THE CALIBRATIONS OF SPACE SHUTTLE MAIN ENGINES HIGH PRESSURE TRANSDUCERS

A Technical Report

written by

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ABSTRACT

Previously, high pressure transducers that were used on the Space Shuttles Main Engine (SSME) exhibited a severe drift after being tested on the SSME. The Experimental Testing Technology Division (ETTD) designed some new transducers that would not exhibit a severe drift over a short period of time. These transducers were calibrated at the Test Bed at Marshal Space Flight Center (MSFC). After the high pressure transducers were calibrated, the transducers were placed on the SSME and fired. The transducers were then sent to the NASA LaRC to be recalibrated. The main objectives of the recalibrations was to make sure that the transducers possessed the same qualities as they did before they were fired on the SSME. Other objectives of the project were to determine the stability of the transducers and to determine whether the transducers exhibited a severe drift.

INTRODUCTION

A multichannel high pressure transducer using miniature piezoresistive silicon pressure sensors has been designed and developed in the ETTD. It was developed to measure fuel and oxidizer pressure of SSME. The transducer is able to accurately measure pressure to within 0.25% full scale up to 30 MPa for LH_2/GH_2 and LOX/GOX in NASA Launch Vehicles. The pressure sensor unit consists of four silicon piezoresistive pressure sensor dice bonded to two aluminum nitride substrates with Indium or Au/Sn. Three of these high pressure transducers were tested last year on a shuttle engine at Test Bed (MSFC). After four runs these transducers were taken off and are being recalibrated at Langley Research Center.

PROCEDURE

Part I :

In Part I of my project, one of the high pressure transducers were mounted on the cold head in Cryogenic chamber. A Platinum Resistance Thermometer (PRT) was also placed inside the Cryogenic chamber along with the transducer. I brought the pressure from 0psi to 1,000psi and back down to 0psi in 1,000psi increments. During this time, I measured and recorded the output voltages of the 4 pressure sensors and the PRT at each 1,000psi increment. A constant current source was sent through the PRT to obtain an output voltage from it as well. The output voltage from the PRT could be used to determine the exact temperature in the Cryogenic chamber.

Part II :

In Part II of my project, The high pressure transducer remained mounted on the cold head inside the Cryogenic chamber. First, I raised the temperature to 1,000psi and let it stabilize. Next, I lowered the temperature from 295k (Room Temperature) to 10k in 10k increments. I measured and recorded the output voltages from the PRT and the 4 pressure sensors individually at each increment.

PRESSURE SENSOR CALIBRATION SHEET

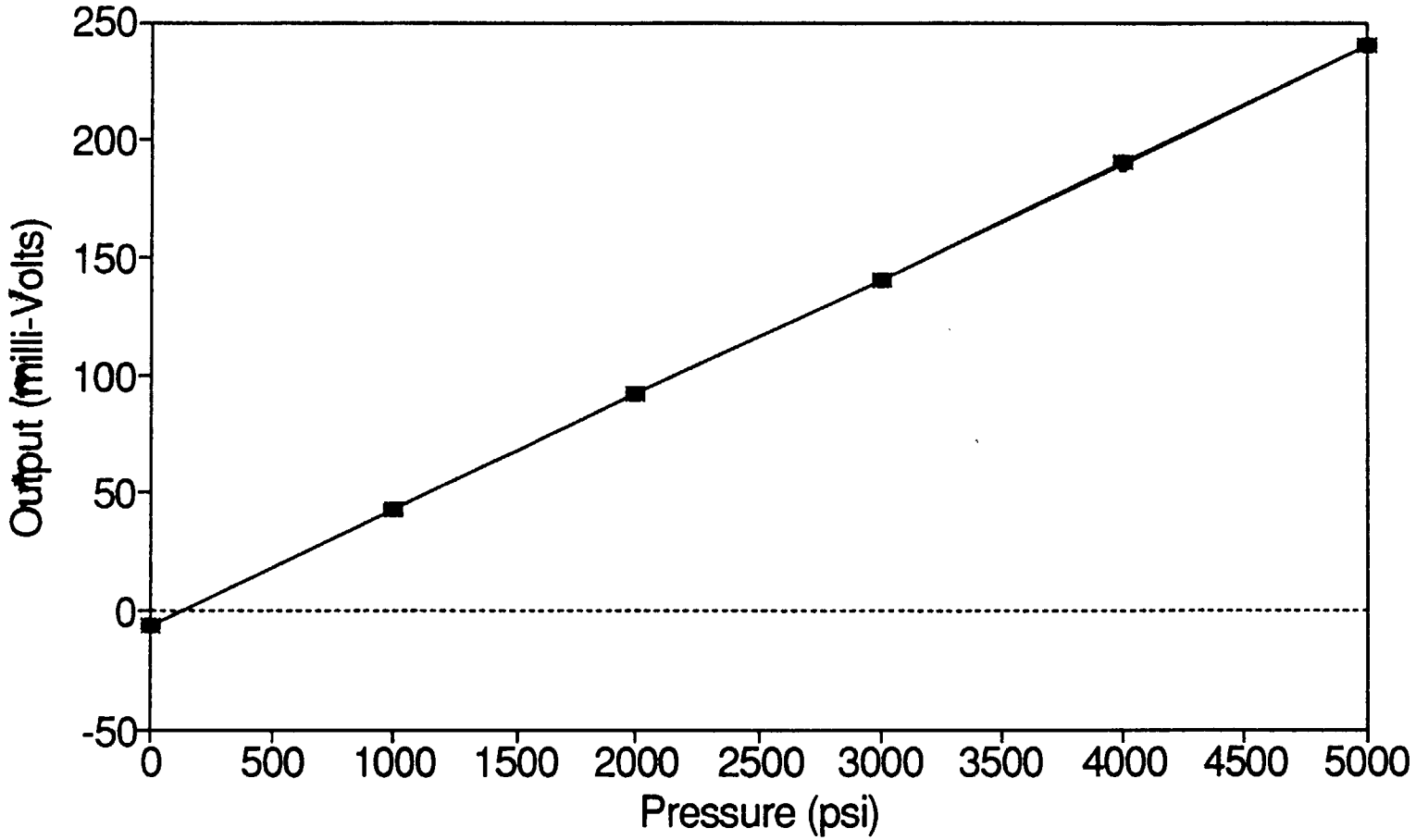
Date : June 26, 1995
Sr. No.: SSME #5
Die : After Testing at MSFC
Medium : R.T. (3rd Run)
Input : 5 volts
File : Sensor #1

Test Pressure	BFSL Rm Temp Outputs	-----Run #1----- Rm Temp Outputs	Error %FSO	-----Run #2----- Rm Temp Outputs	Error %FSO
0	-6.279	-5.9985	0.1144	-6.0329	0.1003
1000	42.777	42.7590	-0.0073	42.6810	-0.0391
2000	91.832	91.6520	-0.0734	91.5430	-0.1178
3000	140.888	140.7300	-0.0644	140.6090	-0.1137
4000	189.944	190.0890	0.0591	189.9500	0.0024
5000	238.999	239.3700	0.1513	239.2270	0.0930
4000	189.944	190.0310	0.0355	190.0690	0.0510
3000	140.888	140.7630	-0.0510	140.6730	-0.0877
2000	91.832	91.5790	-0.1031	91.6280	-0.0832
1000	42.777	42.7180	-0.0241	42.6810	-0.0391
0	-6.279	-6.0329	0.1003	-6.0413	0.0969

Max Static Error :	0.1513	%FSO	TCO(%F/C
Std Dev of Error :	0.0596		TCS(%F/PC)
Avg Static Error :	0.0456	%FSO	
Max Nonrepeatab'ty :	-0.0583	%FSO	
Sensitivity :	0.0098	mV/psi/V	S(mV/P/V):
Thermal Span :	1.7906	%FSO/C	
Remarks :			

TEST FOR MSFC TRANSDUCER #5

Room Temp., Sensor #1,



PRESSURE SENSOR CALIBRATION

Pressure =2000 psi

PRT (Volts)	Output (m-V)
1.0487	87.250
1.003	89.957
0.97258	91.782
0.94757	93.336
0.89432	96.788
0.88192	97.677
0.86723	98.761
0.85126	99.945
0.83784	100.976
0.81728	102.571
0.77001	106.440
0.76305	107.090
0.75223	108.032
0.72154	110.822
0.70378	112.508
0.66879	115.857
0.65784	116.994
0.63160	119.798
0.60171	123.208
0.53720	131.177
0.50971	134.852
0.44180	144.110
0.39173	151.243
0.35815	156.052
0.31458	162.156
0.28190	166.404
0.27898	166.780

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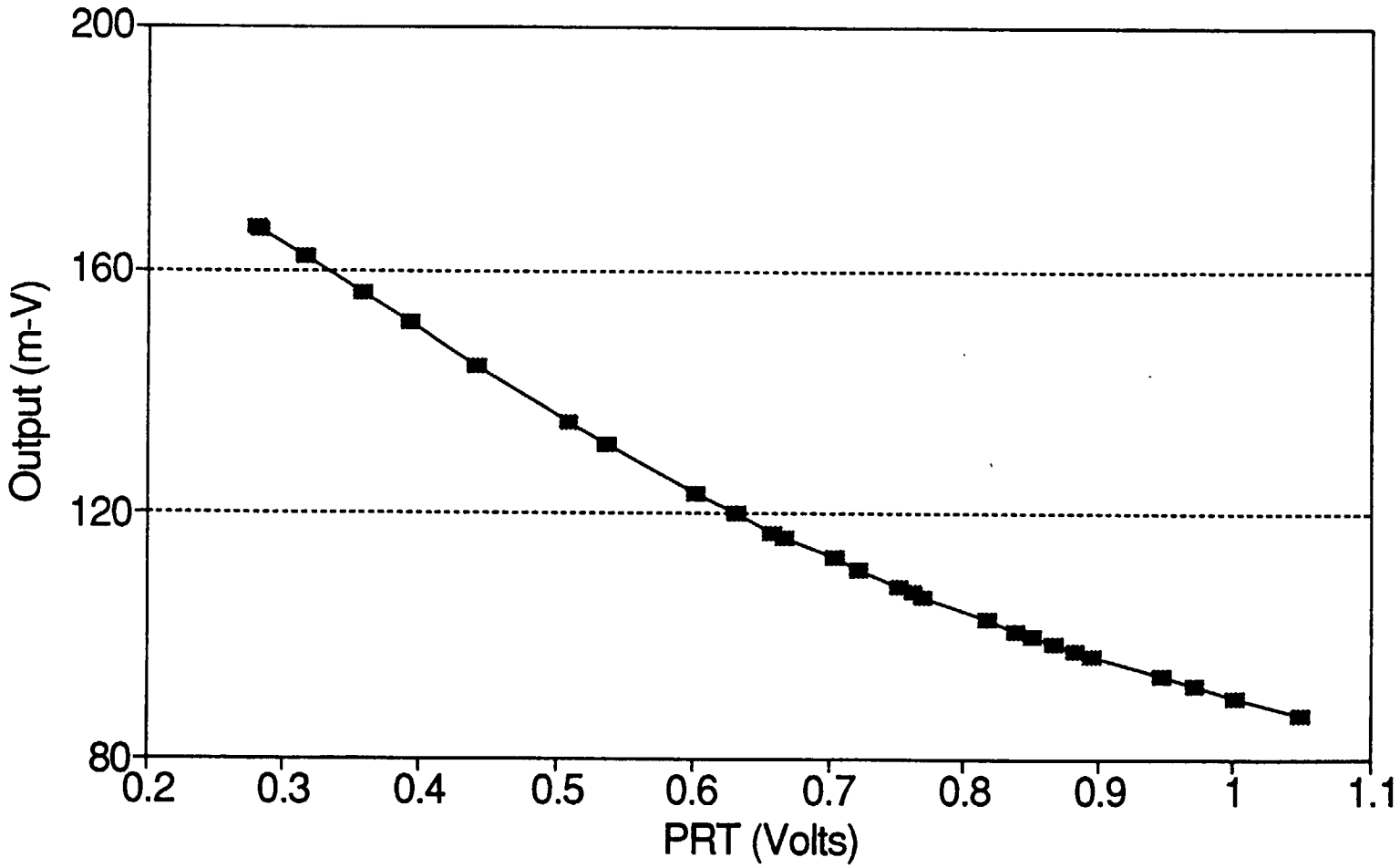
Pressure = 2000 psi



EQUIPMENT and FACILITIES

Equipment:

Positive-Shutoff Pressure Controller/Calibrator (PPCK) - a self-contained pneumatic pressure setting system intended for use in calibrating and testing all sorts of pressure measuring devices.

Multimeter (5) - a high performance 5-1/2 digital instrument designed for general purposes or systems applications.

Digital Temperature Controller (Model 9650) - a device used in calibrations to control the temperature in a Cryogenic chamber.

Compressor Module (Model HC-4 MK1) - The HC-4 MK1 compressor module is a single-stage, water-cooled rotary compressor designed to deliver high-pressure, oil-free helium gas to Cryogenic refrigerators.

Facilities:

The high pressure transducers were calibrated in the Component's Verification Building (1248B).

FUTURE WORKS

Future development involves the advanced engineering design to incorporate diagnostic and signal conditioning electronics into a Cryogenic pressure sensor for applications at the MSFC's Space Shuttle Main Engine (SSME) Test Facility. The new "Smart" Sensor requirements are required to integrate Cryogenic pressure sensor into the data system at the test facility.

CONCLUSION

After I completed my project, I was very pleased with my results. Although previous high pressure transducers exhibited a severe drift, the new LaRC developed transducers exhibited only a limited finite drift. All 12 of the pressure sensors in the three transducers followed the earlier calibrations profile very closely. We were able to observe a long term stability of less than 0.5% of full scale output for six months. During the calibration experiment, I was able to conclude that the pressure and output voltage of the pressure sensors were directly proportional. I was also able to conclude that the temperature inside the Cryogenic chamber and the output voltage were inversely proportional.