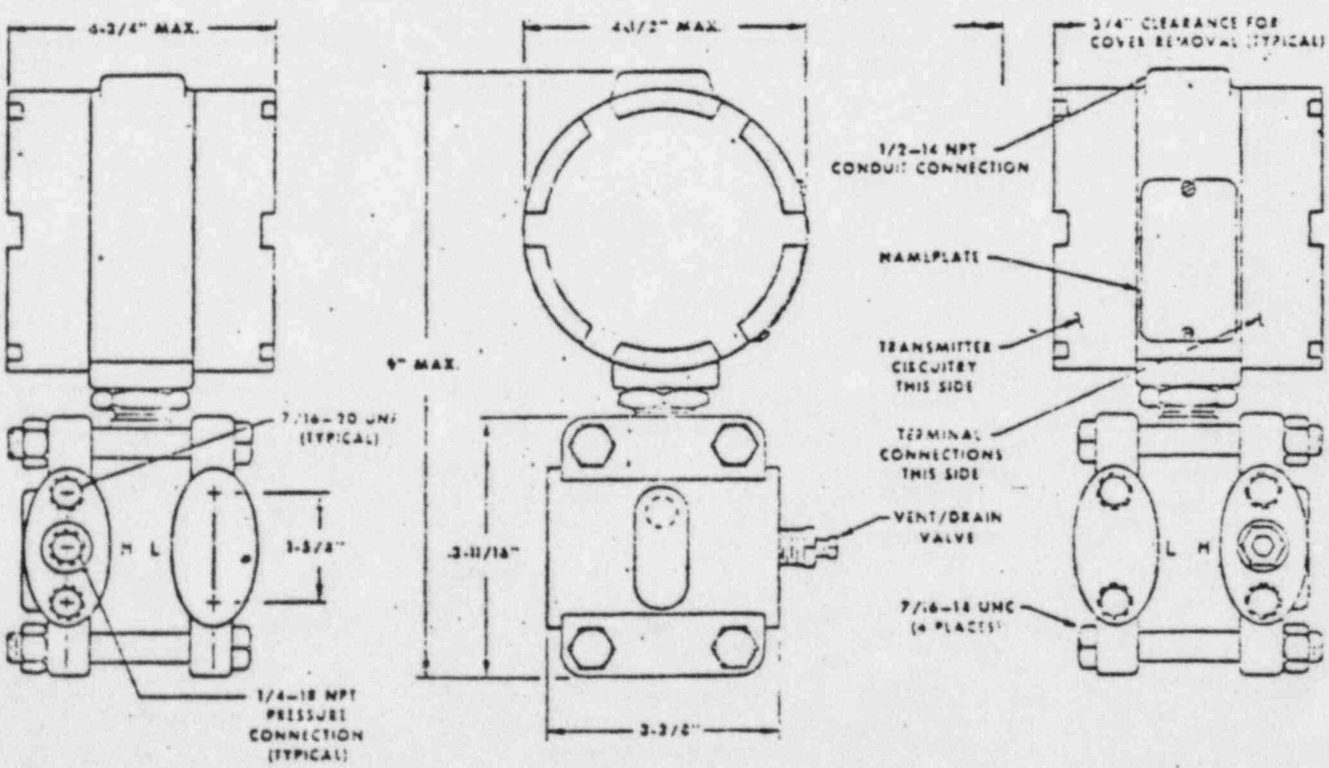


FIGURE 2.1

3.2 Calibration Checks

A 21-point calibration check per SAMA standard PMC 20.1-1973 was performed on each transmitter prior to the start of testing and after each major phase of the test. This data serves as a measure of the change in reference accuracy due to the test conditions. A summary of this data appears in table 3.1

An 11-point calibration check was also performed on the test units to verify operability at various points in the test.

3.3 Time Response

A rough measurement of the time response of each transmitter was made before and after irradiation in order to gage degradation. The measurement was made by computing the first order time constant of the transmitter response to a step change input. The measurement was made for input step changes of 5-95%, 95-5%, 45-55% of calibrated span. The measurement was made at room temperature and 130°F. Results of these measurements appears in table 3.2.

3.4 Test Sequence

The test was performed in the following sequence: initial inspection, 21-point calibration check, time response, 21-point calibration check, irradiation, 21-point calibration check, time response, 21-point calibration check, seismic simulation, 21-point calibration check, high temperature steam test, final 21-point calibration check.

After irradiation, the test units were not opened for inspection until after the high temperature steam test. No calibration adjustments were made after the initial calibration.

4.0 IRRADIATION

4.1 Test Facility

Irradiation was performed at Isomedix, Inc. in Parsippany, N.J. The test facility uses a 1,500,000 curie cobalt-60 source arranged in a rectangular array to provide a fairly uniform field strength over a 3 ft by 2 ft area. The source is stored in a water pool located below the test area and it can be raised or lowered by means of a hydraulic control. The test was performed using equipment and personnel from WPWRSD Forest Hills site.

CALIBRATION CHECKS

	Initial	Post T-R	52.5°C	Pre Rad	1 MRAD	Post Rad	Pre TR	Post TR	Post Seismic	Post Steam
AW-1	+0.437	+0.144	+1.437	+0.250	+2.50	+5.250	+4.338	+4.406	+5.219	+4.294
	-0.113	-0.288	+0.944	-0.313	0	+3.188	+3.719	+3.900	+4.644	+3.744
AW-2	+0.056	+0.025	-0.150	+0.062	+2.563	-0.125	-	-0.056	-	2.5 ma
	-0.350	-0.363	-0.550	-0.313	-0.375	-0.563	-0.513	-0.150	-	
AX-1	+0.269	+0.219	+0.362	+0.250	+1.375	+1.312	+1.606	+1.675	+0.769	25.8 ma
	+0.006	-0.069	-0.131	0	+0.875	+1.063	+1.331	+1.488	-0.462	
AX-2	+0.006	+0.019	-	-0.063	+0.437	+1.750	+2.225	+2.413	+5.831	29.3 ma
	-0.081	-0.138	-	-0.125	+0.125	+1.563	+1.913	+2.031	+4.200	

NOTE: VALUES ARE IN % CALIBRATED SPAN UNLESS OTHERWISE NOTED

TABLE 3.1

DRW 8245 L

TIME RESPONSE (MS)

	Input Step	Pre-Radiation		Post-Radiation	
	%	80°F	130°F	80°F	130°F
AW-1	5-95	35	40	39	42
	95-5	43	40	39	39
	45-55	34	34	34	36
AW-2	5-95	43	49	39	53
	95-5	40	44	38	45
	45-55	34	33	34	34
AX-1	5-95	100	44	128	47
	95-5	138	47	129	42
	45-55	102	33	124	39
AX-2	5-95	211	55	137	50
	95-5	122	52	134	53
	45-55	171	55	134	70

TABLE 3.2

4.2 Test Set-Up

The test units were unpacked and a 21-point calibration check was performed. The test units were then installed in the hot cell with pressure and electrical lines run out to the working area.

Pressure was supplied from a bottled nitrogen supply so that all transmitters were supplied with a 2000 PSIG static pressure as well as a 342 in. W.C. differential pressure for test units AX-1 and 2. The static and differential pressure was monitored by reference transducers located outside of the hot cell.

Power was supplied to the transmitters from WISD 7300 series NLP cards in series with a 500 ohm load. The NPL card output is 40 VDC. The voltage drop across a 100 ohm resistor was connected to data acquisition equipment. The test units were at power and monitored at all times the source was up.

Data acquisition consisted of Texas Instruments analog recorders and a Fluke digital data logger. Calibration checks as well as test data were simultaneously recorded on these. Figure 4.1 illustrates the set-up.

4.3 Test Procedure

Once the transmitters were installed in the hot cell an 11-point calibration check was performed to verify the operability of the test units and set-up. A thirty minute dose check was then performed. A dose rate of 2.5M Rad/hr was desired for a total integrated dose of 50M Rad.

Dosimetry was accomplished using red perspex dosimeters placed on the face, middle and back of each test unit. The average of the dosimeters placed at the center of all the test units is used to determine the dose rate.

After the first thirty minutes of radiation, which corresponds to approximately 1M Rad, a 21-point calibration check was performed.

At the half way point (i.e. 25M Rad) the test units were switched to the opposite side of the source so that an even overall exposure could be obtained. An 11-point calibration check was again performed. A thirty minute dose check was also done for the second half of radiation.

After 50M Rad had been accumulated the test units were removed from the cell and a 21-point calibration check was again performed.

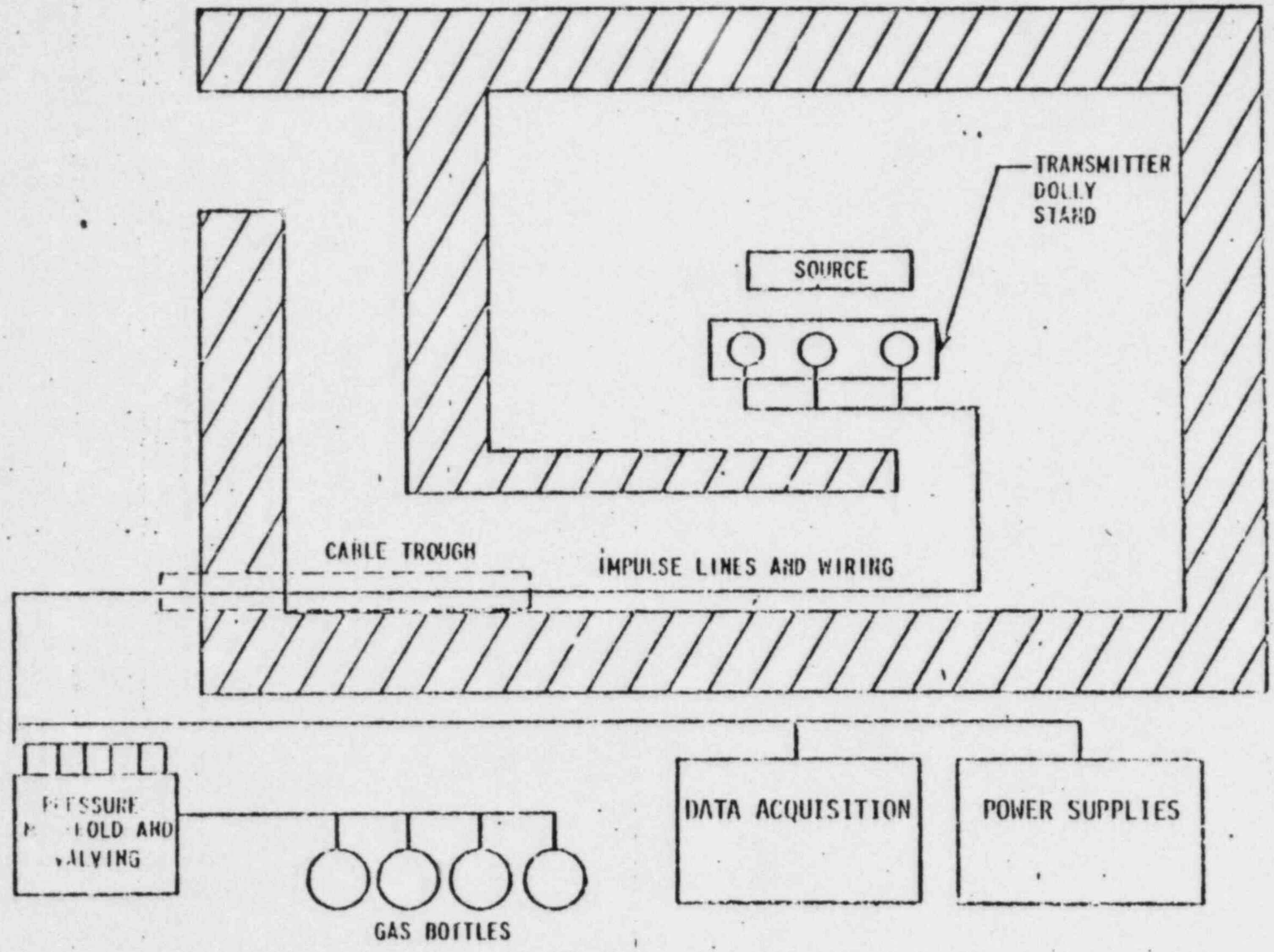


FIGURE 4.1
IRRADIATION TEST SET-UP

4.4 Test Results

During the pre-irradiation 21-point calibration check test, unit AW-1 showed a constant 30 ma output for all pressure inputs. This condition was corrected by unplugging the circuit board and then reinstalling it.

The test results are shown in figure 4.2 . This graph illustrates the error in the output of the test units versus time. The error is calculated by subtracting the percent of span change in the reference from the percent of span change of the test unit, the span used being the calibrated span of the test unit. This graph also shows the dose rate during each segment of the test. Table 4.1 gives the worst error and the total integrated dose at which it occurred.

5.0 SEISMIC SIMULATION

5.1 Test Facility

The seismic simulation was performed at the Westinghouse Advanced Energy System (WAESD) seismic laboratory in Large, Pa. This facility has the capability for conducting biaxial multi-frequency tests to IEEE-344-1975.

The test table used has a 6 feet by 6 feet surface. The driving piston has a 20 inch peak to peak stroke and is capable of delivering 22,000 lbs of force and a peak velocity of 100 inches per second.

5.2 Test Set-Up

The test units were mounted on a test fixture which was bolted to the test table at a 45 degree angle to the movement of the piston. The piston was at a 35 degree angle from the horizontal plane of the test table, so that equal motion was in three mutually perpendicular axis of the test units' reference.

The test table motion was controlled by inputs fed into a hydraulic controller. A control accelerometer provided feedback to the controller as well as input to a shock spectrum analyzer. The control accelerometer sensed the horozontal table motion in the plane of the piston, so that its response was 1.4 times the acceleration in any of the axes of the test units' reference.

The shock spectrum analyzer was a Spectrual Dynamics Model 13192 unit. Its output plotted on an X-Y recorder was used to determine the success of any one seismic simulation.

FIGURE 4.2

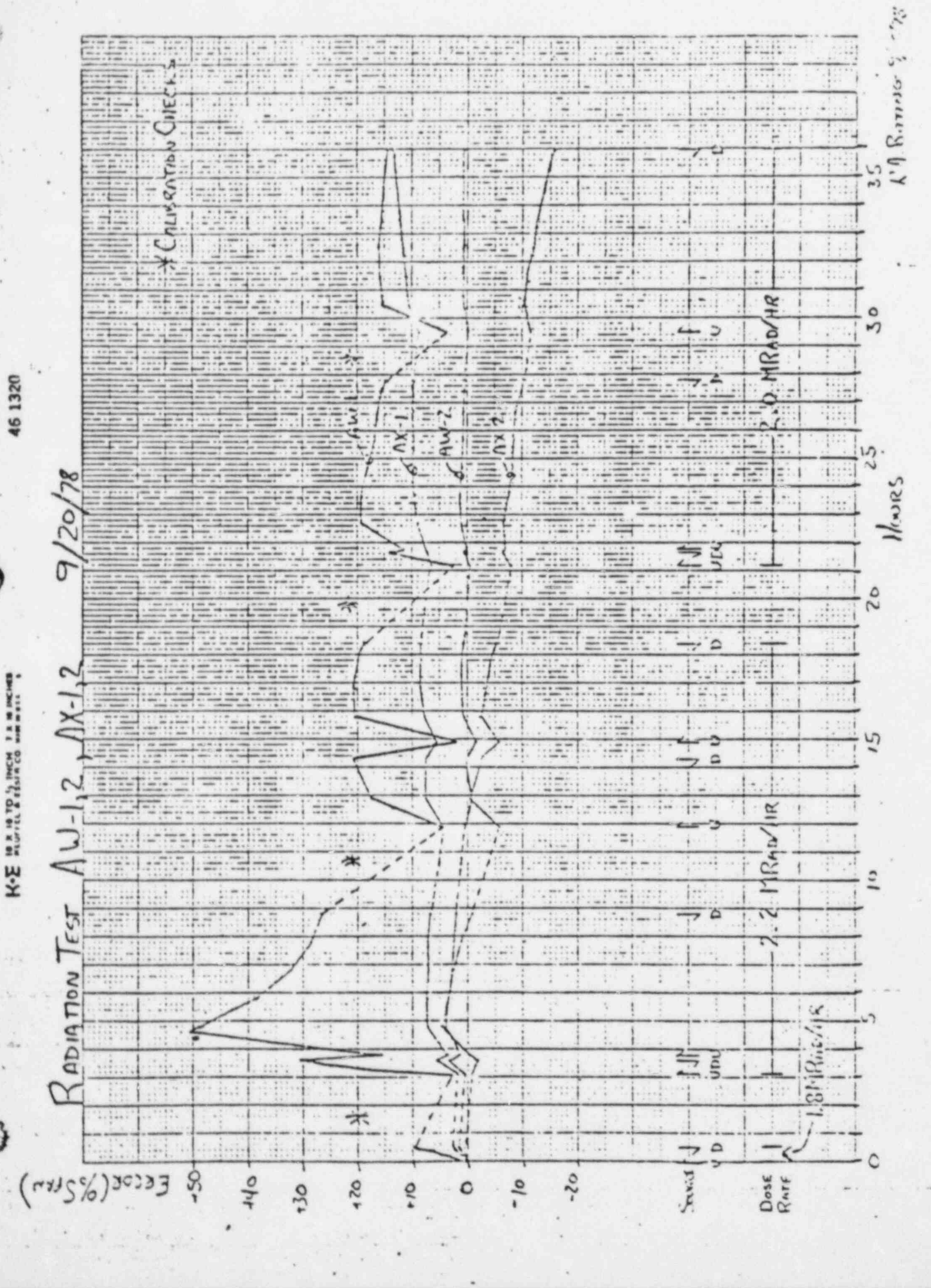

RADIATION TEST AW-1,2 AX-1,2 9/20/78
*CALIBRATION CHECKS
AW-1
AX-1
AW-2
AX-2
ERROR (% SPAN)
+50
+40
+30
+20
+10
0
-10
-20
SWITCH
DOSE RATE
1.8 MRAD/HR
2.2 MRAD/HR
2.0 MRAD/HR
0
5
10
15
20
25
30
35
HOURS
46 1320

TABLE 4.1

MAXIMUM IRRADIATION ERRORS

TEST UNIT	ERROR (%)	TOTAL INTEGRATED DOSE (MRAD)
AW-1	+ 50.2	3.8
AW-2	+ 4.0	4.2
AX-1	+ 13.2	50
AX-2	- 15.9	50

5.2 Test Set-Up (Continued)

The test units were connected to 3/8" O.D. stainless steel tubing which was attached to a pressure manifold located adjacent to the test table by means of flexible lines. The pressure manifold contained reference transmitters which were capable of sensing the same pressure as the test units.

Pressure was maintained by filling the pressure lines with water, then applying a static pressure from a nitrogen supply. The pressure lines were then valved off from the supply. A differential pressure was established for the differential pressure units by bleeding the low pressure side until the correct output was seen on the reference unit. This set-up is illustrated in figure 5.1.

Power was supplied to the test units and the reference units from WISD model 7300 NLP cards in series with a 503 ohm load. The transmitter output across a 120 ohm resistor was conditioned and recorded on Brush Mark 200 recorders. Conditioning was such that the full scale on the recorder represented ±10% of the calibrated span of the test and reference units. This set-up is illustrated in figure 5.2.

5.3 Test Procedure

The test consisted of 5 operating basis earthquakes (OBE's) followed by 4 safe shutdown earthquakes (SSE's). The OBE's were all performed with the test fixture in the same position. The SSE's were performed one each in four different positions, 0°, 90°, 180°, and 270° from the OBE position. The test inputs were labeled A,B and C to cover low, middle and high frequencies. An SSE was done using one successful run for each input. The OBE's were done using input B. The required response spectra (RRS) for the OBE's and the SSE's are shown in figures 5.3 and 5.4 respectively.

Prior to the start of testing, calibrations were recorded for all accelerometers, and pressure was applied to all the test and reference units. Test units AW-1 and AW-2 were tested at 2250 PSIG. Test unit AX-1 was tested at 2000 psig static pressure with 462 in. W.C. differential. Test Unit AX-2 was tested at 1300 PSIG static pressure with 342 in. W.C. differential.

During a series of runs, measurements were made of the output of each test unit and reference using a digital volt-meter. Measurements were made at the beginning and end of the series and in between each run.

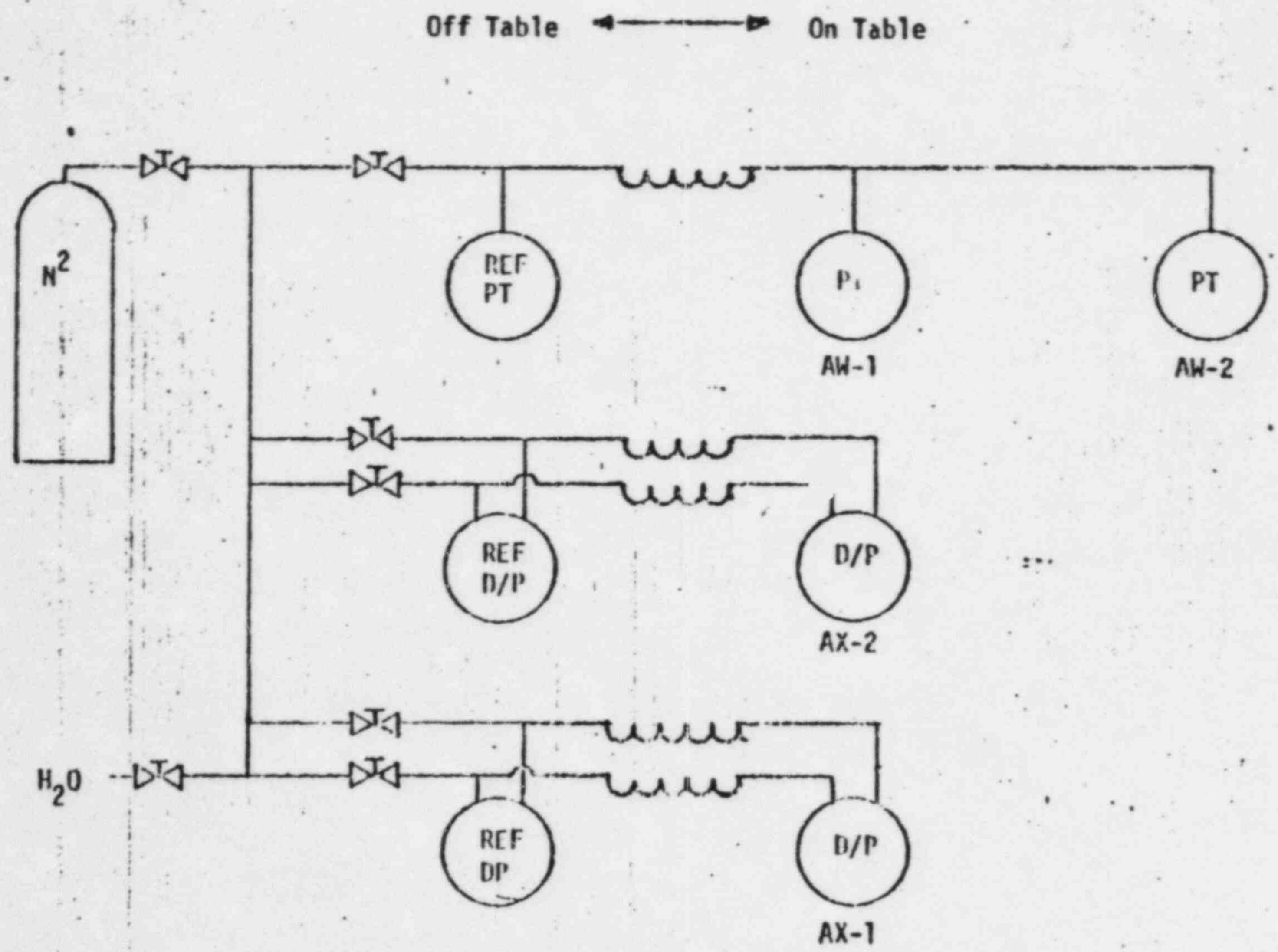
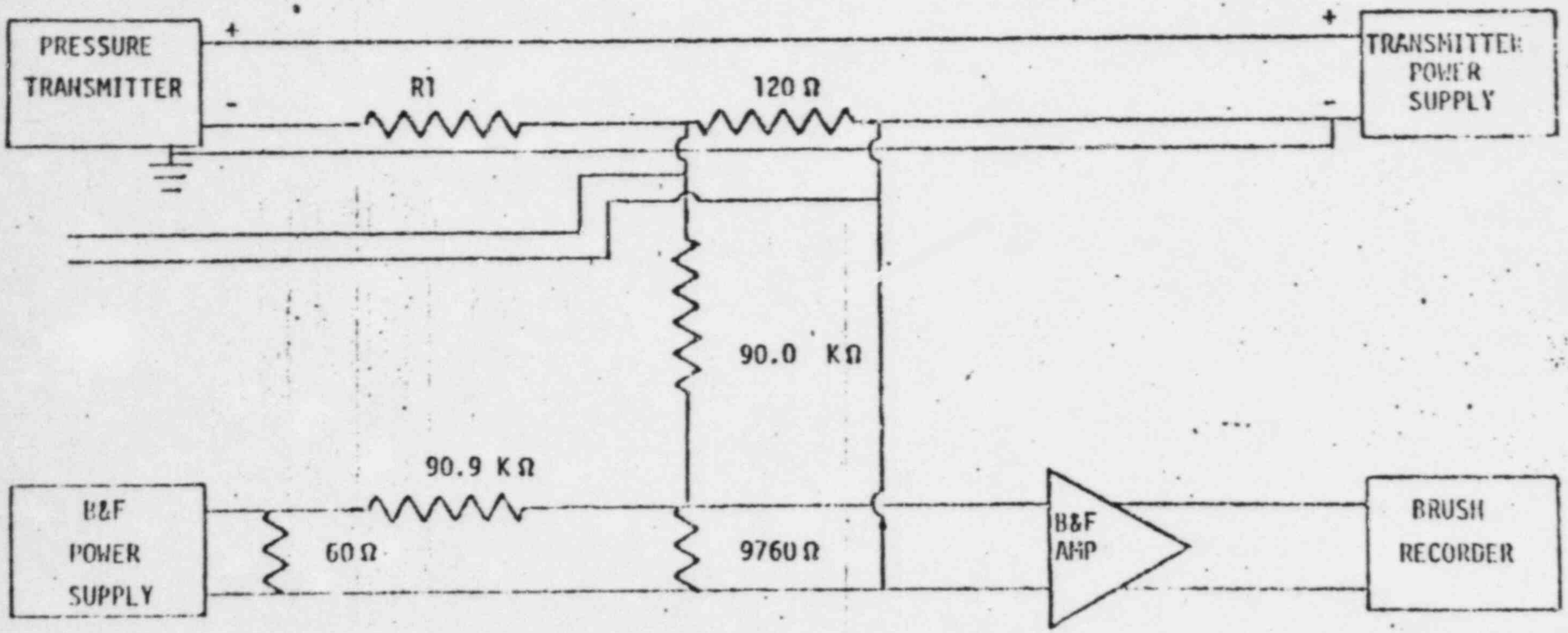
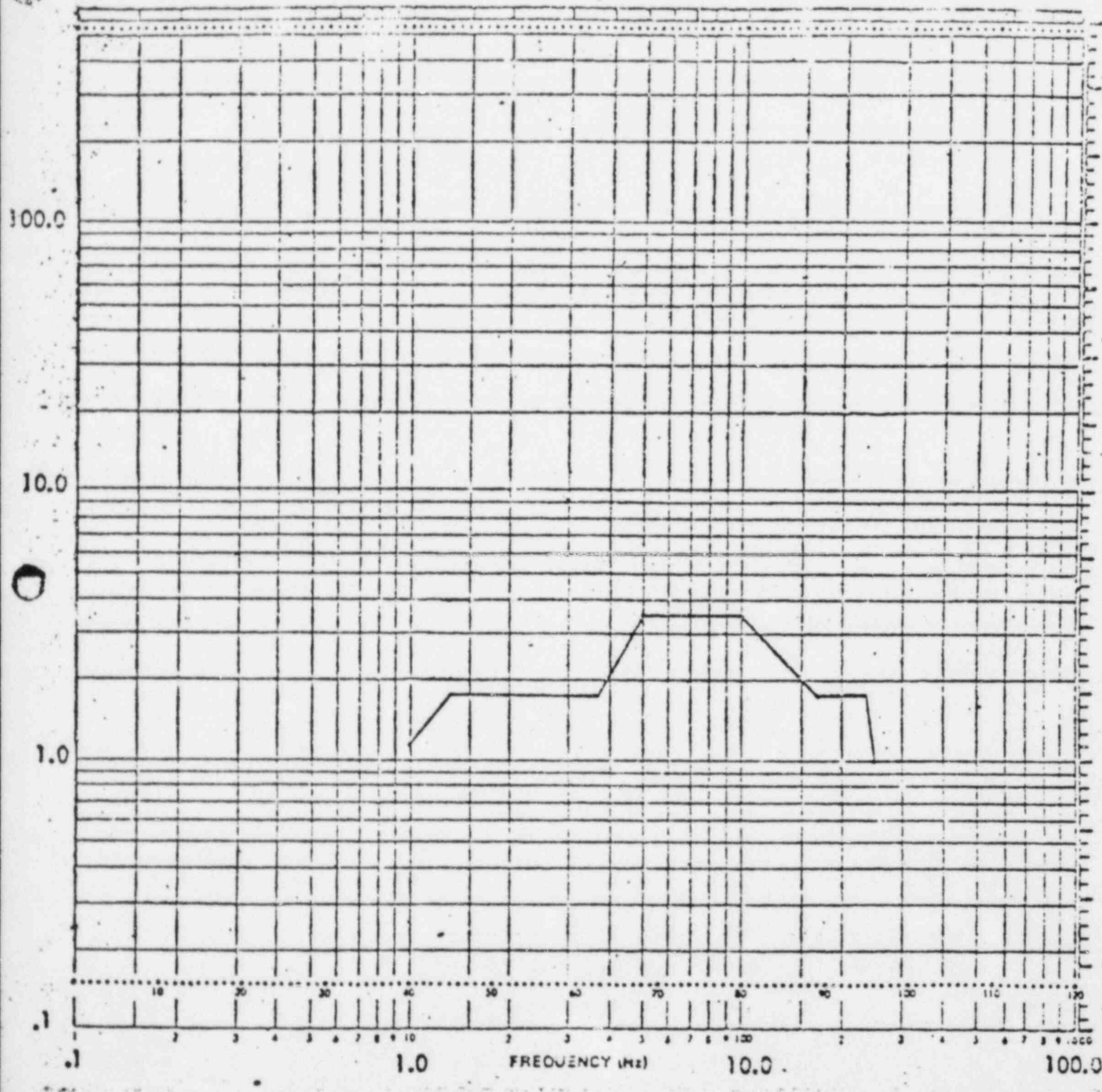


Figure 5.1 Plumbing Diagram for All Transmitters.



R1 = 350 Ω for 10 - 50 ma transmitter.
380 Ω for 4 - 20 ma transmitter.

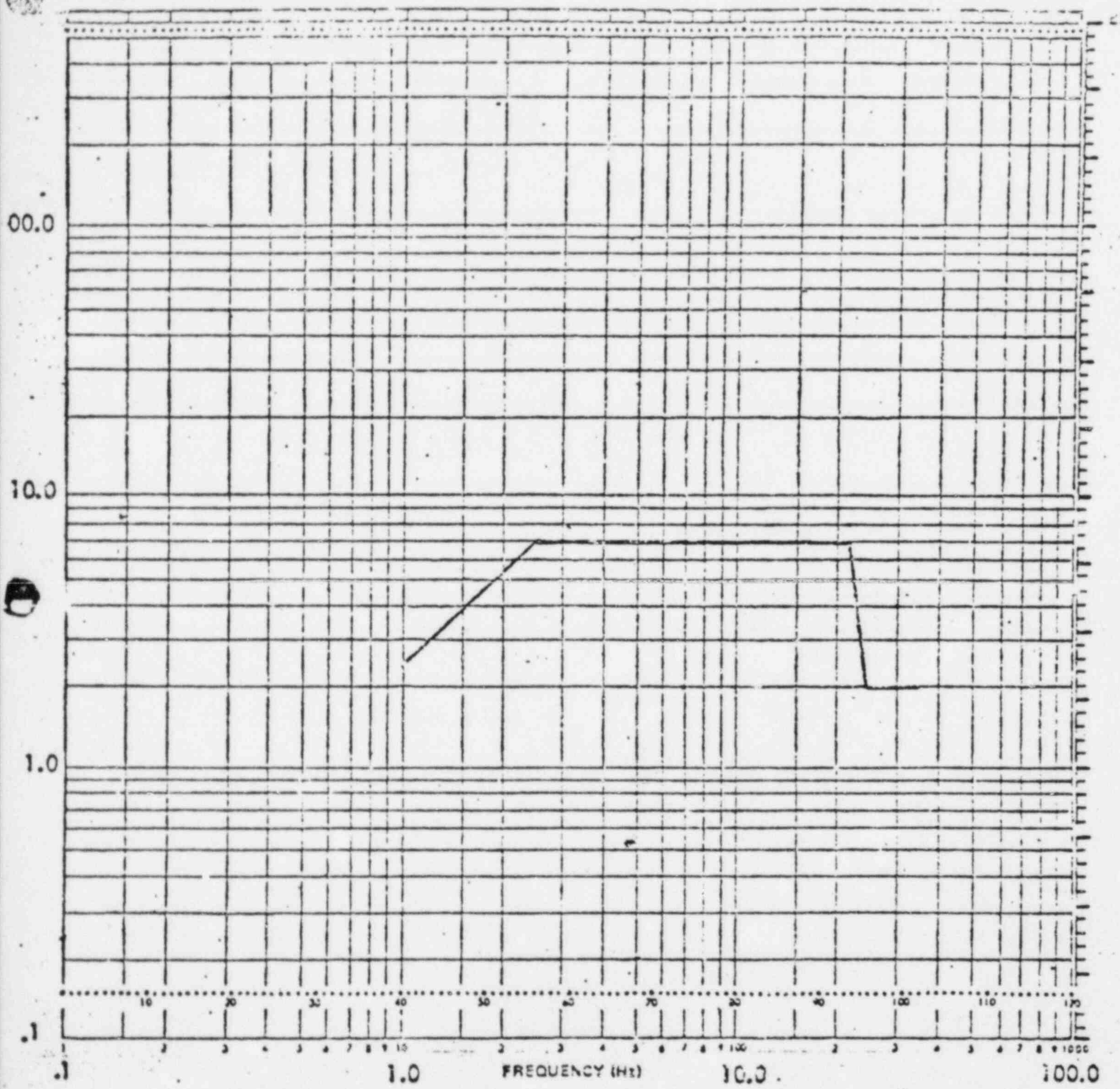
Figure 5.2 Powering and Monitoring Schematic.



REQUIRED RESPONSE SPECTRUM
FOR OBE'S

MEASURED IN THE TEST UNIT'S AXES

FIGURE 5.3



REQUIRED RESPONSE SPECTRUM
FOR SSE'S
MEASURED IN THE TEST UNITS' AXES

FIGURE 5.4

5.4 Test Results

During set up for the first OBE, test unit AW-2 began to behave erratically. Operation from 0 to 50% of span appeared normal, but above 50% of input pressure, the output went to 29 ma. The electrical leads were disconnected and resistance to ground checks were made. Everything appeared normal. The electrical leads were reconnected and the unit behaved normally over its entire input span. The test then resumed.

All units remain operational throughout the test. Table 5.1 gives the maximum errors during the OBE's and the SSE's.

TABLE 5.1

MAXIMUM ERROR DURING SEISMIC TESTING

	OBE	SSE
AW-1	1.3	3.8
AW-2	0	1.8
AX-1	0.8	3.3
AX-2	1.8	6.5

ERRORS ARE ±% CALIBRATED SPAN

6.0 HIGH TEMPERATURE STEAM ENVIRONMENT

6.1 Test Facility

The test was conducted at WPWRSD, Forest Hills site. This facility has the capability of performing a high temperature, saturated steam test simultaneously with a caustic chemical spray environment. Up to three transmitters may be tested in any one of three autoclaves. The test units can be tested while operating at static and differential pressure.

6.2 Test Set-Up

Test units AW-1 and AW-2 were installed in test chamber B and test units AX-1 and AX-2 were installed in test chamber C as shown in figure 6.1. Pressure lines were connected to the test units and to the same type of pressure regulating equipment as was used for the Radiation Test.

The electrical lead wires were brought out of the test chamber through a conax seal gland. The lead wires were then connected to an instrumentation loop consisting of a WISD 7300 NLP card and a 500 ohm series resistance. Data acquisition equipment received its signal from across a 100 ohm resistor. Data acquisition consisted of Texas Instruments recorders in parallel with a Fluke digital data logger. Transmitter outputs as well as reference transducers were recorded.

Chamber temperature was monitored in two ways. There were two fast response type K thermocouples, one located 1 inch from the surface of each test unit in the chamber. These signals were recorded on the analog recorder and as millivolt signals on the datalogger. The average of these signals was used for the chamber rise time. Also, there was a slower response type K thermocouple which sensed chamber temperature. This output was recorded by the datalogger and shown as degree Fahrenheit.

Chamber pressure was sensed by a transducer. Its output was recorded by both the analog recorders and the datalogger.

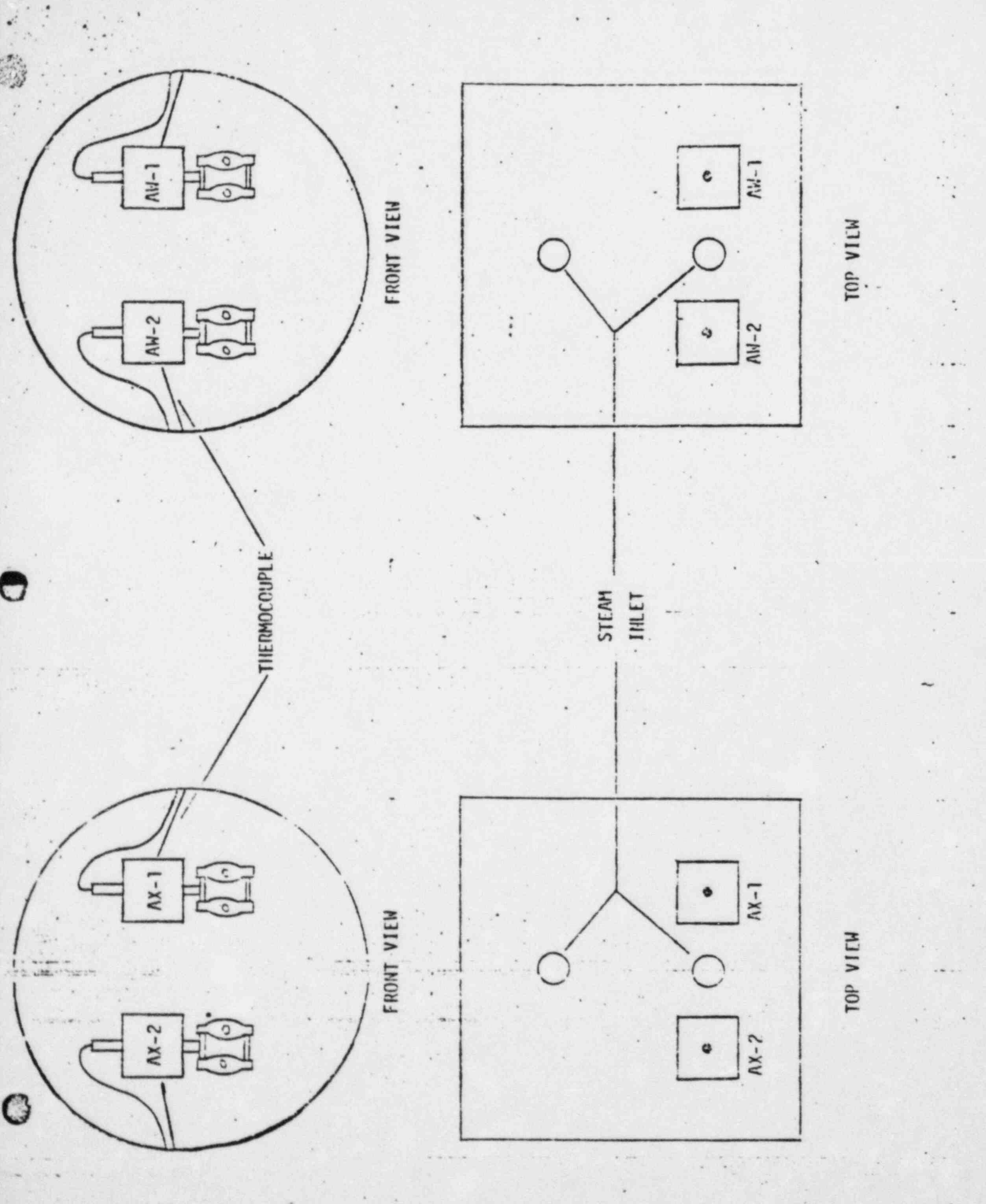
6.3 Test Procedure

After the transmitters were installed in the test chamber, an 11-point calibration check was run to verify the operability of all equipment.

The temperature profile for the test is shown in figure 6.2. The two week post-accident accelerated aging period at 220°F is meant to be equivalent to four months at 160°F.

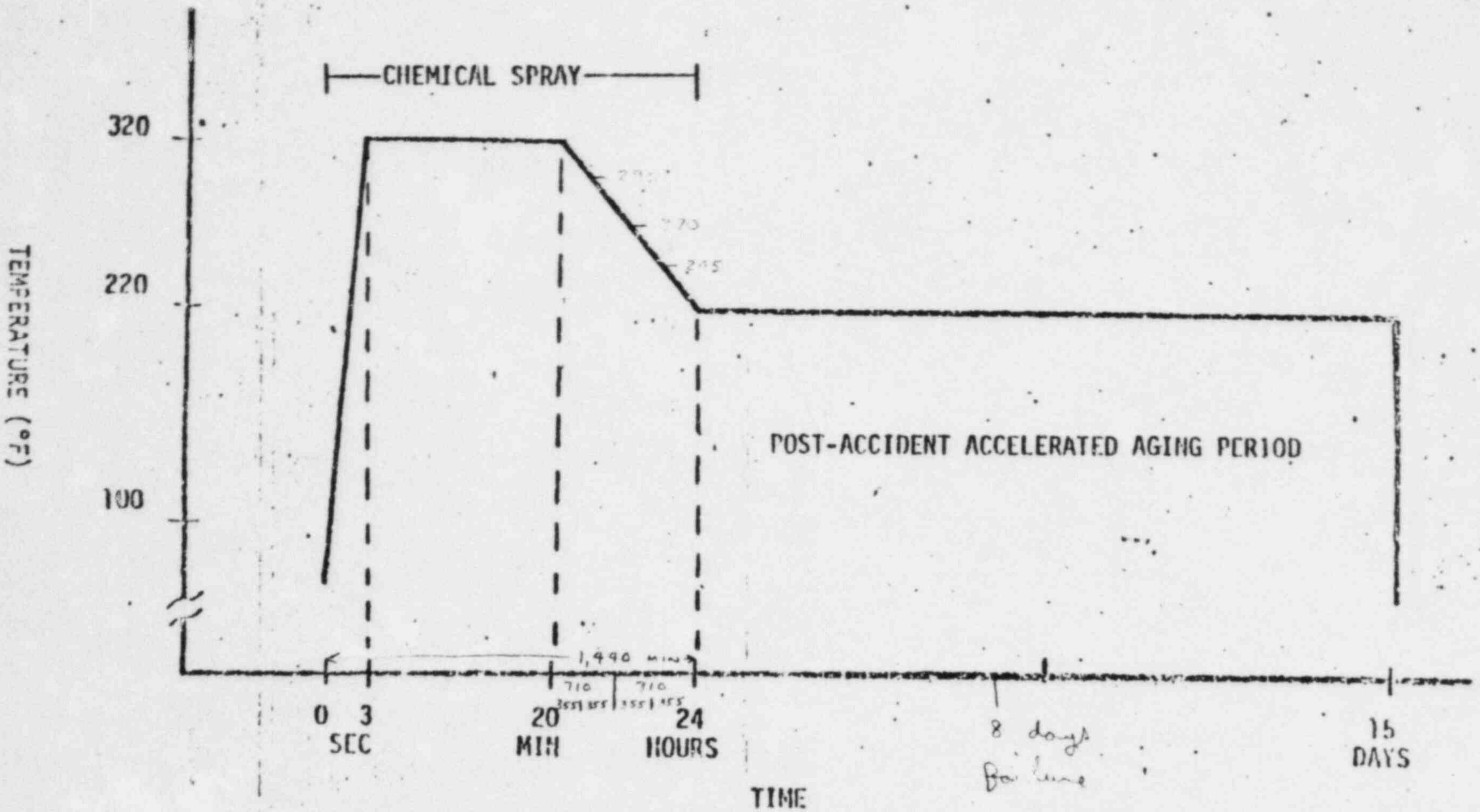
The chemical spray used during the test consisted of 5.82 gpm of a caustic solution that was mixed with the incoming steam during the first 24-hours of the test. The chemical analysis of the solution was 2000 ppm Boric Acid mixed with 1.7 gm/l Sodium Hydroxide to make a pH of 9.25.

FIGURE 5.1



AW-1
AW-2
FRONT VIEW
THERMOCOUPLE
AX-1
AX-2
FRONT VIEW
AW-1
AW-2
TOP VIEW
STEAM
INLET
AX-1
AX-2
TOP VIEW

FIGURE 6.2



710

TEMPERATURE ENVELOPE

= 7.67 yr

Chamber C was started on November 1 and chamber B was started on November 3.

The analog recorders were used for the first 24 hours of the test. For the remaining 14 days, only the datalogger was used, at a sampling rate of one reading every 15 minutes.

6.4 Test Results

Graphs of test unit error versus time are shown as figure 6.3 for test units AX-1 & 2 and figure 6.4 for test units AW-1 & 2. These graphs are for the first 24 hours of the test. The error shown is percent of span change in the test unit minus the percent of span change in the reference unit. The span used being the calibrated span of the test unit. The graphs also show chamber temperature versus time.

During the 21-point calibration check that was done in between the seismic test and the steam test, test unit AW-2 again behaved erratically. Data taken from this unit shows that it continued to behave erratically during the steam test, with the output generally staying higher than normal. At fourteen days into the test, the output suddenly went low. When the unit was put through a calibration check after the termination of the test, it did not respond at all.

The output signal from test unit AX-2 went high at 12 hours into the test. At the conclusion of the first 24 hours of the test, the chamber was cooled down and opened. At this point, the test unit was operating again. Inspection of the unit revealed evidence of steam leakage through the conax seal into the terminal area of the transmitter. There was also evidence that condensation had gotten under the kapton insulation of the lead wires in an area just outside of the conax seal. The terminal area was then cleaned out and more RTV sealant was applied around the area of the conax seal. The test was restarted for the 2 week aging period at 220°F. The output of the unit again went high after three days and remained there for the rest of the test. When the unit was put through a calibration check after the termination of the test, it did not respond at all. Its output remained at 29.3 ma.

The output signal from test unit AX-1 went high after 8 days of testing. The signal periodically returned to normal until after 12 days when it remained high for the rest of the test. When this unit was put through a calibration check after the termination of the test, it did not respond. Its output remained at 25.8 ma.

Test unit AW-1 remained functional throughout the test.

Maximum and minimum errors exhibited by the test units (prior to failure for AX-1 and AX-2) during the two week aging period at 220°F are shown in table 6.1.

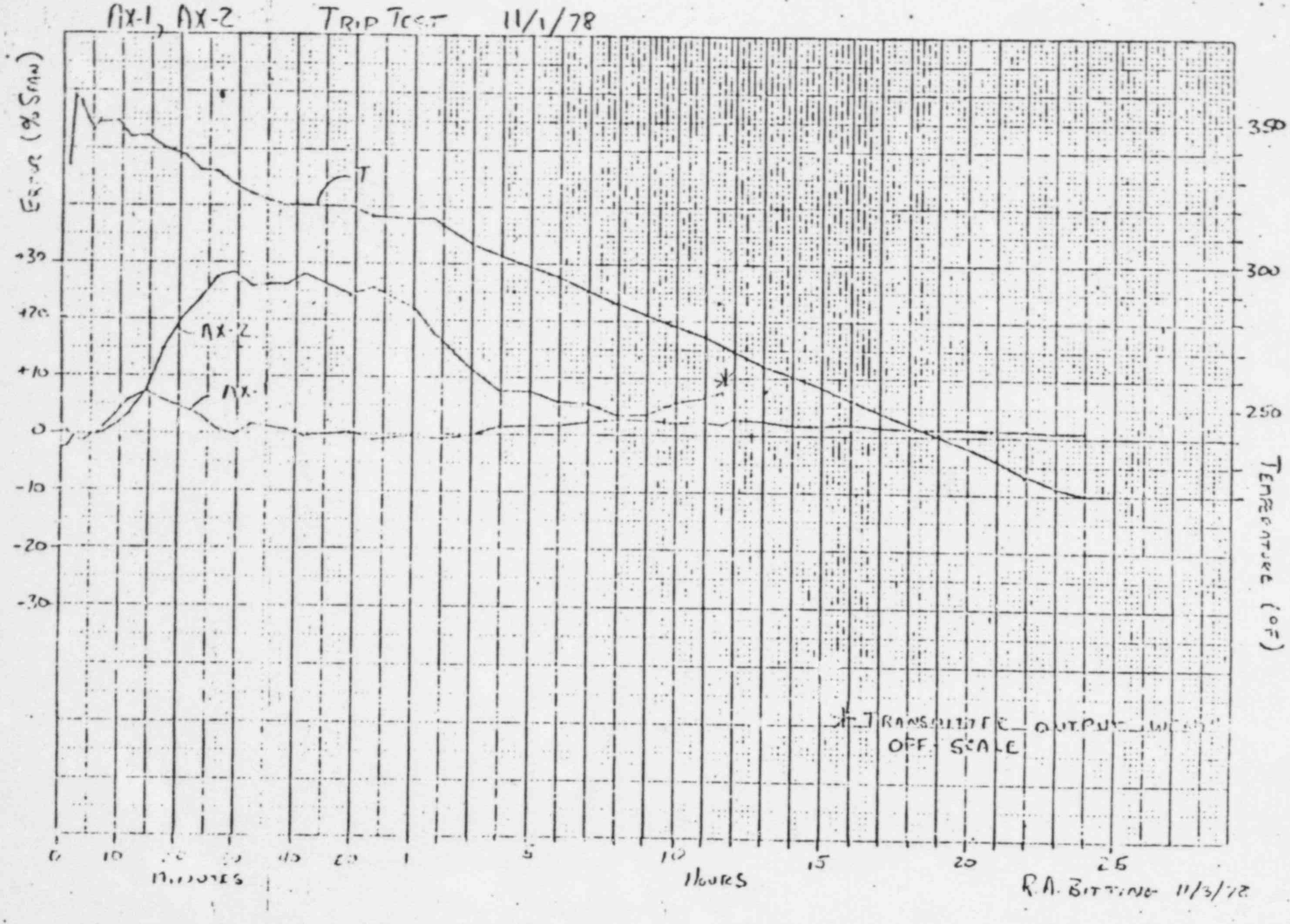

AX-1, AX-2 TRIP TEST 11/1/78
ERROR (% SPAN)
+30
+20
+10
0
-10
-20
-30
TEMPERATURE (°F)
350
300
250
T
AX-2
AX-
0
10
20
30
40
50
1
5
10
15
20
25
MINUTES
HOURS
* TRANSMITTER OUTPUT W...
OFF SCALE
R.A. BITTING 11/3/78

FIGURE 6-3

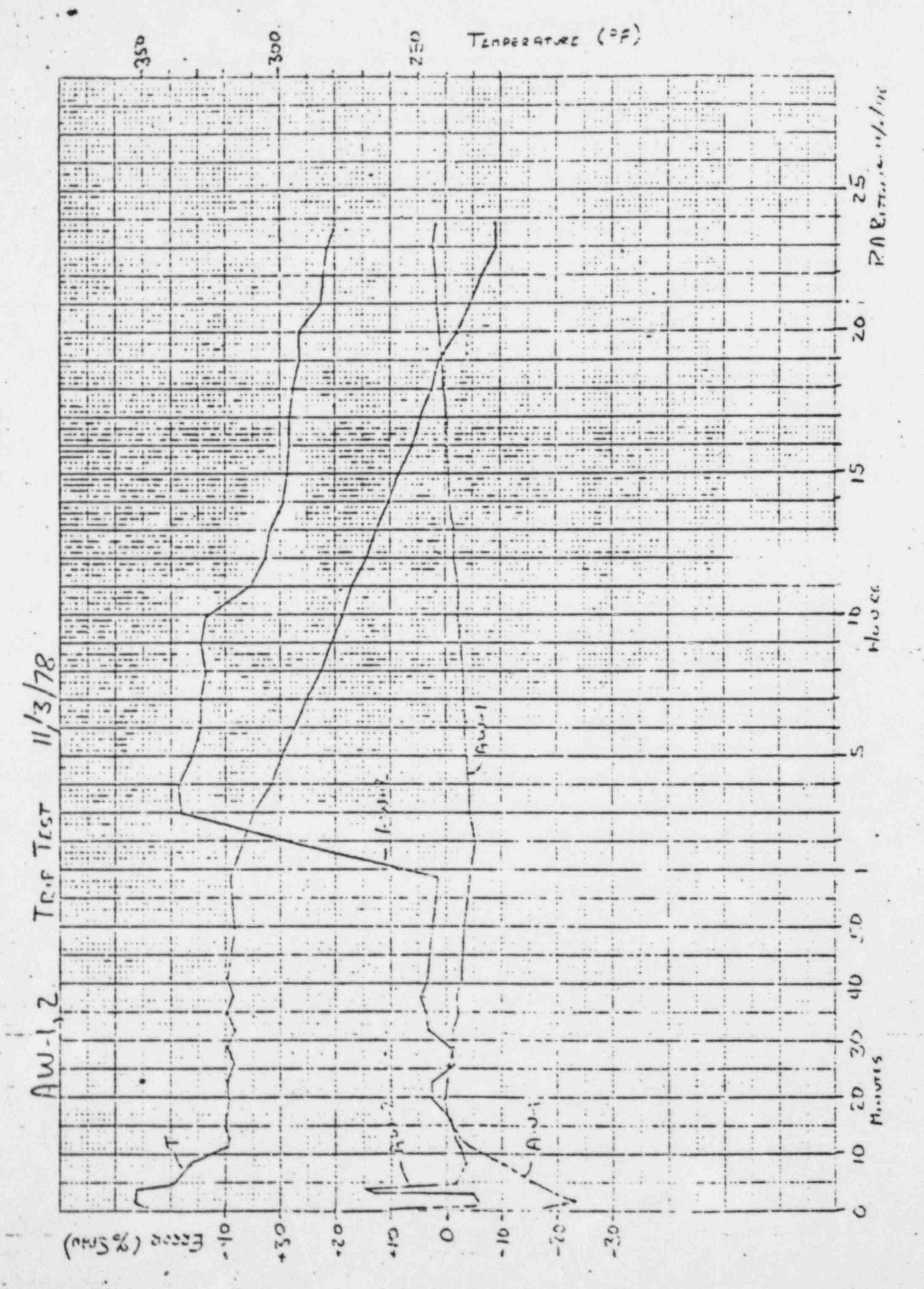

AW-1,2
Trip Test 11/3/78
46 1320
Temperature (°F)
350
300
250
Hours
Minutes
AW-1
AW-2
T
+30
-20
-10
0
-10
-20
-30
0
10
20
30
40
50
1
5
10
15
20
25

FIGURE 5.4

TABLE 6.1

ERRORS DURING POST-ACCIDENT AGING PERIOD

	Maximum Error	Minimum Error
AW-1	+2.2	-1.1
AW-2	*	*
AX-1	+2.6	+0.4
AX-2	-2.8	-4.1

NOTE: Errors are in % calibrated span

*Output Erratic

7.0 CONCLUSIONS

Generic preformance specifications for WPWRSD supplied transmitters are based on requirements for specific functions. What follows is a comparison of the performance specifications with the test data for the test unit that would be used for that function.

Pressurizer Pressure

The specification is ± 10% accuracy for short term reactor trip functions during a loss of coolant accident (LOCA). The test unit applicable to this function is AX-1 (1700 - 2500 PSIG).

During the steam test, AW-1 showed an error of -23% to +3% with -10% being due to chamber pressure. During radiation, the test unit showed a maximum error of approximately + 50% with errors of +10 to +20% within the first few minutes.

WPWRSD cannot conclude that the errors for this test unit would be within ±10% for the combined effects of radiation and steam. Also, Rosemount has indicated that the radiation errors due to the dose rate might have been observed in the results from any of the test units, however the magnitude would be proportional to the turn-down ratio.

Pressurizer Level

The specifications for this function are ±10% accuracy for short term safety injection initiation following a LOCA or steam-line break accident and ±25% accuracy for long term monitoring. The test unit applicable to this function is AX-2 (475-210 in. W.C.).

This unit would meet the ±10% requirement with a qualification due to the uncertainty in the effects of radiation as shown by AW-1. AX-2 exhibited a large error (+28%) during the first hour of the test and had two failures, the first of which was certainly due to leakage of the conax seal. Not enough data is available from these tests to say what the effects would be due to a lower dose rate as in a steam-line break accident.

Steam Flow

The specification for this function is ±10% accuracy during a steam-line break accident. Either AX-1 or AX-2 could be used in this function.

These test units appear adequate for short term trip functions. No data is available on the effects of the lower radiation dose rate seen during a steam line break accident.

Steam Generator Level

The specification for this function is +10% accuracy during a feed-line break accident and +25% accuracy for monitoring functions following a LOCA or steam-line break accident. Test unit AX-2 would be used for this function.

The same comments as for Pressurizer Level apply.

Reactor Coolant System Wide Range Pressure

The specification for this function is ±10% for monitoring functions following a steam-line break accident. Test unit AW-2 (0-3000 PSIG) would be used for this function.

Results from this test unit were unacceptable.

Attachment 5