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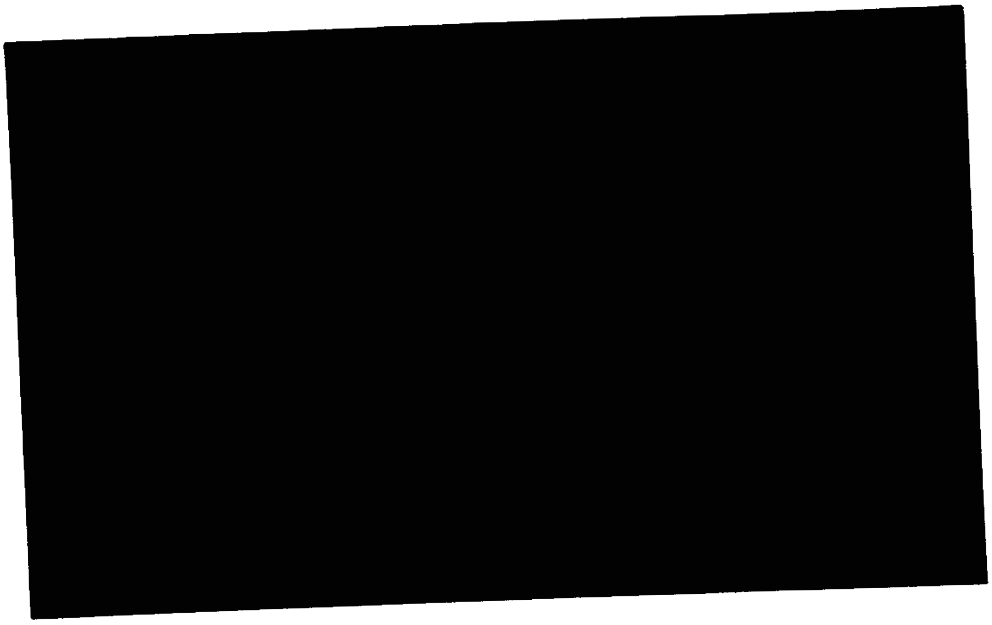

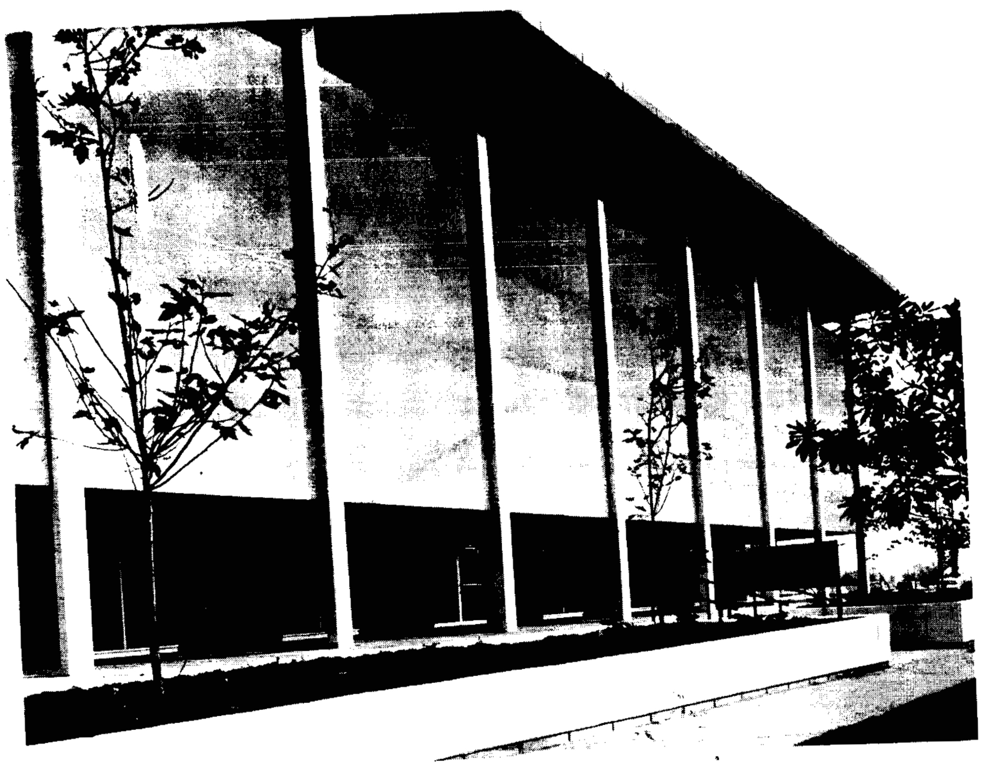

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Final Report

THE DEVELOPMENT AND FABRICATION OF FOUR LOW PRESSURE TRANSDUCERS (EOS MODEL 6081-1)

Prepared for
National Aeronautics and Space Administration
Langley Research Center
Langley Station
Hampton, Virginia
Attention: W. E. Hutcheson, Contracting Officer

NAS1-4482

EOS Report 6081-Final 12 April 1965

Prepared by
H. Painter, Transducer Department

Approved by

William H. Foster fa
M. B. Prince, Manager
AEROSPACE ELECTRONICS DIVISION

ELECTRO-OPTICAL SYSTEMS, INC. — PASADENA, CALIFORNIA

ABSTRACT

This final report covers the design, manufacture, and testing of four very low pressure transducers for NASA/Langley. The transducers had a range of 0 to 0.1 psia and an error band of better than 1 percent. The specification details are contained in the report. The transducers were of the convoluted diaphragm type with a semiconductor strain gage sensor system. The instrument is referred to as EOS Model 6081-1.

CONTENTS

1. TRANSDUCER DESIGN

The transducer (Figs. 1, 2, and 3) used a convoluted diaphragm 1-inch in diameter to the OD of the convolution. A cruciform was embossed into the center of the diaphragm to stiffen it in this area. High energy rate forming was employed in the manufacturing of the diaphragms. The transducer over-pressure stop-plate itself was used as the die, thereby ensuring perfect nesting of the diaphragm into its stop-plate. After forming, the diaphragm is welded into position by two concentric spot-weld seams. This operation is carried out on an automatic seam-welder. The diaphragm is coupled to a cantilever beam via a push-rod which goes through a hole in the center of the stop-plate. This cantilever beam has a semiconductor strain gage bridge bonded to it, at the maximum strain point. The connections go to a header containing glass-insulated, through terminals. It also has a capillary tube for sealing the reference cavity and a secondary stop which is adjusted to stop the end of the cantilever beam. This header is electron-beam welded into position. The strain gage bridge is excited by constant current from an electronic package contained in the transducer.

The materials used were 17-7 PH for the diaphragm and cantilever beam and push-rod; 410 stainless steel for the pressure and reference cavities; and aluminum alloy for the case.

2. MANUFACTURE

The manufacture of these transducers did present some unanticipated problems. The cantilever beam was originally welded to its support post, but it was found necessary to change this system and substitute a screwed-on beam to facilitate repair.

The diaphragms were formed after being welded in place on the first models and the spring-back relied upon to supply the working gap between the stop and the diaphragm. As it transpired, this method was

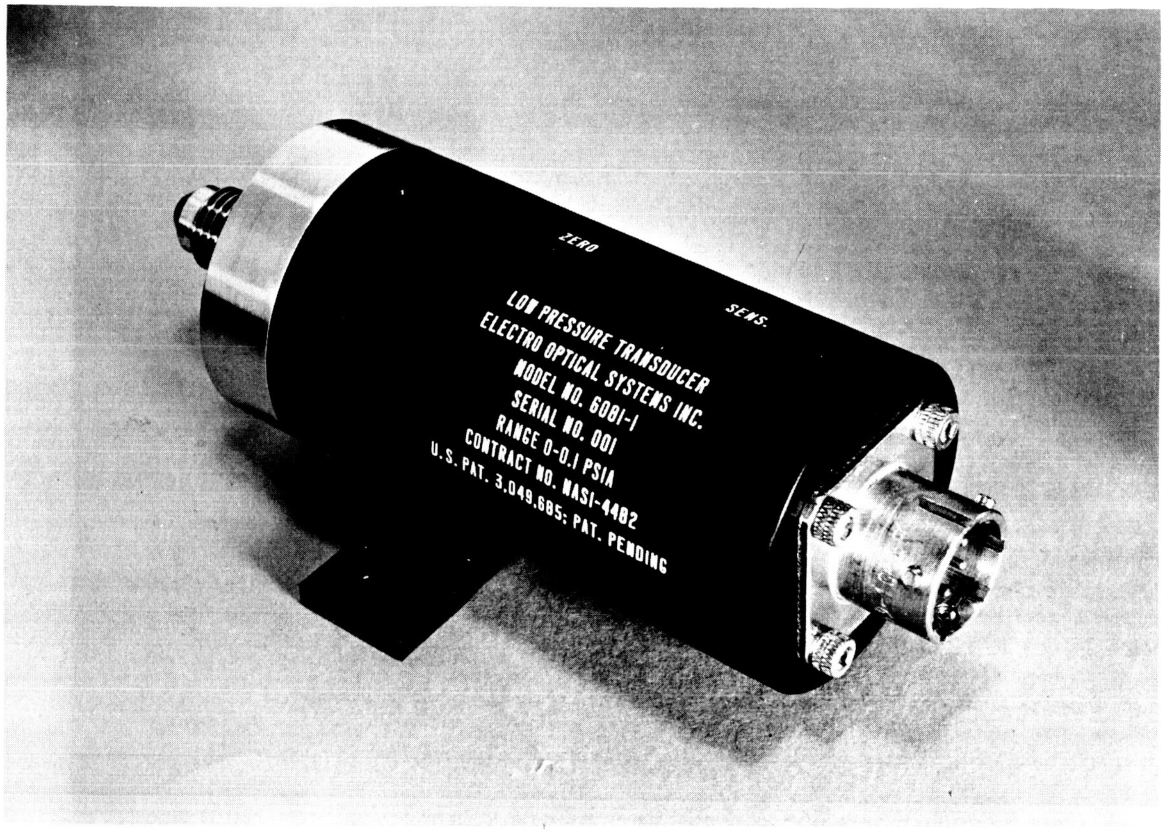
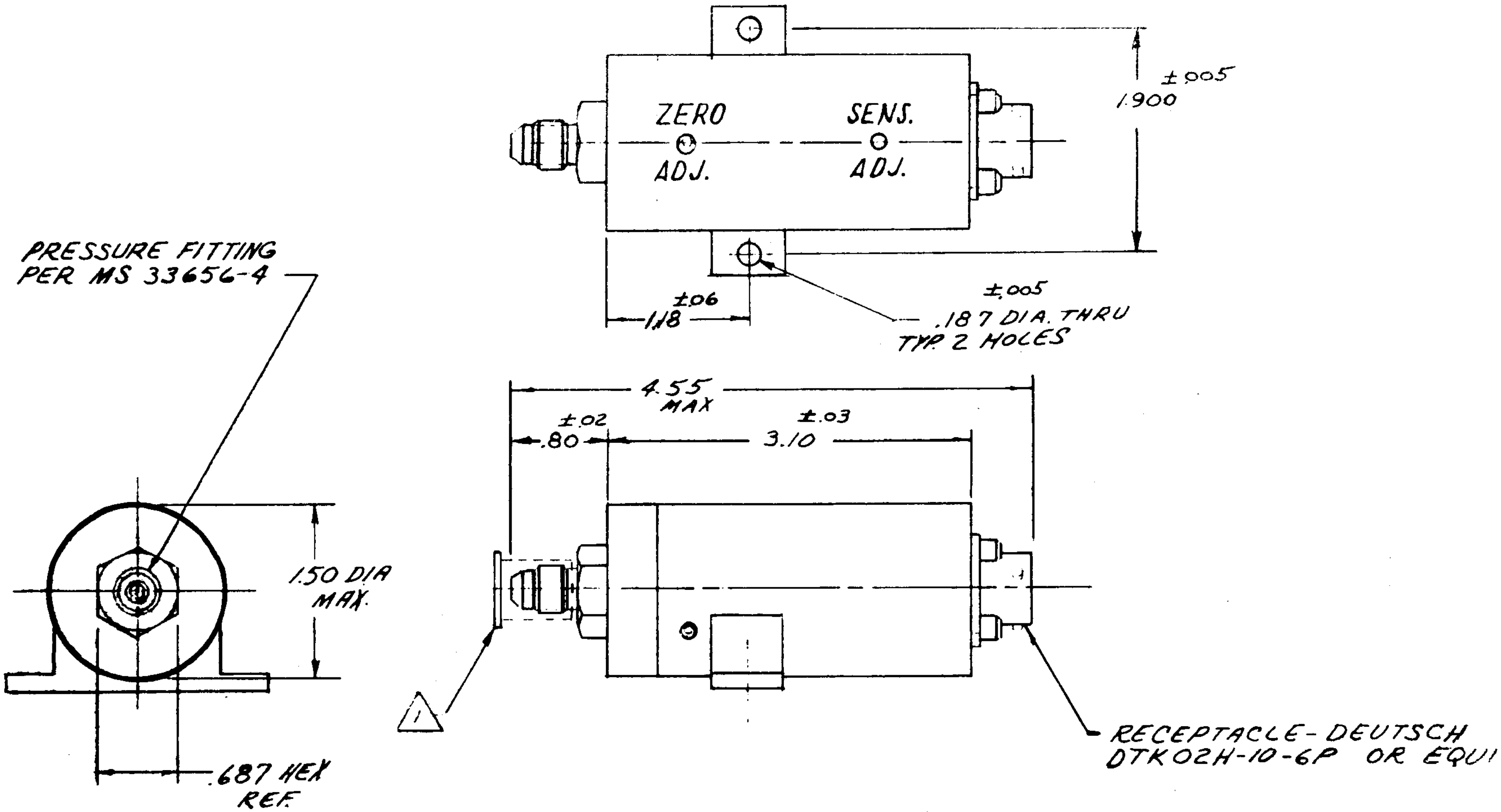
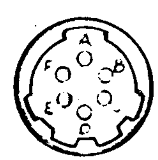


FIG. 1 EOS LOW PRESSURE TRANSDUCER-MODEL 6081-1



CONTACT ARRANGEMENT



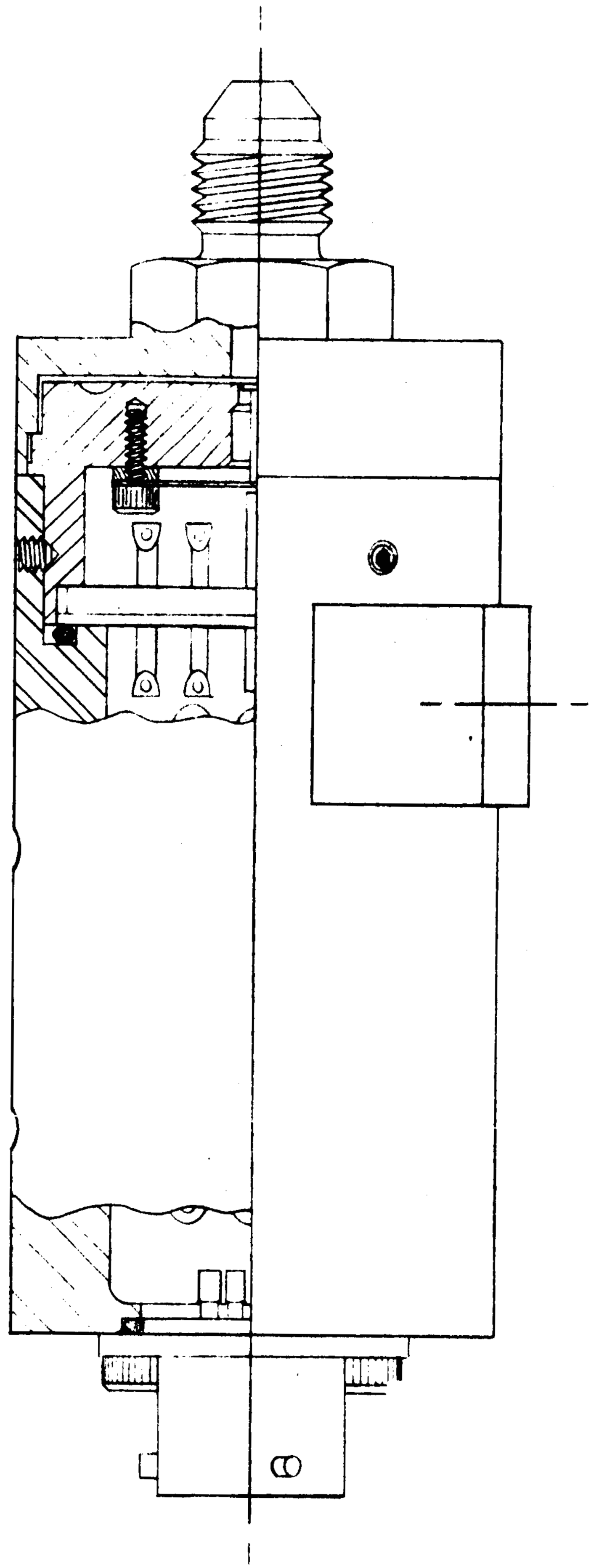
(ORIENTATION OPTIONAL)

PIN IDENTIFICATION

A	EXCITATION +28VDC
B	EXCITATION "0" VDC
C	+ OUTPUT
D	− OUTPUT
E	NO CONNECTION
F	NO CONNECTION

1 PROTECT THREADS WITH DUST CAP WHEN HANDLING, SHIPPING OR STORING

FIG. 2 OUTLINE DRAWING



CONSTRUCTION MODEL NO. 6081-1

FIGURE 3

not successful and the system was therefore modified. The diaphragm is now first welded to a holding ring which is carefully located while forming takes place. The holding ring and diaphragm together are then removed and the working gap machined out of the stop-plate. After the diaphragm is relocated, the seam weld is made, the holding ring removed, and the diaphragm trimmed.

3. TESTING

Testing was carried out per the Test Procedure which, together with the test data, forms the appendix of this report. The results show that all of the instruments had sufficient output and remarkably good linearity, repeatability, and hysteresis, the worst being serial No. 006 with 0.8 percent nonlinearity.

Temperature compensation was carried out for zero shift. Temperature compensation for sensitivity was found to be unnecessary.

The test equipment used was a low pressure test console manufactured by Volumetrics, Inc., Inglewood, California, to an EOS specification. The Knudsen system of volume ratio is used as the test method. It was calibrated against an EOS micromanometer.

Vibration data is also supplied in the appendix and shows that all instruments have a resonant frequency between 1,500 and 1,800 cps, but that they do meet the vibration specifications.

The return to zero after over-pressure is excellent.

4. SPECIFICATIONS

4.1	Range	0 to 0.1 psia
4.2	Trapped cavity volume (excluding pressure port)	0.030 cu in
4.3	Input voltage	28 ± 2 vdc
4.4	Output nominal	0 to 1000 vdc
4.5	Output impedance	1000 ohms max.
4.6	Zero balance - initial	-0 to +10% F.S.
4.7	Error (nonlinearity, hysteresis, and nonrepeatability)	± 1% inc
4.8	Temperature operating range	0 to + 150°F

4.9	Temperature compensated range	+60°F to 110°F
4.10	Temperature error over compensated range centered at 80°F	
	Zero	± 5%
	Sensitivity	± 3%
4.11	Vibration error: 10g, 20 to 2000 cps	0.25%/g

5. CONCLUSIONS

The Model 6081-1 is a good 0 to 0.1 psia transducer. Its linearity, hysteresis, and repeatability are very good for an instrument of such a low range. One of the major problems with very low range absolute pressure transducers, namely, return to zero after over-pressure, seems to have been satisfactorily overcome in the EOS 6081-1. Future work to be considered should include (a) increasing the natural frequency, and (b) reducing the physical size of the transducer. Both of these aims do seem possible of achievement.

APPENDIX

TEST PROCEDURE

0.1 PSIA TRANSDUCERS FOR NAS1-4482

0.1 PSIA TRANSDUCERS FOR NASI-4482

3-12-65

1.0 Scope

This test procedure covers the method of testing the 0.1 psia transducers, for contract number NASI-4482, to insure that said transducers meet all the customer requirements for acceptance as outlined in foresaid contract.

2.0 Applicable Documents

Contract No. NASI-4482, EOS WA 6081, Proposal 64-567.

3.0 Test Equipment

3.1 Low Pressure Calibrator

3.2 Fluke Differential Voltmeter Model 825A

3.3 Power Supply - Power Designs Model 4005

3.4 EOS Calibration Control Console

3.5 Vibration System - MB Electronics C-50

3.6 Centrifuge - Genisco "G" Accelerator Model 1220-1

3.7 Oscilloscope - Tektronics 53A

4.0 Test Procedure

4.1 Configuration

4.1.1 The transducers shall be inspected for overall length and diameter. The length inclusive shall not exceed 5 inches nor shall the diameter exceed 1.5 inches, including pressure fitting and electrical receptacle, and excluding mounting lugs.

4.1.2 The vendor shall supply certification that the trapped cavity volume containing the media to be measured is less than 0.03 cubic inches, not including the pressure fitting.

4.2 Calibration

4.2.1 The transducer shall be connected to the test equipment as shown in Figure 1.

4.2.2 Adjust the power supply for 28 VDC ±.1 VDC input to the transducer.

4.2.3 Adjust zero output to $0 \begin{array}{l} +10 \text{ mV} \\ -0 \text{ mV} \end{array}$ at zero psia and record. Apply full scale pressure of 0.1 psia. Adjust the output to 100 mV DC plus the recorded zero reading with external adjust.

4.3 Linearity, Hysteresis and Repeatability

4.3.1 Connect the transducer as shown in Figure 1.

4.3.2 Apply 0 psia (50 microns approximately) to the transducer. Record millivolt output reading read on differential voltmeter.

4.3.3 With the transducer at 0 psia, increase the input pressure in successive steps of 0.01 psia. Record the millivolt output reading at each successive increase in pressure until full scale pressure is obtained.

4.3.4 Repeat Paragraph 4.3.3 with the pressure increments descending from 0.1 psia to 0 psia.

4.3.5 Increase pressure from 0 psia to 0.05 psia. Read the output and record.

4.3.6 Plot all points recorded in carrying out Paragraphs 4.3.3, 4.3.4, and 4.3.5 and draw the most favourable straight line through these points. The maximum difference between this line and any point must not exceed 1% of full scale output.

4.4 Output Impedance

4.4.1 Apply full scale pressure and note the output.

4.4.2 Connect a 100,000 ohm ±5% resistor across the output of the transducer.

4.4.3 Note the change in output and record. If change is less than 1 mV, transducer has an output impedance of less than 1000 ohms.

4.4.4 Remove 100,000 ohm resistor after test.

4.5 Regulation

4.5.1 Set power supply for 28 VDC ±0.1 VDC.

4.5.2 Apply 0.1 psia. Note and record output.

4.5.3 Decrease power supply voltage to 26 VDC + 0, -0.1 VDC. Record output.

4.5.4 Compute change in output from 28 VDC to 26 VDC. Change should be less than 1%/FS.

4.5.5 Increase power supply voltage to 30 VDC + 0.1, -0 VDC. Record output.

4.5.6 Compute change in output from 28 VDC to 30 VDC. Change should be less than 1%/FS.

4.6 Temperature Test

4.6.1 Connect transducer as shown in Figure 1, setting power supply to 28 VDC.

4.6.2 At ambient temperature (80° ±5°F) record the millivolt output readings at 0 psia (50 microns approximately) and full scale pressure 0.1 psia. Compute sensitivity by subtracting the 0 psia reading from the full scale reading and record.

4.6.3 Decrease temperature in test chamber to +60°F. Stabilize at this temperature for 1 hour. Record output readings at 0 and full scale pressures. Compute sensitivity and record.

4.6.4 Increase temperature in test chamber to +110°F. Stabilize at this temperature for 1 hour. Record output readings at 0 and full scale pressures. Compute sensitivity and record.

4.6.5 Express the difference between zero readings recorded at +80°F and +60°F as a percentage of full scale output at 80°F. Express the difference between the zero readings recorded at +80°F and +110°F as a percentage of full scale output at 80°F. These values of zero deviation shall not exceed ±5% from the 80°F value.

4.6.6 Express the difference in sensitivity readings recorded at +60°F and +80°F as a percentage of full scale output at 80°F. Express the difference in sensitivity readings recorded at 80°F and 110°F as a percentage of full scale output at 80°F . These values of sensitivity deviation shall not exceed ±3% from the 80°F value.

4.7 Overload Test

4.7.1 Take millivolt output readings at 0 and full scale pressures. Record. Compute and record sensitivity.

4.7.2 Remove transducer from pressure source.

4.7.3 Connect transducer to pressure source and apply 0 psia pressure.

4.7.4 Repeat steps 4.7.2 and 4.7.3 ten times. In this manner, repeated overloads of 15 psia will be applied to the transducer.

4.7.5 After completion of ten overload cycles, take 0 and full scale output millivolt readings.

4.7.6 Note and record changes in output, from step 4.7.1 of 0 and full scale, computing sensitivity changes.

4.7.7 Compute percentage change of full scale for 0 and sensitivity.

4.7.8 These percentages must be less than 1% of full scale.

4.8 Vibration

4.8.1 Complete test setup as shown in Figure 2, with evacuation fixture connected to head of exciter with cabling and plumbing installed for the performance of the test as required.

4.8.2 Adjust power supply to 28 VDC ±0.1 VDC.

4.8.3 Apply 0 psia (50 microns approximately) to the transducer and record the output voltage before vibration.

4.8.4 Specifications for Vibration:

1. Frequency range of 5 to 200 cps with crossover at 20 cps.
2. From 5 to 20 cps displacement will be $\frac{1}{2}$" double amplitude.
3. From 20 to 200 cps acceleration will be ±10 g's.
4. Time duration will be 5 minutes total time from 5 cps to 2000 cps and back to 5 cps.

4.8.5 Commence vibration run.

4.8.6 Note and record all resonances exhibiting amplification factors greater than 1.5.

4.8.7 Repeat vibration run for three orthogonal directions.

4.8.8 Sensitivity should be less 0.25%/g of full scale output when measured on the plotter or oscilloscope.

**4.9 Acceleration Test

4.9.1 Complete test setup as shown in Figure 3 with transducer connected to the centrifuge with cabling installed for the performance of the test as required.

4.9.2 Transducer will have been brought to 0 psia with a device which will be leak proof.

4.9.3 Adjust power supply to 28 VDC ±0.1 VDC.

4.9.4 Record the output voltage before acceleration test.

4.9.5 Commence acceleration test, bringing centrifuge to 10 g's for two minutes.

4.9.6 Note and record change in output at acceleration.

4.9.7 Sensitivity should be less than 0.25%/g of full scale output when measured on the DC voltmeter.

**This test, because of complexity and cost, will be considered by EOS to be optional.

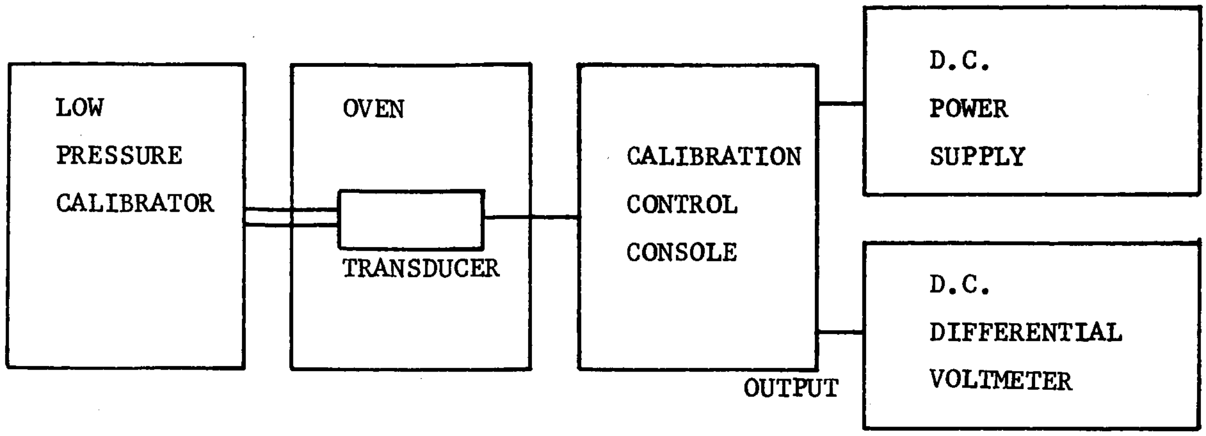


FIGURE 1.

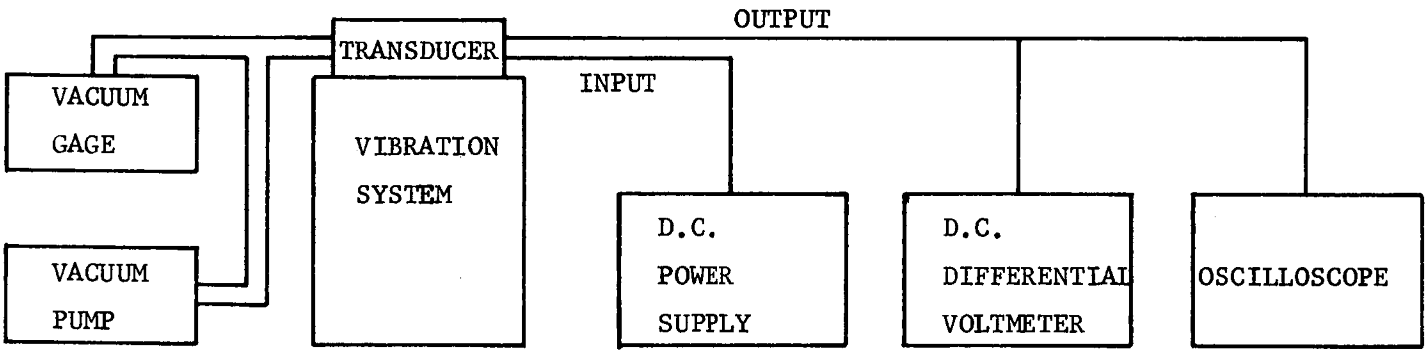


FIGURE 2.

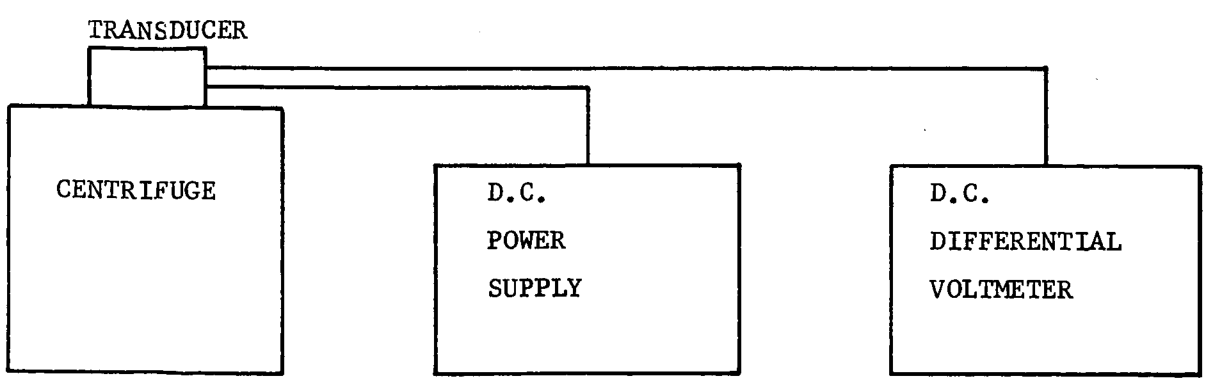


FIGURE 3.

PRESSURE TRANSDUCER

RANGE - 0 TO 0.1PSIA
CONTRACT NO NAS1-4482

MODEL NO 6081-1
SERIAL NO .001

ZERO SET .05 mm HG

INPUT PRESSURE PSIA.	OUTPUT IN MILLIVOLTS			
	+80°F.	+60°F	+110°F	+80°F
0	+1.1	+.8	+1.1	+1.2
0.01	11.1	10.7	11.3	11.2
0.02	21.1	20.6	21.5	21.1
0.03	31.3	30.5	31.7	31.1
0.04	41.4	40.3	41.8	41.1
0.05	51.4	50.2	52.0	51.0
0.06	61.3	60.2	62.1	60.9
0.07	71.4	70.0	72.3	70.9
0.08	81.4	79.8	82.4	80.9
0.09	91.4	89.6	92.7	90.8
0.10	101.4	99.4	102.8	100.8

LINEARITY
+ .18%
REPEATABILITY
- .1%
HYSTERESIS
- .2%
TEMP TEST
SENS: 1.7%
ZERO: .3%

RETURN
To 50% 50.8
UP To 50% 50.9

OUTPUT IMPEDANCE 500Ω
VOLTAGE REGULATION .1%
OVERLOAD HaP.
VIBRATION HaP
CONFIGURATION HaP
TRAPPED VOLUME HaP.

PERFOMED BY D.R.S.
DATE 3/23/65
APPROVED BY HaP
DATE 23 MAR 65

PRESSURE TRANSDUCER

RANGE - 0 TO 0.1PSIA
CONTRACT NO NAS1-4482

MODEL NO 6081-1
SERIAL NO 002

ZERO SET .05 MM HG

INPUT PRESSURE PSIA.	OUTPUT IN MILLIVOLTS			
	+80°F.	+60°F	+110°F	+80°F
0	+1.5	+1.7	+1.1	+1.4
0.01	12.1	11.7	11.8	11.6
0.02	22.3	21.7	22.1	21.7
0.03	32.4	31.5	32.6	31.8
0.04	42.5	41.5	42.9	41.8
0.05	52.6	51.7	53.3	51.8
0.06	62.6	61.5	63.7	61.9
0.07	72.7	71.3	74.0	71.9
0.08	82.8	81.1	84.4	81.9
0.09	92.8	90.9	94.6	91.8
0.10	102.9	100.7	105.0	101.9

LINEARITY
+ .51%
REPEATABILITY
+ .5%
HYSTERESIS
− .1%
TEMP TEST
SENS: 2.46%
ZERO: .4%

RETURN TO 50% 51.7
UP TO 50% 52.3

OUTPUT IMPEDANCE 400Ω
VOLTAGE REGULATION .1%
OVERLOAD HaP
VIBRATION HaP
CONFIGURATION HaP
TRAPPED VOLUME HaP

PERFORMED BY D.P.
DATE 3/23/65
APPROVED BY HaP
DATE 23 MAR 65

PRESSURE TRANSDUCER

RANGE - 0 TO 0.1PSIA
CONTRACT NO

MODEL NO 6081-1
SERIAL NO .006

INPUT PRESSURE PSIA.	OUTPUT IN MILLIVOLTS			
	+80°F.	+60°F	+110°F	+80°F
0	+1.9	+.8	+2.3	+1.3
0.01	12.2			11.8
0.02	22.4			22.0
0.03	32.5			32.1
0.04	42.7			42.1
0.05	52.8			52.2
0.06	62.8			62.1
0.07	72.7			72.0
0.08	82.6			81.9
0.09	92.5			91.8
0.10	102.5	99.1	106.0	101.6

LINEARITY
+.8 % F.S.
REPEATABILITY
+.1 % F.S.
HYSTERESIS
-.3 % F.S.
TEMP TEST
SENS: +2.99 % F.S.
ZERO: -1.2 % F.S.

OUTPUT IMPEDANCE 600 Ω
VOLTAGE REGULATION NO △
OVERLOAD .3 % F.S. △
VIBRATION DaP
CONFIGURATION DaP
TRAPPED VOLUME DaP.

PERFOMED BY D.P.S.
DATE 3/31/65
APPROVED BY DaP
DATE 3/31/65

PRESSURE TRANSDUCER

RANGE - 0 TO 0.1 PSIA
CONTRACT NO

MODEL NO 6081-1
SERIAL NO .005

INPUT PRESSURE PSIA.	OUTPUT IN MILLIVOLTS			
	+80°F.	+60°F	+110°F	+80°F
0	+2.6	+1.4	+3.0	+1.9
0.01	12.1			11.7
0.02	21.9			21.7
0.03	31.8			31.6
0.04	41.7			41.5
0.05	51.6			51.5
0.06	61.5			61.4
0.07	71.4			71.3
0.08	81.3			81.0
0.09	91.1			90.8
0.10	101.0	97.5	103.9	100.6

LINEARITY
+.32% F.S.
REPEATABILITY
-.9% F.S.
HYSTERESIS
+1% F.S.
TEMP TEST
SENS: +2.5%
ZERO: -1.3%

OUTPUT IMPEDANCE 500 Ω
VOLTAGE REGULATION NO △
OVERLOAD .2% F.S. △
VIBRATION DaP.
CONFIGURATION DaP
TRAPPED VOLUME DaP

PERFOMED BY D.P.S.
DATE 3/31/65
APPROVED BY DaP
DATE 3/31/65.

Model 6081-1

Per Test Spec. 6081-1

S/N .001 Vibration 3/31/65, conducted by D. P. Torgerson

AC Background 4.8mV

cps	AC mV (rms)
20	5.3
50	5.2
100	5.4
150	5.4
200	5.4
250	5.4
300	5.4
350	5.4
400	5.5
450	5.6
500	5.6
600	5.7
700	5.8
800	5.9
900	6.2
1000	6.8
1100	7.8
1200	9.3
1300	12.0
1400	32.0
1500	110.0
1600	14.0
1700	8.2
1800	6.2
1900	5.6
2000	5.3

Resonant Frequency: 1475 cps

Sweep 20 to 2000 to 20 cps in 15 min. at 10G.

Full Scale Output: 118 mV DC

S/N .002 Vibration, conducted by W. Magruder

AC Background .7 mV

cps	AC mV (rms)
20	3.2
50	4.2
100	4.0
150	3.9
200	3.9
250	3.9
300	3.9
350	3.9
400	4.2
450	4.3
500	4.4
600	4.4
700	4.5
800	5.0
900	5.8
1000	8.0
1100	10.0
1200	15.0
1300	25.0
1400	140.0
1500	230.0
1600	15.0
1700	10.0
1800	8.0
1900	6.2
2000	5.1

Resonant Frequency: 1400 cps - 1500 cps

Full Scale Output: 97 mV DC

S/N .005 Vibration Test 3/31/65, conducted by D. P. Torgerson

AC Background 5% mV

cps	AC mV (rms)
20	6.3
50	7.2
100	7.2
200	7.6
300	7.8
400	8.1
500	8.1
600	6.5
700	6.6
800	7.3
900	8.2
1000	8.4
1100	8.7
1200	14.0
1300	12.0
1400	13.0
1500	18.0
1600	60.0
1700	200.0
1800	20.0
1900	15.0
2000	15.0

Resonant Frequency: 1700 cps

Sub-harmonic (130 cps) - 10 mV
Sub-harmonic (275 cps) - 16 mV
Sub-harmonic (550 cps) - 50 mV

Full Scale Output: 100.6 mV DC

Model 6081-1 Per Test Spec. 6081-1

S/N .006 Vibration 3/31/65, conducted by D. P. Torgerson

AC Background 3.6% mV

cps	AC mV (rms)
20	4.7
50	5.8
100	6.0
200	6.4
300	10.0
400	6.9
500	6.9
600	5.2
700	4.9
800	5.5
900	10.0
1000	8.0
1100	9.5
1200	9.0
1300	10.0
1400	11.0
1500	14.5
1600	25.0
1700	100.0
1800	320.0
1900	10.0
2000	8.0

Resonant Frequency: 1800 cps

Sub-harmonic (450 cps) - 80 mV
Sub-harmonic (900 cps) - 32 mV

Full Scale Output: 101.6 mV DC