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MEASUREMENT SYSTEM SUPPORT AT THE JAERI - CRT
FACILITY - PRESSURE TRANSDUCERS

W. M. Shay, Jr.
E. W. McCauley

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Lawrence
Livermore
Laboratory

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ABSTRACT

As part of a continuing liaison between the U.S. NRC and foreign full scale containment research programs, measurements assistance in the form of the loan of 30 flush diaphragm pressure transducers has been provided to the JAERI - CRT^a MK II research program at Tokai-Mura, Japan.

Procedures developed earlier at the Lawrence Livermore National Laboratory (LLNL) under similar research work sponsored by the U.S. NRC were used by LLNL to successfully complete final installation and in-situ end-to-end calibration of the transducers in the CRT facility. The results from this calibration showed a very close agreement between sensitivities and linearities calculated at LLNL and the ones calculated at JAERI and indicate the transducers should give valid data during future testing.

^aJapan Atomic Energy Research Institute - Containment Response Tests

MEASUREMENT SYSTEM SUPPORT AT THE JAERI - CRT FACILITY -- PRESSURE TRANSDUCERS

by W. M. Shay, Jr. and E. W. McCauley

INTRODUCTION

A full-scale multivent pressure suppression system experimental program is in progress in Japan at the Tokai-Mura establishment of the Japan Atomic Energy Research Institute (JAERI). Begun in February 1979, the results of this test program are of interest to the U.S. NRC in the areas of analytical model development and licensing of the U.S. Boiling Water Reactor using the MK II containment design.

As part of the continuing technical liaison to the JAERI containment research testing (CRT) program for the U.S. NRC, we developed a measurements assistance plan which provided 30 flush diaphragm pressure transducers with complete mounting hardware for enhancement of the existing CRT wetwell measurement system. Following delivery and emplacement of 25 pressure transducers from this system at JAERI by their staff, final installation and an end-to-end calibration of the pressure transducers was completed during June 22-26, 1981.

The pressure transducers used were manufactured by Senso-Metrics, Inc., model number 601087 with a range of 0-100 psia. The transducers were designed by LLNL in 1976 for the 1/5-scale experiment we conducted on the suppression system for a Mark I Boiling Water Reactor (Ref. 1). This transducer has a 30 ft.

integral cable, a flange mount, and a 0.25 inch of room temperature vulcanizing (RTV) material over it to reduce the thermal transient effects. With the RTV in place the natural frequency of the transducer is approximately 15 kHz. This is approximately two orders of magnitude higher than required by JAERI.

INSTALLATION PROCEDURES

The installation for each transducer, along with the fabrication of the special mounting hardware, was designed and manufactured at LLNL. The actual installation of each transducer was completed by technicians from JAERI. Figure 1 shows two of the shipping containers at JAERI that were used to ship the equipment to Japan.

The final installation and in-situ calibration of 25 pressure transducers was completed on June 26, 1981. Seven transducers were installed on the wetwell floor, each nominally centered beneath a vent pipe as shown in Figure 2. Seven transducers were installed in the vent pipes 0.5 m above the vent exit as shown in Figure 3. Six transducers were installed on the lateral rigid walls at vent pipe exit level, each adjacent to a vent pipe as shown in Figure 4. Two transducers were installed on the large shell and one on the small shell as shown in Figures 5 and 6, respectively.

In addition to these 23 pressure transducers, two other transducers were installed; one external to vent pipe No. 5 (VP5), 100 mm above the exit as seen in Figure 7; and one internal to vent pipe No 7 (VP7), 11.5m above the exit (there is no photograph of this installation). Figure 8 shows the lateral wall pressure transducer installed at VP7 exit level.

FIGURE 1. SHIPPING CONTAINERS AT JAERI.

FIGURE 2. TYPICAL INSTALLATION OF SENSO-METRICS PRESSURE TRANSDUCER ON WETWELL FLOOR.

FIGURE 3. TYPICAL INSTALLATION OF SENDO-METRICS PRESSURE TRANSDUCER, 0.5M ABOVE VENT PIPE EXIT. 6

FIGURE 4. TYPICAL INSTALLATION OF SENSO-METRICS PRESSURE TRANSDUCER AT RIGID LATERAL WALL,

FIGURE 5. SENSO-METRICS PRESSURE TRANSDUCER INSTALLATION ON LARGE SHELL AT VENT PIPE EXIT LEVEL. 8

FIGURE 6. SENSO-METRICS PRESSURE TRANSDUCER ON SMALL SHELL AT VENT PIPE EXIT LEVEL.

FIGURE 7. SENSO-METRICS PRESSURE TRANSDUCER EXTERNAL TO VENT PIPE NO. FIVE (VPS) 100/MM ABOVE EXIT LEVEL. 10

FIGURE 8. SENSO-METRICS PRESSURE TRANSDUCER AT VENT PIPE NO. SEVEN (VPT)
EXIT AND AT RIGID LATERAL BOUNDARY. 11

IN-PLACE CALIBRATION PROCEDURES

Before the 30 pressure transducers were sent to Japan, each one was calibrated at LLNL to determine the sensitivity and linearity. Each transducer was statically calibrated three times from 0-100 psia at room temperature. The linearity of the transducer is then determined using the terminal point method. This method uses the initial zero data points and the full scale data points by fitting a straight line between them. The deviations, or linearity, is calculated from this line. Figure 9 is a typical terminal point plot for one of the thirty pressure transducers. The plot contains 21 data points and is the first of three calibration runs.

The sensitivity of the transducer is determined from the slope of the terminal line. The linearity and sensitivity and other information is contained on this plot.

Figure 10 is a typical least squares plot for the same pressure transducer. It is calculated from the three individual calibration runs. From this plot the error band can be found.

These pressure transducers were not originally designed to be installed underwater as would be necessary for JAERI. Water could enter the back of the transducer where the internal cable exited, causing a short of the bridge circuit. To prevent this problem we built a special piece that had a flared tube fitting welded on it and an O-ring groove. This piece mounted to the transducer to prevent water from leaking into the back of the transducer. The internal cable from the transducer was placed in a copper tube which was attached to the flared fitting.

SENSOMETRIC PRESSURE TRANSDUCER MOD.NO. 601087
 CALIBRATED 2/13/81 AT 13:29 HRS AT 22.0 DEG.C.

S/N5381

FILE 118

SERIAL NUMBER

NUMBER OF RUN

RUN 1 OF 3 RUNS

TERMINAL POINT ERROR PLOT

CALIBRATED WITH GAS

INPUT PRESSURE	OUTPUT	
	(MV) INCR	(MV) DECR
FS:A		
0	-11.176	-11.186
10,000	8.683	8.643
20,000	28.615	28.567
30,000	48.609	48.551
40,000	68.671	68.615
50,000	88.772	88.716
60,000	108.920	108.865
70,000	129.057	129.017
80,000	149.249	149.209
90,000	169.460	169.440
100,000	189.652	

TERMINAL POINT VALUES		
THEORETICAL (MV)	DEVIATION (MV)	
	INCR	DECR
-11.176	-.000	-.010
8.906	-.223	-.265
28.985	-.374	-.422
49.072	-.463	-.515
69.155	-.484	-.540
89.238	-.465	-.521
109.321	-.396	-.456
129.403	-.346	-.386
149.486	-.257	-.277
169.569	-.121	-.129
189.652	.0	.0

CALIBRATION DATA

WRSQ RECEPTACLE AND WIRING CODE			
(1)	(A)	RED	EXCIT. (+)
(2)	(B)	GRN	SIGNAL (+)
(3)	(C)	WHT	SIGNAL (-)
(4)	(D)	BLK	EXCIT. (-)

TRANSducer WIRING CODE

PARAMETERS DERIVED FROM CALIBRATION

EXCITATION = 10.0000 VOLTS
 SENSITIVITY = 2.00828E-01 (MV /VOLT)/PSIA
 SPAN = 200.8284 MV
 ZERO OFFSET = -11.1764 MV
 ERROR BAND = - .27 % TO + .0 % OF FSO
 INPUT RESISTANCE = 1656.0 OHMS; OUTPUT RESISTANCE = 473.00 OHMS
 SHUNT CALIB = .0

LLL-FORCE AND PRESSURE
 CALIBRATION FACILITY
 BLDG. 231, RM 1662
 EXT. 27180

FIGURE 9. A TYPICAL TERMINAL POINT CALIBRATION FOR A SENSO-METRICS PRESSURE TRANSDUCER.

SENSOMETRIC PRESSURE TRANSDUCER MOD.NO. 601087 , S/N5381
 CALIBRATED 2/13/81 AT 13:29 HRS AT 22.0 DEG.C.

FILE 118

WRSQ RECIPTACLE AND WIPING CODE

(1)	(A)	RED	EXCIT.	(+)
(2)	(B)	GRN	SIGNAL	(+)
(3)	(C)	WHI	SIGNAL	(-)
(4)	(D)	BLK	EXCIT.	(-)

EXCITATION = 10.0000 VOLTS
 SENSITIVITY = 2.00898E-01 (MV /VOLT)/PSIA
 SPAN = 200.8975 MV
 ERROR BAND = -0.11 % TO + 0.17 % OF FSO
 ZERO OFFSET = -11.5144 MV
 INPUT RESISTANCE = 1656.0 OHMS; OUTPUT RESISTANCE = 473.004MS
 SHUNT CALIB. = .0

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 BLDG. 231, RM 1662
 EXT. 2718U

FIGURE 10. A TYPICAL LEAST SQUARES PLOT FOR A SENSO-METRICS
 PRESSURE TRANSDUCER.

The other end of the copper tubing terminated into junction boxes that JAERI technicians installed inside the wetwell. Figures 11 through 14 show the two junction boxes inside the wetwell, before and after final installation. The cable from each pressure transducer was spliced inside the junction box to cable from the data acquisition system. This system made a water-tight seal, keeping water out of the inside of the transducer and junction box.

An end-to-end calibration is what all Measurements Engineers hope they can do to determine the accuracy for a test. To perform an end-to-end calibration, the complete experiment is subjected to accurately known measurands and the data recorded and reduced from each transducer just as if it were an actual test. The complete instrumentation system, from the transducer to the final recorded data, is used during this type of calibration to determine the accuracy of the experimental data. A determination of the accuracy of the data can be made by comparing the results of the end-to-end data with Laboratory data.

The accuracy of the end-to-end calibrations, therefore, depends on the accuracy of the instrument that is measuring the known input. For this calibration, a 'standard' pressure gage was furnished by the staff at JAERI. Its accuracy was $\pm 0.15\%$ of the full scale reading, which is 72 psi.

The end-to-end calibration was done with approximately 7 m of water in the wetwell. The suppression system was pressurized to a nominal 50 psi in 7 psi increments, both increasing and decreasing pressure. The output of each pressure transducer was recorded using the data acquisition system at JAERI. During the actual end-to-end

FIGURE 11. INLET END OF JUNCTION BOX INSIDE OF WETWELL USED TO WATERPROOF SENSO-METRICS PRESSURE TRANSDUCERS.

FIGURE 12. EXIT END OF JUNCTION BOX INSIDE OF WETWELL USED TO WATERPROOF SENSO-METRICS PRESSURE TRANSDUCERS.

FIGURE 13. COMPLETED JUNCTION BOX, EXIT END, INSIDE OF NETWELL WHICH IS USED TO WATERPROOF SEN30-METRICS PRESSURE TRANSDUCERS, 18

FIGURE 14. COMPLETED JUNCTION BOX, INLET END, INSIDE OF WETWELL WHICH IS USED TO WATERPROOF SENSO-METRICS PRESSURE TRANSDUCERS.

calibration we were able to reduce the data as it was being recorded. This gave us a 'first-hand' look at the data to verify the sensitivity and linearity of each transducer. Figure 15 shows Dr. Y. Kukita, W. Shay, M. Takeshita and K. Namatame reviewing calibration data.

The 7m of water in the wetwell causes an output from each pressure transducer. This output was not desirable for the data acquisition system at JAERI. In order to get an output compatible with their data acquisition system, a DC offset control circuit, shown in Figure 16, was used. This circuit should have no effect on the output of a pressure transducer.

Table I lists the pressure and actual output data recorded at JAERI on June 26, 1981, from the end-to-end calibration. From this data we can calculate the degree of linearity and sensitivity for each transducer and compare that to the LLNL calibrations. This table shows data from only 23 pressure transducers, as two failed* during the calibration. An effort to determine the reason for failure will be made when JAERI staff replaces these units.

Figures 17 through 25 show the deviation, or linearity, for each individual pressure transducer using the data in Table I. In general, the non-linearity of these transducers is less than $\pm 0.5\%$ of full scale, and only three transducers had non-linearities exceeding 1%.

* wetwell floor below VP6 (S/N 5402) and 11.5m above exit of VP5 (S/N 5381)

FIGURE 13. FROM LEFT TO RIGHT; DR. Y. KUKITA, W. SHAY, M. TAKESHITA AND K. NAMTANE
INSIDE CONTROL ROOM REVIEWING CALIBRATION DATA.

FIGURE 16. DC OFFSET CIRCUIT USED BY JAERI FOR THE SENSOMETRICS PRESSURE TRANSDUCERS.

TABLE I. PRESSURE AND OUTPUT FROM SENSO-METRICS, INC. PRESSURE TRANSDUCERS DURING END-TO-END CALIBRATION, JUNE 26, 1981.

TRANSDUCER IDENTIFICATION	INCREASING PRESSURE				DECREASING PRESSURE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	(PRESSURE - PSI)				(PRESSURE - PSI)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
S/N	LOCATION	Q	7.456 (MV)	14.550 (MV)	21.635 (MV)	28.750 (MV)	35.572 (MV)	42.783 (MV)	49.152 (MV)	55.445 (MV)	61.737 (MV)	68.022 (MV)	74.311 (MV)	80.602 (MV)	86.891 (MV)	93.181 (MV)	99.471 (MV)	105.761 (MV)	112.051 (MV)	118.341 (MV)	124.631 (MV)	130.921 (MV)	137.211 (MV)	143.501 (MV)	149.791 (MV)	156.081 (MV)	162.371 (MV)	168.661 (MV)	174.951 (MV)	181.241 (MV)	187.531 (MV)	193.821 (MV)	200.111 (MV)	206.401 (MV)	212.691 (MV)	218.981 (MV)	225.271 (MV)	231.561 (MV)	237.851 (MV)	244.141 (MV)	250.431 (MV)	256.721 (MV)	263.011 (MV)	269.301 (MV)	275.591 (MV)	281.881 (MV)	288.171 (MV)	294.461 (MV)	300.751 (MV)	307.041 (MV)	313.331 (MV)	319.621 (MV)	325.911 (MV)	332.201 (MV)	338.491 (MV)	344.781 (MV)	351.071 (MV)	357.361 (MV)	363.651 (MV)	369.941 (MV)	376.231 (MV)	382.521 (MV)	388.811 (MV)	395.101 (MV)	401.391 (MV)	407.681 (MV)	413.971 (MV)	420.261 (MV)	426.551 (MV)	432.841 (MV)	439.131 (MV)	445.421 (MV)	451.711 (MV)	458.001 (MV)	464.291 (MV)	470.581 (MV)	476.871 (MV)	483.161 (MV)	489.451 (MV)	495.741 (MV)	502.031 (MV)	508.321 (MV)	514.611 (MV)	520.901 (MV)	527.191 (MV)	533.481 (MV)	539.771 (MV)	546.061 (MV)	552.351 (MV)	558.641 (MV)	564.931 (MV)	571.221 (MV)	577.511 (MV)	583.801 (MV)	590.091 (MV)	596.381 (MV)	602.671 (MV)	608.961 (MV)	615.251 (MV)	621.541 (MV)	627.831 (MV)	634.121 (MV)	640.411 (MV)	646.701 (MV)	653.00 (MV)	659.29 (MV)	665.58 (MV)	671.87 (MV)	678.16 (MV)	684.45 (MV)	690.74 (MV)	697.03 (MV)	703.32 (MV)	709.61 (MV)	715.90 (MV)	722.19 (MV)	728.48 (MV)	734.77 (MV)	741.06 (MV)	747.35 (MV)	753.64 (MV)	759.93 (MV)	766.22 (MV)	772.51 (MV)	778.80 (MV)	785.09 (MV)	791.38 (MV)	797.67 (MV)	803.96 (MV)	810.25 (MV)	816.54 (MV)	822.83 (MV)	829.12 (MV)	835.41 (MV)	841.70 (MV)	848.00 (MV)	854.29 (MV)	860.58 (MV)	866.87 (MV)	873.16 (MV)	879.45 (MV)	885.74 (MV)	892.03 (MV)	898.32 (MV)	904.61 (MV)	910.90 (MV)	917.19 (MV)	923.48 (MV)	929.77 (MV)	936.06 (MV)	942.35 (MV)	948.64 (MV)	954.93 (MV)	961.22 (MV)	967.51 (MV)	973.80 (MV)	980.09 (MV)	986.38 (MV)	992.67 (MV)	998.96 (MV)	1005.25 (MV)	1011.54 (MV)	1017.83 (MV)	1024.12 (MV)	1030.41 (MV)	1036.70 (MV)	1043.00 (MV)	1049.29 (MV)	1055.58 (MV)	1061.87 (MV)	1068.16 (MV)	1074.45 (MV)	1080.74 (MV)	1087.03 (MV)	1093.32 (MV)	1099.61 (MV)	1105.90 (MV)	1112.19 (MV)	1118.48 (MV)	1124.77 (MV)	1131.06 (MV)	1137.35 (MV)	1143.64 (MV)	1149.93 (MV)	1156.22 (MV)	1162.51 (MV)	1168.80 (MV)	1175.09 (MV)	1181.38 (MV)	1187.67 (MV)	1193.96 (MV)	1200.25 (MV)	1206.54 (MV)	1212.83 (MV)	1219.12 (MV)	1225.41 (MV)	1231.70 (MV)	1238.00 (MV)	1244.29 (MV)	1250.58 (MV)	1256.87 (MV)	1263.16 (MV)	1269.45 (MV)	1275.74 (MV)	1282.03 (MV)	1288.32 (MV)	1294.61 (MV)	1300.90 (MV)	1307.19 (MV)	1313.48 (MV)	1319.77 (MV)	1326.06 (MV)	1332.35 (MV)	1338.64 (MV)	1344.93 (MV)	1351.22 (MV)	1357.51 (MV)	1363.80 (MV)	1370.09 (MV)	1376.38 (MV)	1382.67 (MV)	1388.96 (MV)	1395.25 (MV)	1401.54 (MV)	1407.83 (MV)	1414.12 (MV)	1420.41 (MV)	1426.70 (MV)	1433.00 (MV)	1439.29 (MV)	1445.58 (MV)	1451.87 (MV)	1458.16 (MV)	1464.45 (MV)	1470.74 (MV)	1477.03 (MV)	1483.32 (MV)	1489.61 (MV)	1495.90 (MV)	1502.19 (MV)	1508.48 (MV)	1514.77 (MV)	1521.06 (MV)	1527.35 (MV)	1533.64 (MV)	1539.93 (MV)	1546.22 (MV)	1552.51 (MV)	1558.80 (MV)	1565.09 (MV)	1571.38 (MV)	1577.67 (MV)	1583.96 (MV)	1590.25 (MV)	1596.54 (MV)	1602.83 (MV)	1609.12 (MV)	1615.41 (MV)	1621.70 (MV)	1628.00 (MV)	1634.29 (MV)	1640.58 (MV)	1646.87 (MV)	1653.16 (MV)	1659.45 (MV)	1665.74 (MV)	1672.03 (MV)	1678.32 (MV)	1684.61 (MV)	1690.90 (MV)	1697.19 (MV)	1703.48 (MV)	1709.77 (MV)	1716.06 (MV)	1722.35 (MV)	1728.64 (MV)	1734.93 (MV)	1741.22 (MV)	1747.51 (MV)	1753.80 (MV)	1760.09 (MV)	1766.38 (MV)	1772.67 (MV)	1778.96 (MV)	1785.25 (MV)	1791.54 (MV)	1797.83 (MV)	1804.12 (MV)	1810.41 (MV)	1816.70 (MV)	1823.00 (MV)	1829.29 (MV)	1835.58 (MV)	1841.87 (MV)	1848.16 (MV)	1854.45 (MV)	1860.74 (MV)	1867.03 (MV)	1873.32 (MV)	1879.61 (MV)	1885.90 (MV)	1892.19 (MV)	1898.48 (MV)	1904.77 (MV)	1911.06 (MV)	1917.35 (MV)	1923.64 (MV)	1929.93 (MV)	1936.22 (MV)	1942.51 (MV)	1948.80 (MV)	1955.09 (MV)	1961.38 (MV)	1967.67 (MV)	1973.96 (MV)	1980.25 (MV)	1986.54 (MV)	1992.83 (MV)	1999.12 (MV)	2005.41 (MV)	2011.70 (MV)	2018.00 (MV)	2024.29 (MV)	2030.58 (MV)	2036.87 (MV)	2043.16 (MV)	2049.45 (MV)	2055.74 (MV)	2062.03 (MV)	2068.32 (MV)	2074.61 (MV)	2080.90 (MV)	2087.19 (MV)	2093.48 (MV)	2100.00 (MV)	2106.50 (MV)	2113.00 (MV)	2119.50 (MV)	2126.00 (MV)	2132.50 (MV)	2139.00 (MV)	2145.50 (MV)	2152.00 (MV)	2158.50 (MV)	2165.00 (MV)	2171.50 (MV)	2178.00 (MV)	2184.50 (MV)	2191.00 (MV)	2197.50 (MV)	2204.00 (MV)	2210.50 (MV)	2217.00 (MV)	2223.50 (MV)	2230.00 (MV)	2236.50 (MV)	2243.00 (MV)	2249.50 (MV)	2256.00 (MV)	2262.50 (MV)	2269.00 (MV)	2275.50 (MV)	2282.00 (MV)	2288.50 (MV)	2295.00 (MV)	2301.50 (MV)	2308.00 (MV)	2314.50 (MV)	2321.00 (MV)	2327.50 (MV)	2334.00 (MV)	2340.50 (MV)	2347.00 (MV)	2353.50 (MV)	2360.00 (MV)	2366.50 (MV)	2373.00 (MV)	2379.50 (MV)	2386.00 (MV)	2392.50 (MV)	2399.00 (MV)	2405.50 (MV)	2412.00 (MV)	2418.50 (MV)	2425.00 (MV)	2431.50 (MV)	2438.00 (MV)	2444.50 (MV)	2451.00 (MV)	2457.50 (MV)	2464.00 (MV)	2470.50 (MV)	2477.00 (MV)	2483.50 (MV)	2490.00 (MV)	2496.50 (MV)	2503.00 (MV)	2509.50 (MV)	2516.00 (MV)	2522.50 (MV)	2529.00 (MV)	2535.50 (MV)	2542.00 (MV)	2548.50 (MV)	2555.00 (MV)	2561.50 (MV)	2568.00 (MV)	2574.50 (MV)	2581.00 (MV)	2587.50 (MV)	2594.00 (MV)	2600.50 (MV)	2607.00 (MV)	2613.50 (MV)	2620.00 (MV)	2626.50 (MV)	2633.00 (MV)	2639.50 (MV)	2646.00 (MV)	2652.50 (MV)	2659.00 (MV)	2665.50 (MV)	2672.00 (MV)	2678.50 (MV)	2685.00 (MV)	2691.50 (MV)	2698.00 (MV)	2704.50 (MV)	2711.00 (MV)	2717.50 (MV)	2724.00 (MV)	2730.50 (MV)	2737.00 (MV)	2743.50 (MV)	2750.00 (MV)	2756.50 (MV)	2763.00 (MV)	2769.50 (MV)	2776.00 (MV)	2782.50 (MV)	2789.00 (MV)	2795.50 (MV)	2802.00 (MV)	2808.50 (MV)	2815.00 (MV)	2821.50 (MV)	2828.00 (MV)	2834.50 (MV)	2841.00 (MV)	2847.50 (MV)	2854.00 (MV)	2860.50 (MV)	2867.00 (MV)	2873.50 (MV)	2880.00 (MV)	2886.50 (MV)	2893.00 (MV)	2899.50 (MV)	2906.00 (MV)	2912.50 (MV)	2919.00 (MV)	2925.50 (MV)	2932.00 (MV)	2938.50 (MV)	2945.00 (MV)	2951.50 (MV)	2958.00 (MV)	2964.50 (MV)	2971.00 (MV)	2977.50 (MV)	2984.00 (MV)	2990.50 (MV)	2997.00 (MV)	3003.50 (MV)	3010.00 (MV)	3016.50 (MV)	3023.00 (MV)	3029.50 (MV)	3036.00 (MV)	3042.50 (MV)	3049.00 (MV)	3055.50 (MV)	3062.00 (MV)	3068.50 (MV)	3075.00 (MV)	3081.50 (MV)	3088.00 (MV)	3094.50 (MV)	3101.00 (MV)	3107.50 (MV)	3114.00 (MV)	3120.50 (MV)	3127.00 (MV)	3133.50 (MV)	3140.00 (MV)	3146.50 (MV)	3153.00 (MV)	3159.50 (MV)	3166.00 (MV)	3172.50 (MV)	3179.00 (MV)	3185.50 (MV)	3192.00 (MV)	3198.50 (MV)	3205.00 (MV)	3211.50 (MV)	3218.00 (MV)	3224.50 (MV)	3231.00 (MV)	3237.50 (MV)	3244.00 (MV)	3250.50 (MV)	3257.00 (MV)	3263.50 (MV)	3270.00 (MV)	3276.50 (MV)	3283.00 (MV)	3289.50 (MV)	3296.00 (MV)	3302.50 (MV)	3309.00 (MV)	3315.50 (MV)	3322.00 (MV)	3328.50 (MV)	3335.00 (MV)	3341.50 (MV)	3348.00 (MV)	3354.50 (MV)	3361.00 (MV)	3367.50 (MV)	3374.00 (MV)	3380.50 (MV)	3387.00 (MV)	3393.50 (MV)	3400.00 (MV)	3406.50 (MV)	3413.00 (MV)	3419.50 (MV)	3426.00 (MV)	3432.50 (MV)	3439.00 (MV)	3445.50 (MV)	3452.00 (MV)	3458.50 (MV)	3465.00 (MV)	3471.50 (MV)	3478.00 (MV)	3484.50 (MV)	3491.00 (MV)	3497.50 (MV)	3504.00 (MV)	3510.50 (MV)	3517.00 (MV)	3523.50 (MV)	3530.00 (MV)	3536.50 (MV)	3543.00 (MV)	3549.50 (MV)	3556.00 (MV)	3562.50 (MV)	3569.00 (MV)	3575.50 (MV)	3582.00 (MV)	3588.50 (MV)	3595.00 (MV)	3601.50 (MV)	3608.00 (MV)	3614.50 (MV)	3621.00 (MV)	3627.50 (MV)	3634.00 (MV)	3640.50 (MV)	3647.00 (MV)	3653.50 (MV)	3660.00 (MV)	3666.50 (MV)	3673.00 (MV)	3679.50 (MV)	3686.00 (MV)	3692.50 (MV)	3699.00 (MV)	3705.50 (MV)	3712.00 (MV)	3718.50 (MV)	3725.00 (MV)	3731.50 (MV)	3738.00 (MV)	3744.50 (MV)	3751.00 (MV)	3757.50 (MV)	3764.00 (MV)	3770.50 (MV)	3777.00 (MV)	3783.50 (MV)	3790.00 (MV)	3796.50 (MV)	3803.00 (MV)	3809.50 (MV)	3816.00 (MV)	3822.50 (MV)	3829.00 (MV)	3835.50 (MV)	3842.00 (MV)	3848.50 (MV)	3855.00 (MV)	3861.50 (MV)	3868.00 (MV)	3874.50 (MV)	3881.00 (MV)	3887.50 (MV)	3894.00 (MV)	3900.50 (MV)	3907.00 (MV)	3913.50 (MV)	3920.00 (MV)	3926.50 (MV)	3933.00 (MV)	3939.50 (MV)	3946.00 (MV)	3952.50 (MV)	3959.00 (MV)	3965.50 (MV)	3972.00 (MV)	3978.50 (MV)	3985.00 (MV)	3991.50 (MV)	3998.00 (MV)	4004.50 (MV)	4011.00 (MV)	4017.50 (MV)	4024.00 (MV)	4030.50 (MV)	4037.00 (MV)	4043.50 (MV)	4050.00 (MV)	4056.50 (MV)	4063.00 (MV)	4069.50 (MV)	4076.00 (MV)	4082.50 (MV)	4089.00 (MV)	4095.50 (MV)	4102.00 (MV)	4108.50 (MV)	4115.00 (MV)	4121.50 (MV)	4128.00 (MV)	4134.50 (MV)	4141.00 (MV)	4147.50 (MV)	4154.00 (MV)	4160.50 (MV)	4167.00 (MV)	4173.50 (MV)	4180.00 (MV)	4186.50 (MV)	4193.00 (MV)	4199.50 (MV)	4206.00 (MV)	4212.50 (MV)	4219.00 (MV)	4225.50 (MV)	4232.00 (MV)	4238.50 (MV)	4245.00 (MV)	4251.50 (MV)	4258.00 (MV)	4264.50 (MV)	4271.00 (MV)	4277.50 (MV)	4284.00 (MV)	4290.50 (MV)	4297.00 (MV)	4303.50 (MV)	4310.00 (MV)	4316.50 (MV)	4323.00 (MV)	4329.50 (MV)	4336.00 (MV)	4342.50 (MV)	4349.00 (MV)	4355.50 (MV)	4362.00 (MV)	4368.50 (MV)	4375.00 (MV)	4381.50 (MV)	4388.00 (MV)	4394.50 (MV)	4401.00 (MV)	4407.50 (MV)	4414.00 (MV)	4420.50 (MV)	4427.00 (MV)	4433.50 (MV)	4440.00 (MV)	4446.50 (MV)	4453.00 (MV)	4459.50 (MV)	4466.00 (MV)	4472.50 (MV)	4479.00 (MV)	4485.50 (MV)	4492.00 (MV)	4498.50 (MV)	4505.00 (MV)	4511.50 (MV)	4518.00 (MV)	4524.50 (MV)	4531.00 (MV)	4537.50 (MV)	4544.00 (MV)	4550.50 (MV)	4557.00 (MV)	4563.50 (MV)	4570.00 (MV)	4576.50 (MV)	4583.00 (MV)	4589.50 (MV)	4596.00 (MV)	4602.50 (MV)	4609.00 (MV)	4615.50 (MV)	4622.00 (MV)	4628.50 (MV)	4635.00 (MV)	4641.50 (MV)	4648.00 (MV)	4654.50 (MV)	4661.00 (MV)	4667.50 (MV)	4674.00 (MV)	4680.50 (MV)	4687.00 (MV)	4693.50 (MV)	4700.00 (MV)	4706.50 (MV)	4713.00 (MV)	4719.50 (MV)	4726.00 (MV)	4732.50 (MV)	4739.00 (MV)	4745.50 (MV)	4752.00 (MV)	4758.50 (MV)	4765.00 (MV)	4771.50 (MV)	4778.00 (MV)	4784.50 (MV)	4791.00 (MV)	4797.50 (MV)	4804.00 (MV)	4810.50 (MV)	4817.00 (MV)	4823.50 (MV)	4830.00 (MV)	4836.50 (MV)	4843.00 (MV)	4849.50 (MV)	4856.00 (MV)	4862.50 (MV)	4869.00 (MV)	4875.50 (MV)	4882.00 (MV)	4888.50 (MV)	4895.00 (MV)	4901.50 (MV)	4908.00 (MV)	4914.50 (MV)	4921.00 (MV)	4927.50 (MV)	4934.00 (MV)	4940.50 (MV)	4947.00 (MV)	4953.50 (MV)	4960.00 (MV)	4966.50 (MV)	4973.00 (MV)	4979.50 (MV)	4986.00 (MV)	4992.50 (MV)	4999.00 (MV)	5005.50 (MV)	5012.00 (MV)	5018.50 (MV)	5025.00 (MV)	5031.50 (MV)	5038.00 (MV)	5044.50 (MV)	5051.00 (MV)	5057.50 (MV)	5064.00 (MV)	5070.50 (MV)	5077.00 (MV)	5083.50 (MV)	5090.00 (MV)	5096.50 (MV)	5103.00 (MV)	5109.50 (MV)	5116.00 (MV)	5122.50 (MV)	5129.00 (MV)	5135.50 (MV)	5142.00 (MV)	5148.50 (MV)	5155.00 (MV)	5161.50 (MV)	5168.00 (MV)	5174.50 (MV)	5181.00 (MV)	5187.50 (MV)	5194.00 (MV)	5200.50 (MV)	5207.00 (MV)	5213.50 (MV)	5220.00 (MV)	5226.50 (MV)	5233.00 (MV)	5239.50 (MV)	5246.00 (MV)	5252.50 (MV)	5259.00 (MV)	5265.50 (MV)	5272.00 (MV)	5278.50 (MV)	5285.00 (MV)	5291.50 (MV)	5298.00 (MV)	5304.50 (MV)	5311.00 (MV)	5317.50 (MV)	5324.00 (MV)	5330.50 (MV)	5337.00 (MV)	5343.50 (MV)	5350.00 (MV)	5356.50 (MV)	5363.00 (MV)	5369.50 (MV)	5376.00 (MV)	5382.50 (MV)	5389.00 (MV)	5395.50 (MV)	5402.00 (MV)	5408.50 (MV)	5415.00 (MV)	5421.50 (MV)	5428.00 (MV)	5434.50 (MV)	5441.00 (MV)	5447.50 (MV)	5454.00 (MV)	5460.50 (MV)	5467.00 (MV)	5473.50 (MV)	5480.00 (MV)	5486.50 (MV)	5493.00 (MV)	5499.50 (MV)	5506.00 (MV)	5512.50 (MV)	5519.00 (MV)	5525.50 (MV)	5532.00 (MV)	5538.50 (MV)	5545.00 (MV)	5551.50 (MV)	5558.00 (MV)

END-TO-END CALIBRATION OF SENSO-METRICS PRESSURE TRANSDUCERS

○ INCREASING PRESSURE
 □ DECREASING PRESSURE

FIGURE 17

B.S.
 7/29/81

END-TO-END CALIBRATION OF SENSOMETRIC PRESSURE TRANSDUCERS

S/N 5357 VPPE-321/VP 3 OUTLET

S/N 5359 VPPE-421/VP 4 OUTLET

S/N 5367 VPPE-521/VP 5 OUTLET

○ INCREASING PRESSURE
 □ DECREASING PRESSURE

FIGURE 1B

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1/23/81

END-TO-END CALIBRATION OF SENSOMETRICS PRESSURE TRANSDUCERS

○ INCREASING PRESSURE
 □ DECREASING PRESSURE

FIGURE 19

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 7/29/91

END-TO-END CALIBRATION OF SENSO-METRICS PRESSURE TRANSDUCERS

S/N 5356 VPPF-520/VPS EXTERIOR

S/N 2581B WWPF-121/VPI BOTTOM

S/N 5389 WWPF-122/VPI BOTTOM

FIGURE 20

BS
7/29/81

END-TO-END CALIBRATION OF SENSOMETRIC PRESSURE TRANSDUCERS

S/N 5385 WWPF-123/VP3 BOTTOM

S/N 5386 WWPF-124/VP4 BOTTOM

S/N 5809 WWPF-125/VP5 BOTTOM

○ INCREASING PRESSURE
 □ DECREASING PRESSURE

FIGURE 21

BS
 12/8/81

END-TO-END CALIBRATION OF SENSOMETRICS PRESSURE TRANSDUCERS

S/N 5398 WWP-127/VP7 BOTTOM

S/N 5353 WWP-022/VP1 WALL

S/N 5405 WWP-222/VP2 WALL

○ INCREASING PRESSURE
 □ DECREASING PRESSURE

FIGURE 22

ES
7/2/81

END-TO-END CALIBRATION OF SENSOMETRIC PRESSURE TRANSDUCERS

S/N 5375 WWP-322/VP3 WALL

S/N 5396 WWP-422/VP3 SHELL

S/N 5398 WWP-522/VP4 SHELL

○ INCREASING PRESSURE
□ DECREASING PRESSURE

FIGURE 23

ES
7/29/61

END-TO-END CALIBRATION OF SENSO-METRICS PRESSURE TRANSDUCERS

SIN 2881A WWPF-622/1P4 WALL

SIN 5850 WWPF-722/1F7 WALL

SIN 5349 WWPF-822/1P6 WALL

○ INCREASING PRESSURE
 □ DECREASING PRESSURE

FIGURE 24

RS
 729/81

END-TO-END CALIBRATION OF SENSOR-METRICS PRESSURE TRANSDUCERS

FIGURE 35

BS
7/23/84

Table II lists the average sensitivity from the LLNL calibrations, the sensitivity calculated from the end-to-end at JAERI, and the percent difference between the two sensitivities. The same close agreement of sensitivities can be seen between LLNL and JAERI. The average deviation between our sensitivities and the sensitivities calculated from the end-to-end calibrations at JAERI was $\pm 0.31\%$ for all but three transducers which had deviations greater than 1%.

Based on the above results of the linearity and sensitivity of these twenty-three pressure transducers during the end-to-end calibration, we can say that they should give valid data during testing.

TRANSDUCER S/N	TRANSDUCER LOCATION	*AVERAGE SENSITIVITY (mv/v/psia)	SENSITIVITY AT JAERI (mv/v/psi)	**DEVIATION IN SENSITIVITY (%)
5362	VP1-exit, int.	0.202165	0.20507	1.44
5359	VP2-exit, int.	0.200853	0.19958	-0.63
5357	VP3-exit, int.	0.201063	0.19958	-0.74
5356	VP4-exit, int.	0.201457	0.20036	-0.54
5367	VP5-exit, int.	0.204034	0.20311	-0.45
5380	VP6-exit, int.	0.205165	0.20389	-0.62
5382	VP7-exit, int.	0.201660	0.20232	0.33
5355	VP5-exit, ext.	0.201811	0.20115	-0.33
2581B	VP1-w.w. floor	0.186639	0.18586	-0.42
5389	VP2-w.w. floor	0.203176	0.20076	-1.19
5385	VP3-w.w. floor	0.200908	0.19958	-0.66
5386	VP4-w.w. floor	0.201625	0.20036	-0.63
5809	VP5-w.w. floor	0.201721	0.19997	-0.87
5398	VP7-w.w. floor	0.203903	0.20311	-0.39
5353	VP1-wall	0.200373	0.19958	-0.40
5405	VP2-wall	0.204327	0.20311	-0.60
5375	VP3-wall	0.201804	0.20115	-0.32
5346	VP3-shell	0.202038	0.20075	-0.64
5348	VP4-shell	0.202426	0.20115	-0.63
2518A	VP4-wall	0.235119	0.23409	-0.44
5350	VP7-wall	0.201385	0.20036	-0.51
5349	VP6-wall	0.201170	0.20036	-0.67
5342	VP1/6-shell	0.201935	0.20624	2.13

* Average sensitivity from three individual calibration runs at LLNL.

** Normalized to LLNL sensitivity.

TABLE II. COMPARISON BETWEEN THE SENSITIVITIES FROM LLNL AND JAERI.

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