VIBRATION TESTING OF MINIATURE S-BEAM (LSB200) & MINIATURE BEAM LOAD CELL (LSM400)

ADVANCED SENSOR TECHNOLOGY, INC.

FUTEK ENGINEERING TEAM

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Executive Summary

During this past year FUTEK Advanced Sensor Technology, located in Irvine California, found itself faced with yet another unique challenge from a client requiring a specialized sensor. This new challenge would not only require the sensors in question to endure the usual environmental hazards of high/low temperature and moisture, but also survive vibration testing to a controlled industry vibration standard by an independent testing lab. What follows is a chronological account of the preparation, testing and an analysis of the required vibration testing.

On May 2, 2008, FUTEK Advanced Sensor Technology vibration tested two LSB200, and two LSM400 sensors, while mounted, and operating in a clients application. The Power Spectral Density (PSD) maintained during the testing was $0.01g^2$/Hz over a frequency range of 20 – 2000 Hz as defined in MIL-STD-810E. Power Spectral Density is a positive real function of a frequency variable related to a stationary stochastic process (non-predictable, random process), or a deterministic (predictable) function of time. The units of measure are power per Hz, or energy per Hz, in this case, the established value of gravity "g" (energy) is used to describe the amount of energy per Hz (width). In general, this is referred to as the Spectrum of the signal, in this case, a wave vibration intensity captured during testing by accelerometers. After verifying their credentials, the testing was contracted out to National Technical Services (NTS). NTS tested the units to the defined standard and maintained test integrity, serviceability of testing equipment, and data capture of the accelerometers. Test data is available upon request. A FUTEK Engineer designed and machined all other testing components and tooling needed for the project. The client's test application was operated during the testing by a FUTEK engineer who was responsible for capturing data from each set of units during testing.

The objective was to vibration test to establish survivability and validation of two LSB200 5 lb and two LSM400 5 lb, see figures 4 and 5, while mounted and operating in the test application. Testing was done per MIL STD-810E, with a ten-minute interval in each directional axis x, y, z, for each set of units. A PSD of $0.01g^2$/Hz was maintained during the test intervals of ten minutes per axis per set of sensors.

The contract services of NTS, located in Fullerton California, were used for the testing of the FUTEK units while a FUTEK Engineer ran the clients test Module, capturing data from each sensor during each of the ten-minute intervals at a collection rate of one reading per second, for validation of the units. Comparison of before and after vibration testing calibration results were analyzed to see any significant change in, output signal, nonlinearity, or zero balance. The results of the comparison for both before and after calibration results are shown in figures 7 through 23.

A FUTEK Engineer designed and machined the required tooling in-house. This consisted of a one-inch thick aluminum (6061-T6) plate, twenty-four inches square. The plate was drill/milled to a set bolt pattern that would secure the test application to the plate and in turn secure both to the C-10 vibration-testing table see figure 1, 2 and 3. The test application was secured to PDT00473, Vibration-mounting plate, with four ¼-20 machine cap screws. Two additional points were used for both alignment and mounting, these were the client's spring loaded M6X1 mounting screws locate on the test application, see figure 3. The assembly was then mounted to the NTS C-10 Vibration tester using the 2 X 2 X 3/8 holes pattern, see figure 6. NTS monitored the tests using two accelerometers one oriented in each axis, see figure 6. This set up was repeated for each 10 minute test in each directional axis. During the test runs, data was captured from each sensor insuring the sensor did not fail to produce a signal or fault out during vibration testing. NTS provided test data showing the PSD of $0.01g^2$/hz was maintained during the testing periods.

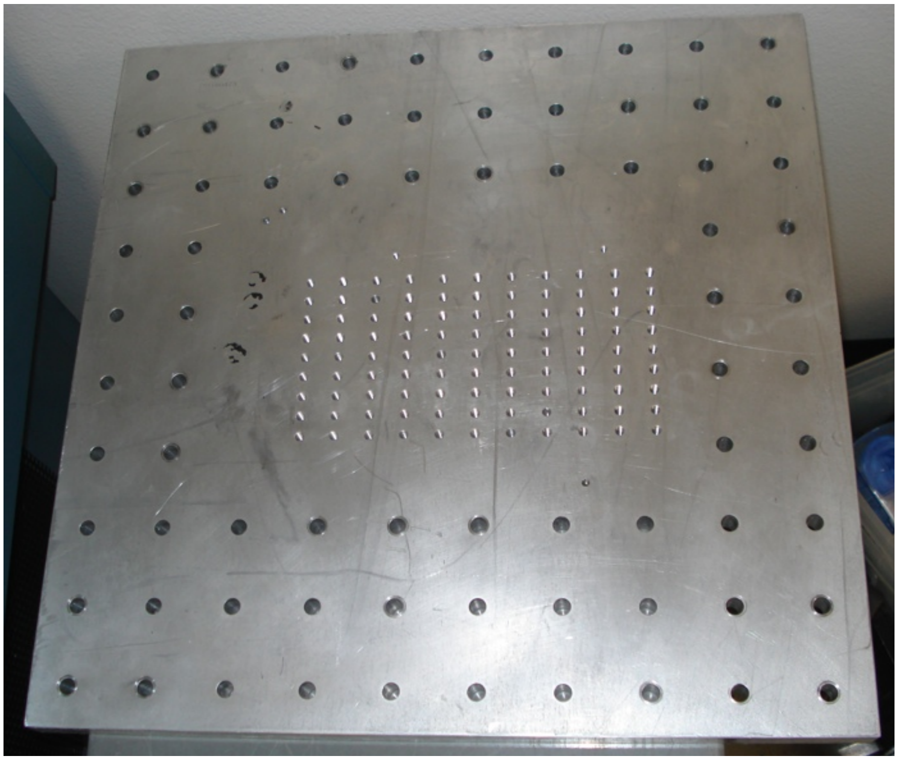


Figure 1, PDT00473 mount plate for vibration testing.

Figure 2, Low Pressure slip table, capable of vibration testing in the x, y, and z-axis.

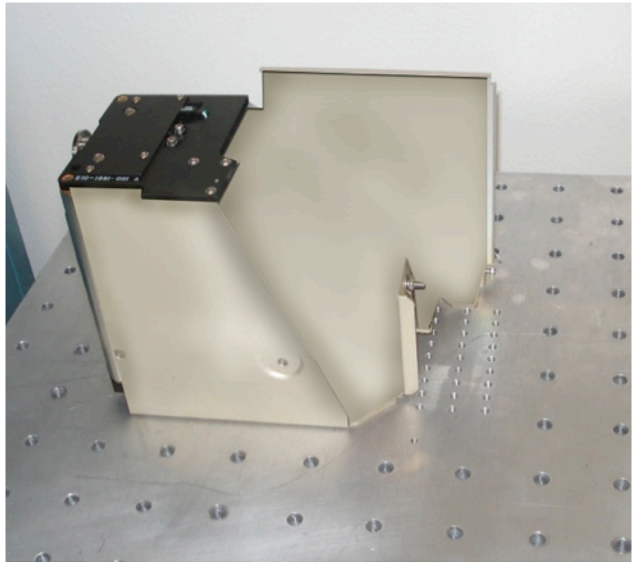


Figure 3, PDT00473 with Client's Module in place; note, unit shown is not bolted down.

Figure 4, LSB200

Figure 5, LSM400

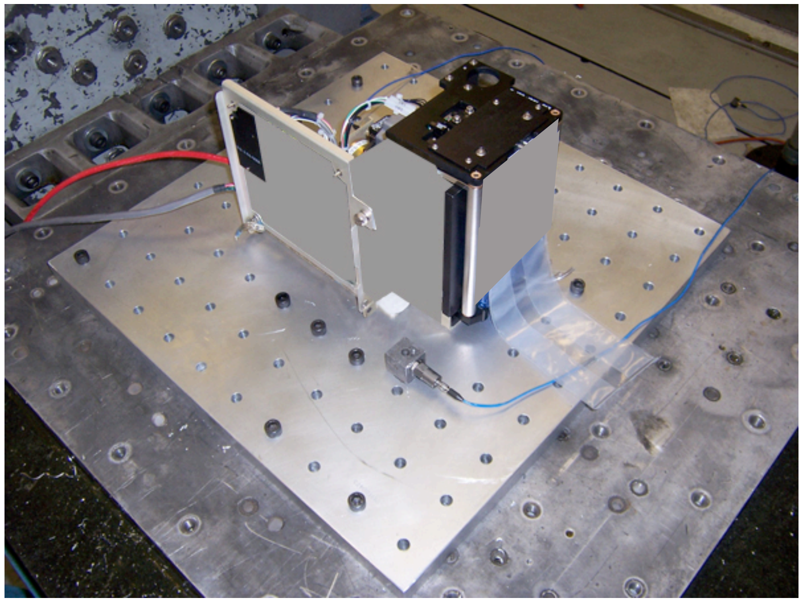


Figure 6, Module shown mounted to the C-10 vibration table oriented in the X-axis.

Of the four FUTEK units tested, none failed during testing, came loose, or had any interruption in signal. Data capture rate was 1/sec as per application software. The plots generated are for comparison to a standard not provided by the client. To better show and validate the robust nature of the units, before and after calibration results were generated which show virtually no change in calibration output signal, nonlinearity, or zero balance, see figure 5 through 12. Further examination of the internal sections show no visible damage, loose or potential disconnects. All adhesives used in the fabrication of the units showed no sign of failure either. Cover screws installed with Loctite 262 held and showed no sign of fatigue or failure. The adapters installed on the LSB200 with Loctite 242 showed no sign of failure either. Cable connections and cable strain relief's were examined and showed no sign of fatigue or potential for failure. It is clear that these two sets of units, LSB200 and LSM400, survived this series of vibration tests. Therefore, it is reasonable to expect these units to survive an environment which could potentially expose them to a vibration Spectral Density of $0.01g^2$/Hz.

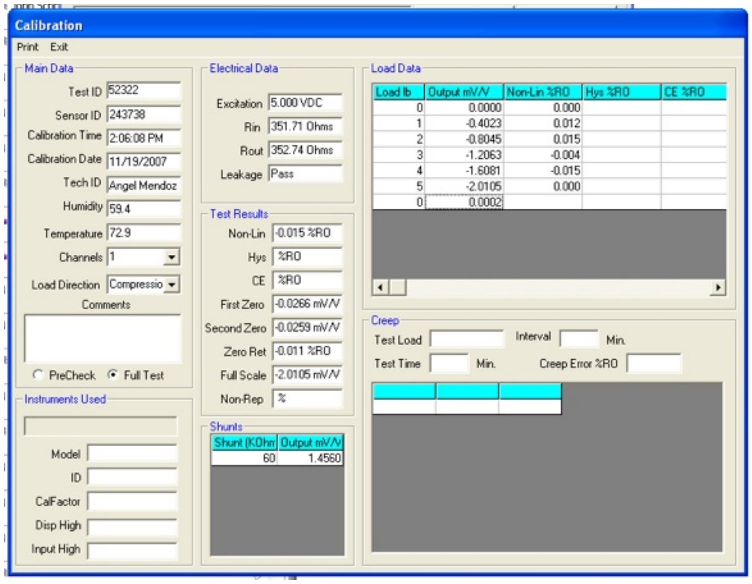


Figure 7, Sensor ID: 243738, LSB200, Calibration results performed on 11/19/2007, before vibration testing, prior to span resistance.

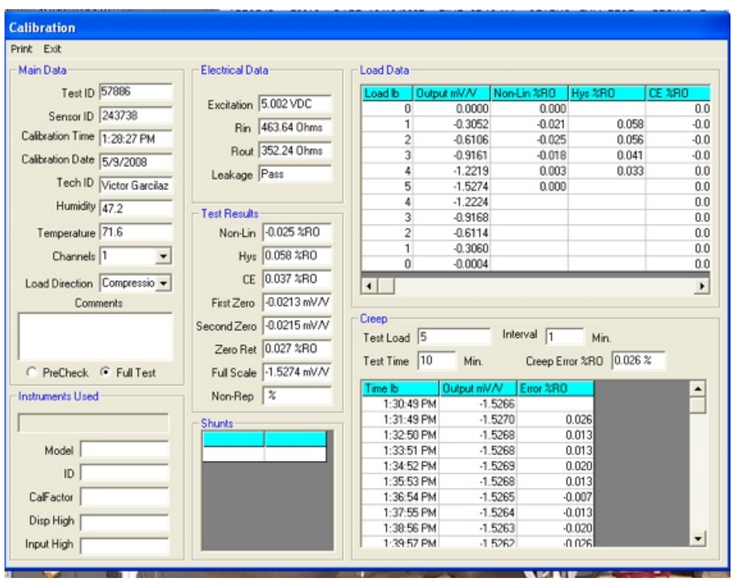


Figure 8, Sensor ID: 243738, LSB200, Calibration results performed on 5/19/2007, after vibration testing, with span resistor.

% Zero balance shift calculation:

$$\left(\frac{Zero_{pre-vib} - Zero_{Post-vib}}{Output_{Max}}\right) \times 100 = xx\%$$

$$\left(\frac{0.0259 - 0.0213}{1.5274}\right) \times 100 = 0.3012\%$$

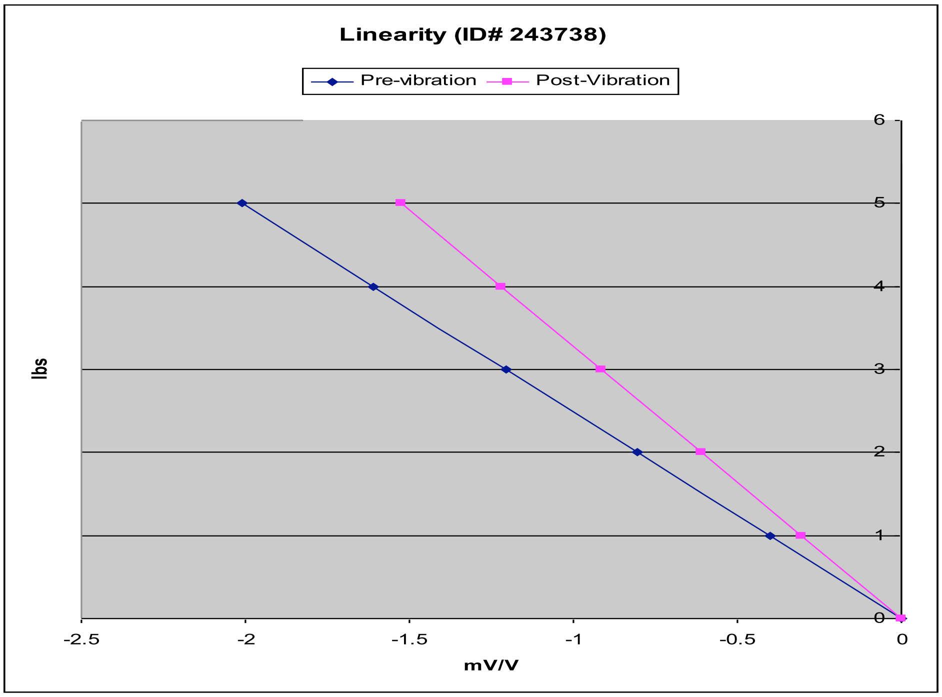


Figure 9, Linear response curve for LSB200 (ID# 243738), note the shift due to 111Ω span resistor.

Span resistor calculation:

$$\left(\frac{(R_B \times V_o) - (V_{spo} \times R_B)}{V_{spo}}\right) = R_{span}$$

$$\left(\frac{(351.71\Omega \times 2.0105 \, {}^{mV}\!/_{V}) - (1.5274 \, {}^{mV}\!/_{V} \times 351.71\Omega)}{1.5274 \, {}^{mV}\!/_{V}}\right) = 111.2420\Omega$$

Pre-vibration rated output calculation with 111Ωresistor:

$$\frac{352\Omega}{(352\Omega + 111\Omega)} \times 2.0105 \, {}^{mV}\!/_{V} = 1.5285 \, {}^{mV}\!/_{V}$$

Output shift error:

$$\frac{\left(1.5285\,{}^{mV}\!/_{V} - 1.5274\,{}^{mV}\!/_{V}\right)}{1.5274\,{}^{mV}\!/_{V}} \times 100 = 0.072\%$$

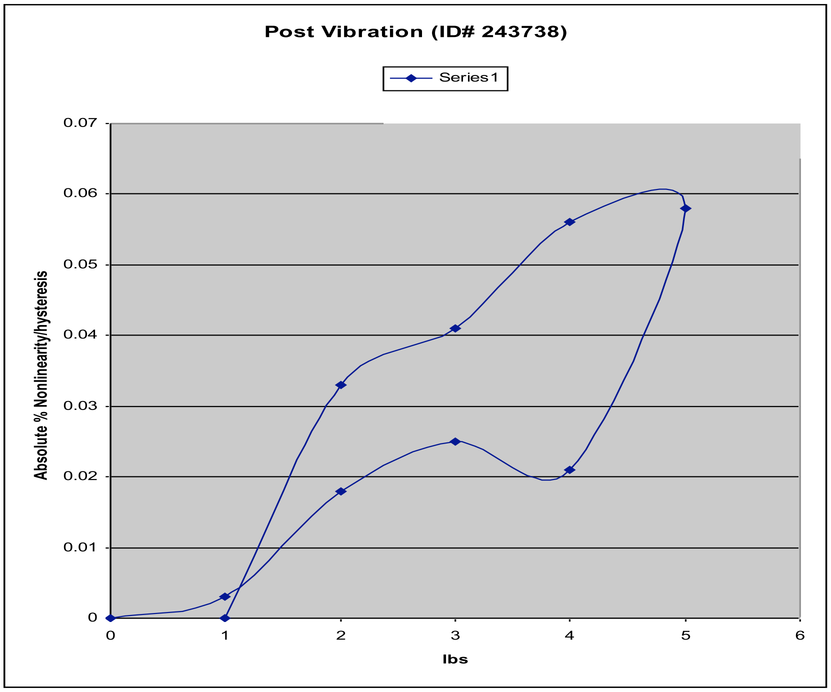


Figure 10, Post vibration % Nonlinearity and Hysteresis.

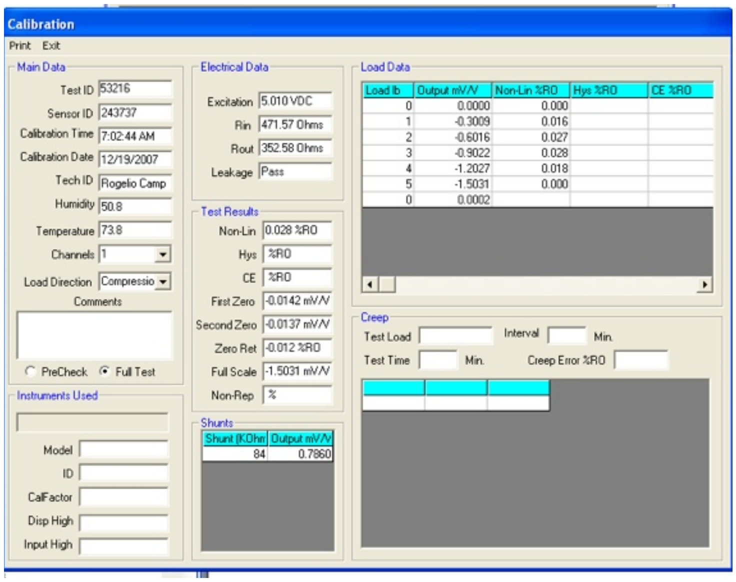


Figure 11, Sensor ID: 243737, LSB200, Calibration results performed on 12/19/2007, before vibration testing.

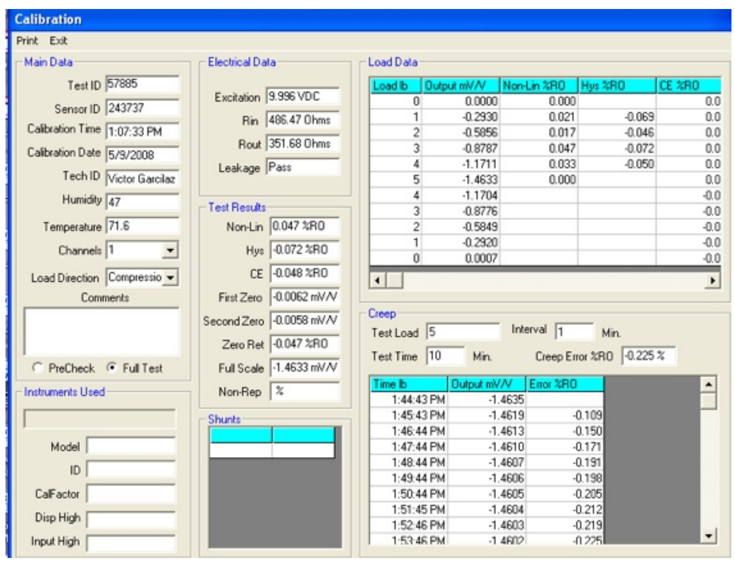


Figure 12, Sensor ID: 243737, LSB200, Calibration results performed on 5/9/2008, after vibration testing.

% Zero shift calculation:

$$\left(\frac{0.0142 - 0.0062}{1.4633}\right) \times 100 = 0.5467\%$$

![FUTEK ADVANCED SENSOR TECHNOLOGY, INC.]

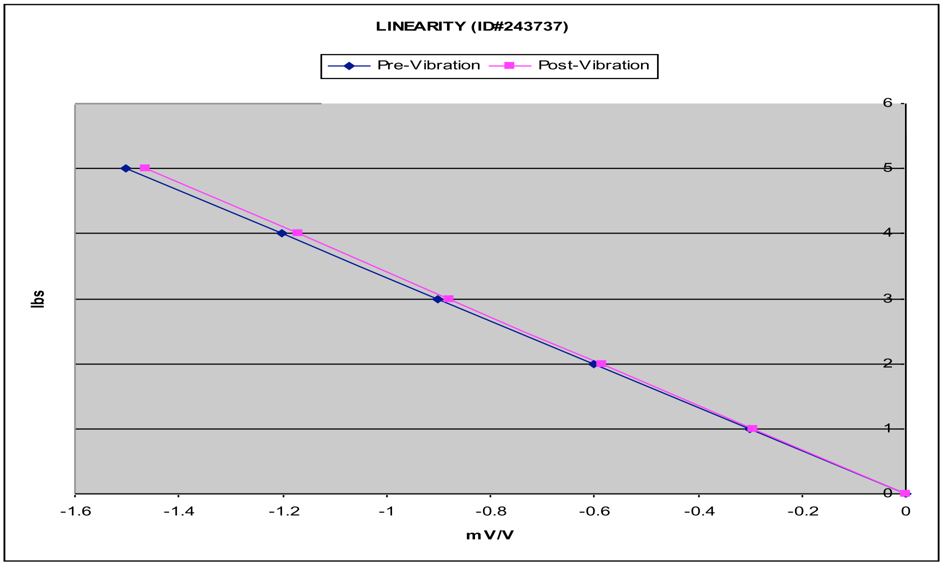


Figure 13, Linear response curve for ID# 243737; note, span resistor installed prior to pre-vibration testing.

Span resistor calculation:

$$\left(\frac{\left(471.57\Omega \times 1.5031 \, {}^{mV}\!/_{V}\right) - \left(1.4633 \, {}^{mV}\!/_{V} \times 471.57\Omega\right)}{1.4633 \, {}^{mV}\!/_{V}}\right) = 12.8213\Omega \approx 13\Omega$$

Pre-vibration rated output calculation with 111Ωresistor:

$$\frac{471.57\Omega}{\left(471.57\Omega + 13\Omega\right)} \times 1.5031 \, {}^{mV}\!/_{V} = 1.4677 \, {}^{mV}\!/_{V}$$

Output shift error:

$$\frac{\left(1.5628 \, {}^{mV}\!/_{V} - 1.4633 \, {}^{mV}\!/_{V}\right)}{1.4633 \, {}^{mV}\!/_{V}} \times 100 = 0.034\%$$

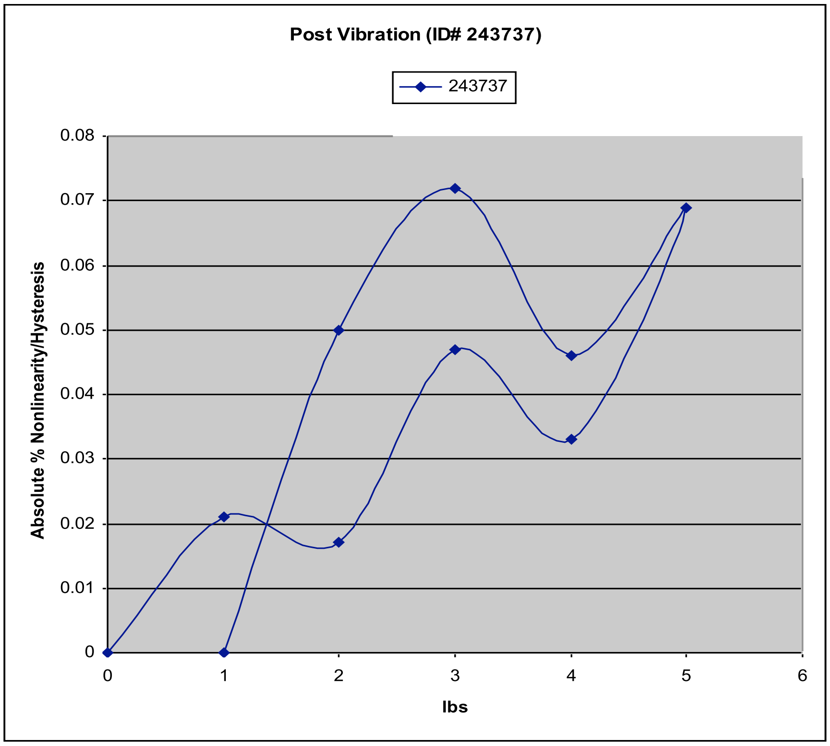


Figure 14, Post vibration Absolute % Nonlinearity/Hysteresis.

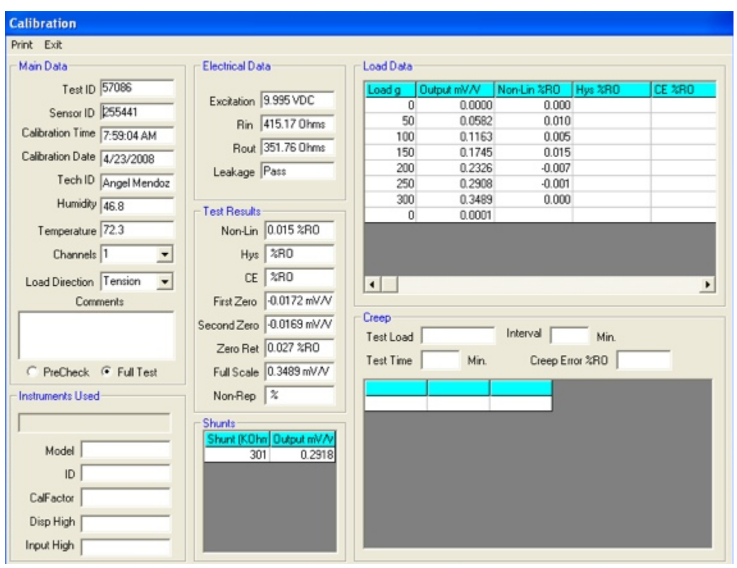


Figure 15, Sensor ID: 255441, LSM400, Calibration results on 4/23/2008, before vibration testing.

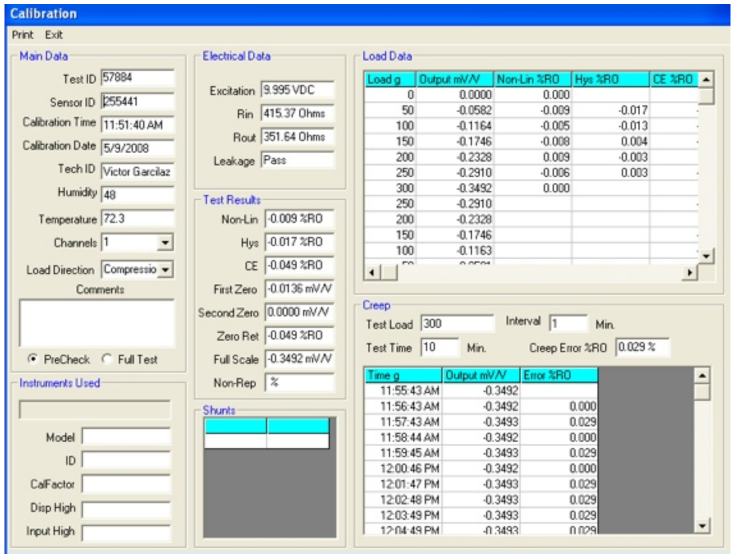


Figure 16, Sensor ID: 255441, LSM400, Calibration results on 5/9/2008, after vibration testing.

% Zero shift calculation:

$$\left(\frac{0.0172 - 0.0136}{0.3492}\right) \times 100 = 1.0309\%$$

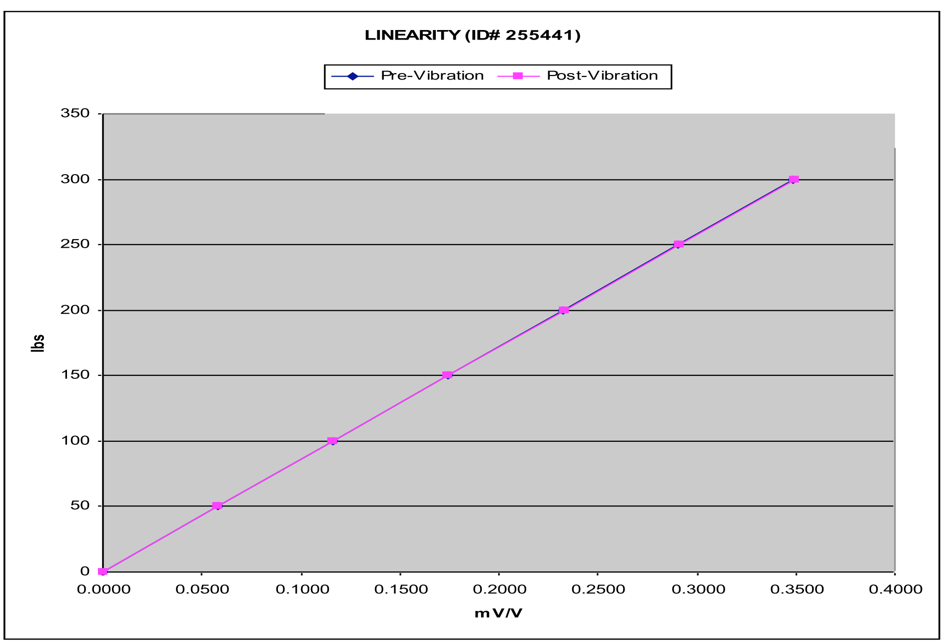


Figure 17, Linearity response curve for ID# 255441.

Output shift error:

$$\frac{\left(0.3489\,{}^{mV}\!/_{V} - 0.3492\,{}^{mV}\!/_{V}\right)}{0.3492\,{}^{mV}\!/_{V}} \times 100 = 0.086\%$$

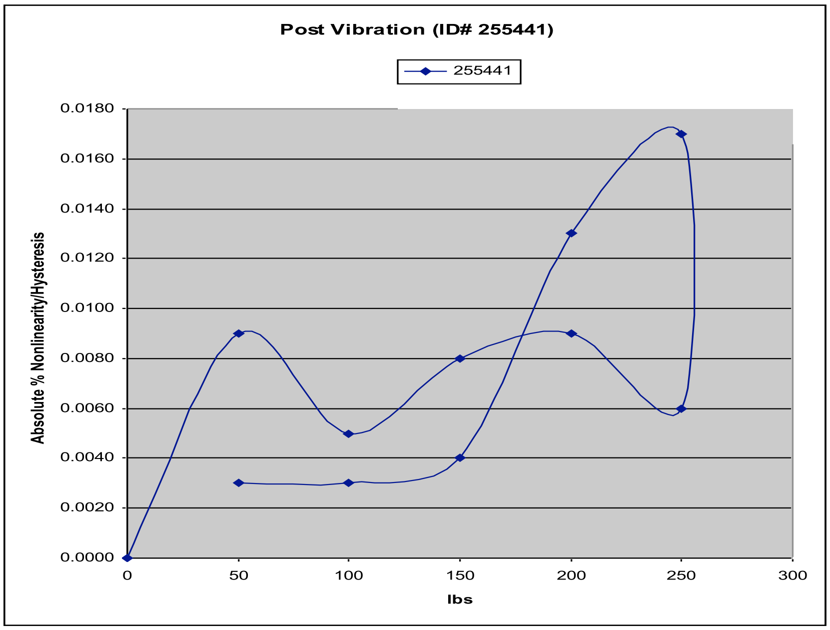
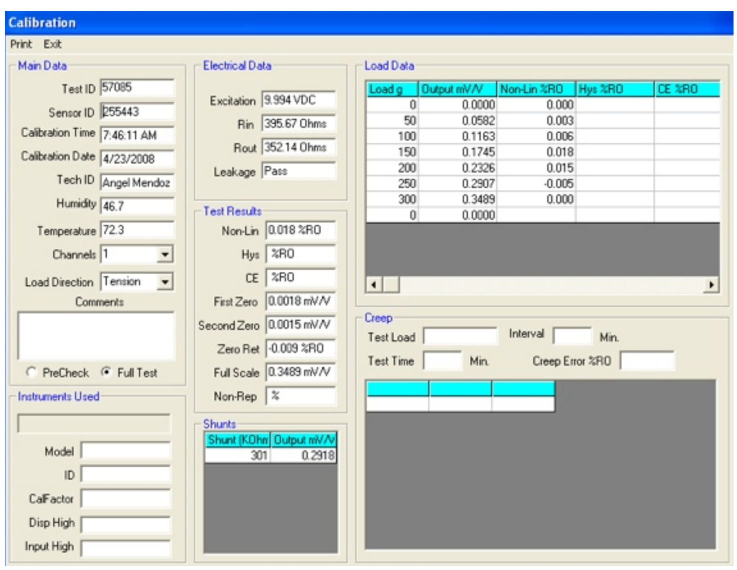


Figure 18, Post vibration Absolute % Nonlinearity/Hysteresis.



Calibration

Print Exit

Main Data

Test ID: 57085
Sensor ID: 255443
Calibration Time: 7:46:11 AM
Calibration Date: 4/23/2008
Tech ID: Angel Mendoz
Humidity: 46.7
Temperature: 72.3
Channels: 1
Load Direction: Tension
Comments:
PreCheck / Full Test

Instruments Used

Model:
ID:
CalFactor:
Disp High:
Input High:

Electrical Data

Excitation: 9.994 VDC
Rin: 395.67 Ohms
Rout: 352.14 Ohms
Leakage: Pass

Test Results

Non-Lin: 0.018 %RO
Hys: %RO
CE: %RO
First Zero: 0.0018 mV/V
Second Zero: 0.0015 mV/V
Zero Ret: -0.009 %RO
Full Scale: 0.3489 mV/V
Non-Rep: %

Shunts

Shunt (KOhm)	Output mV/V
301	0.2918

Load Data

Load g	Output mV/V	Non-Lin %RO	Hys %RO	CE %RO
0	0.0000	0.000		
50	0.0582	0.003		
100	0.1163	0.006		
150	0.1745	0.018		
200	0.2326	0.015		
250	0.2907	-0.005		
300	0.3489	0.000		
0	0.0000			

Creep

Test Load: Interval: Min.
Test Time: Min. Creep Error %RO

Figure 19, Sensor ID: 255443, LSM400, Calibration results on 4/23/2008, before vibration testing.

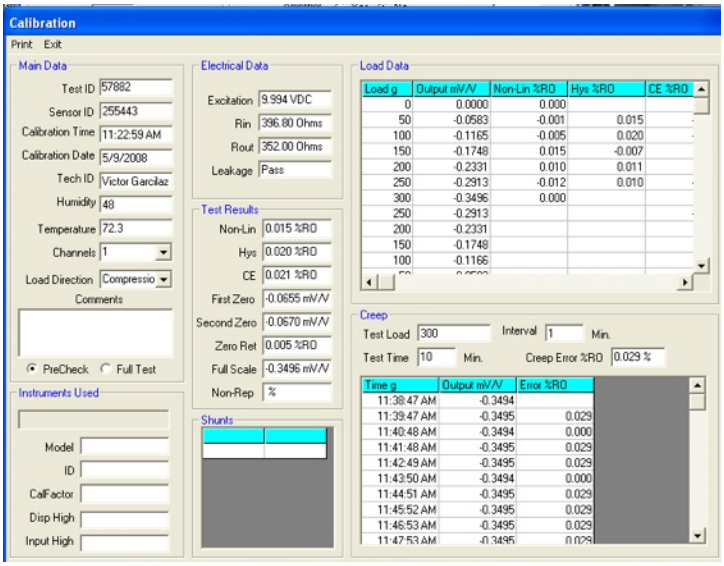


Figure 20, Sensor ID: 255443, LSM400, Calibration results on 4/23/2008, after vibration testing.

% Zero shift calculation:

$$\left(\frac{0.0142 - 0.0062}{0.3496}\right) \times 100 = 2.2883\%$$

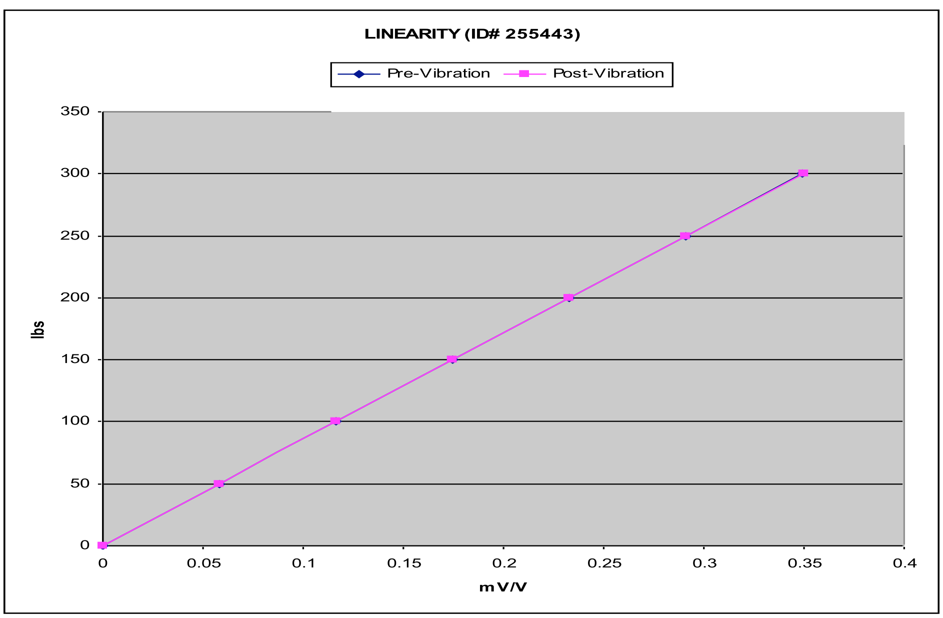


Figure 21, Linearity response curve for ID# 255443.

Output shift error:

$$\frac{\left(0.3498\,{}^{mV}\!/_{V} - 0.3496\,{}^{mV}\!/_{V}\right)}{0.3496\,{}^{mV}\!/_{V}} \times 100 = 0.057\%$$

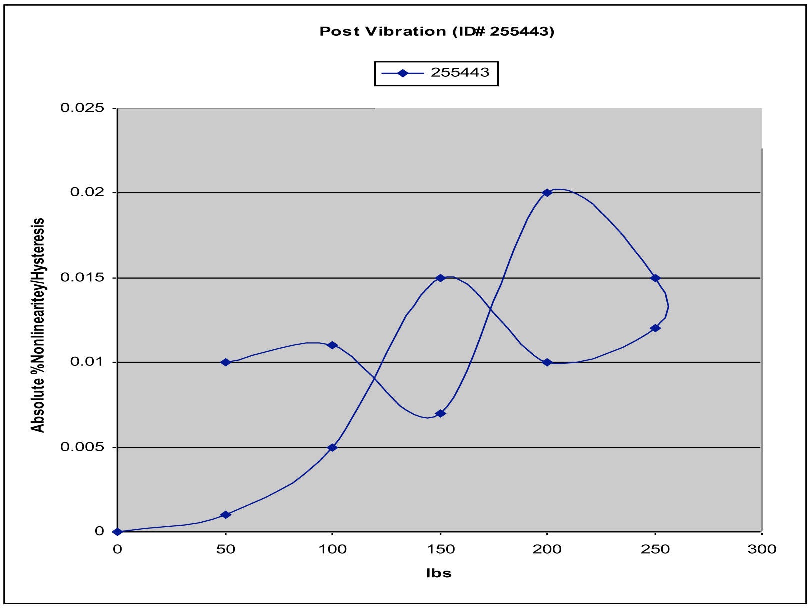


Figure 22, Post vibration Absolute % Nonlinearity/Hysteresis.

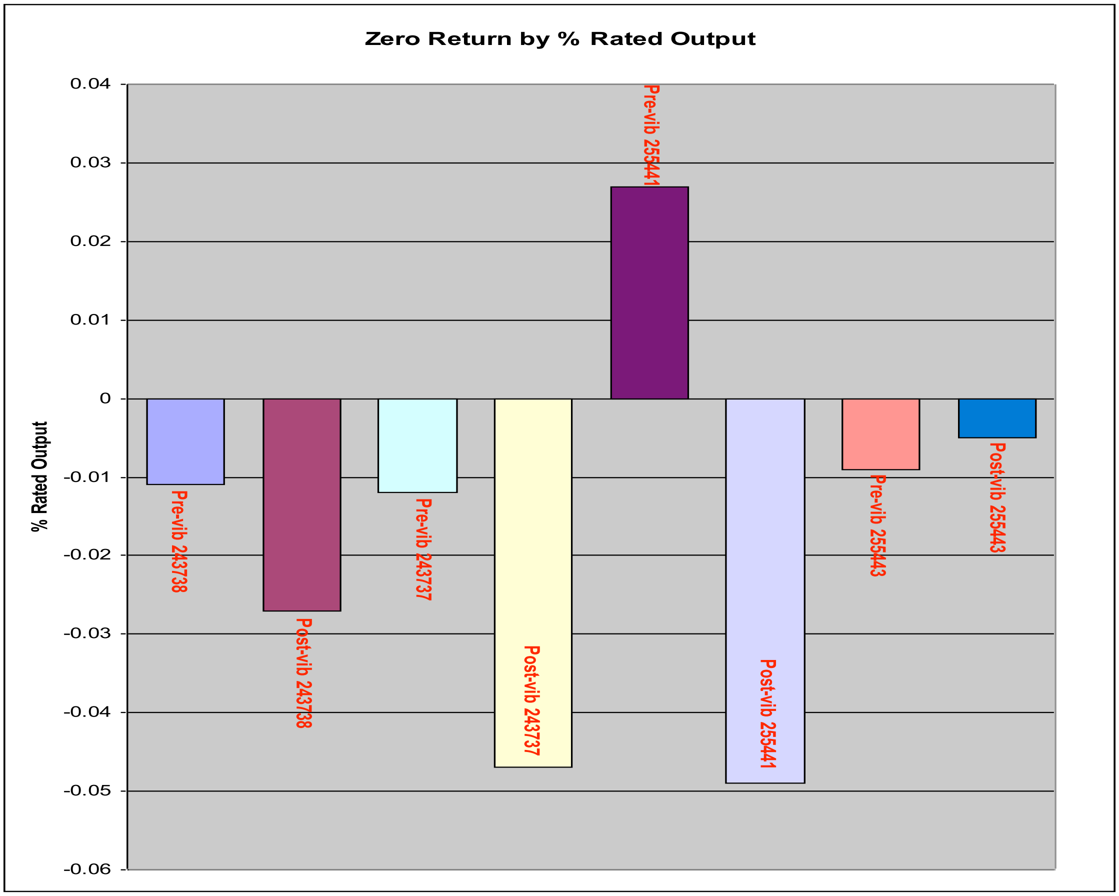


Figure 23, Zero return by percent of rated output.