Lunar Advanced Volatile Analysis Subsystem: Pressure Transducer Trade Study

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Mechanical Engineering
NE-M1 Spring Session
Date: 19 04 2017

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In Situ Resource Utilization (ISRU) is a key factor in paving the way for the future of human space exploration. The ability to harvest resources on foreign astronomical objects to produce consumables and propellant offers potential reduction in mission cost and risk. Through previous missions, the existence of water ice at the poles of the moon has been identified, however the feasibility of water extraction for resources remains unanswered. The Resource Prospector (RP) mission is currently in development to provide ground truth, and will enable us to characterize the distribution of water at one of the lunar poles.

Regolith & Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) is the primary payload on RP that will be used in conjunction with a rover. RESOLVE contains multiple instruments for systematically identifying the presence of water. The main process involves the use of two systems within RESOLVE: the Oxygen Volatile Extraction Node (OVEN) and Lunar Advanced Volatile Analysis (LAVA). Within the LAVA subsystem, there are multiple calculations that depend on accurate pressure readings. One of the most important instances where pressure transducers (PT) are used is for calculating the number of moles in a gas transfer from the OVEN subsystem. As a critical component of the main process, a mixture of custom and commercial off the shelf (COTS) PTs are currently being tested in the expected operating environment to eventually down select an option for integrated testing in the LAVA engineering test unit (ETU).

Nomenclature

%RSD	=	Percent Relative Standard Deviation
Al	=	Aluminum
C	=	Degrees Celsius
DAQ	=	Data Acquisition
ETU	=	Engineering Test Unit
FSS	=	Fluid Subsystem
GC-MS	=	Gas Chromatograph – Mass Spectrometer
GSS	=	Gas Supply System
HA	=	House Air
He	=	Helium
ISRU	=	In Situ Resource Utilization
LAVA	=	Lunar Advanced Volatile Analysis
OVEN	=	Oxygen Volatile Extraction Node
PID	=	Proportional – Integral – Derivative
PSIA	=	Pounds per Square Inch - Absolute
PT	=	Pressure Transducer
RESOLVE	=	Regolith & Environment Science and Oxygen & Lunar Volatile Extraction
RP	=	Resource Prospector
RT	=	Room Temperature
SD	=	Standard Deviation
SS	=	Stainless Steel

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I. Introduction

In Situ Resource Utilization (ISRU) is a key factor in paving the way for the future of human space exploration. The ability to harvest resources on foreign astronomical objects to produce consumables and propellant offers potential reduction in mission cost and risk. Although the existence of water ice at the poles of the moon has been identified, the question of how feasible the resource is to extract still remains unanswered. The Resource Prospector (RP) mission is currently in development to provide ground truth and will enable us to characterize the distribution of water at one of the lunar poles.

Regolith & Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) is the primary payload, paired with a rover, which contains multiple instruments that will be used to systematically identify the presence of water. The main process involves the use of two systems within RESOLVE: the Oxygen Volatile Extraction Node (OVEN) and Lunar Advanced Volatile Analysis (LAVA). The OVEN will retrieve the lunar regolith sample from the drill to weigh and heat. Once this process is completed, the volatiles that evolve from the heated soil are transferred to the LAVA Fluid Subsystem (FSS). The volatiles are stored in the surge tank for recording of pressure and temperature measurements, and are then evaluated by the Gas Chromatograph – Mass Spectrometer (GC-MS). The GC-MS analytically identifies and quantifies the volatiles so that we are able to identify water and other species that may be useful.

II. Pressure Transducer Trade Study

Within the LAVA subsystem, there are multiple calculations that depend on accurate pressure readings. One of the most important instances where Pressure Transducers (PT) are used is for calculating the number of moles in a gas transfer from the OVEN subsystem. As a critical component of the Volatile Analysis process, a mixture of custom and commercial off the shelf (COTS) PTs are currently being tested in the expected operating environment to eventually down select an option for integrated testing in the LAVA engineering test unit (ETU). This report is a continuation of an existing trade study[1], and will concentrate on the data processing and analysis of eleven PTs. In addition, alterations made to the test setup since the beginning of 2017 will also be discussed.

A. Methods

In an attempt to better understand the effects of heat, vacuum, and helium exposure on the PTs' behavior, the units, outlined below in Tables 1 and 2 and shown in Figure 1, are being thoroughly tested in vacuum at roughly $1.0e^{-3}$ Torr. They are exposed to three different conditions: room temperature (RT) house air (HA), 152C house air (HA), and 152C helium (He) at multiple pressure steps. It is expected that 152C He represents the worst-case scenario since helium molecules are smaller than air molecules and have the potential to leak across the diaphragm of the PTs causing degraded performance. Furthermore, the sensors were tested in two manifolds, stainless steel 316 and aluminum 6061, to identify any effects that may result from the different contact materials.

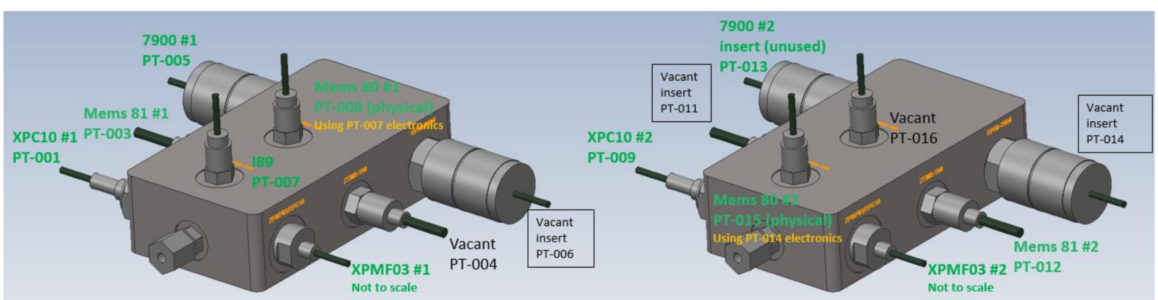


Figure 1. The manifold on the left is stainless steel and the one on the right is aluminum.

With the exception of the GP50 189, both manifolds have identical PTs installed. The GP50 189 has a much larger pressure range than the others, but required evaluation in the trade study due to its low mass and potential use in the high-pressure gas delivery system within LAVA. It is also important to note that the MEMScap PTs were not originally selected for testing, and as a result, were incorporated into the trade study several months late. These sensors offer extremely small and light profiles; however, they were not tested beyond 125C by the vendor. As a fairly simple addition to the original setup, the MEMScap PTs were integrated to test their capabilities at 152C.

Name	Port Designation	Pressure Range (psia)	Mass (g) with wiring
Measurement Specialties XPC10 #1	PT-001	0 to 150	42.30
Tecsis XPMF03 #1	PT-002	0 to 100	29.44
GP50 7900 #1 (amplified)	PT-005	0 to 100	78.92
GP50 189	PT-007	14.7 to 514.7	14.35
MEMScap SP81 R #1	PT-003	0 to 145	10.04
MEMScap SP80 D #1	PT-007	0 to 145	12.30

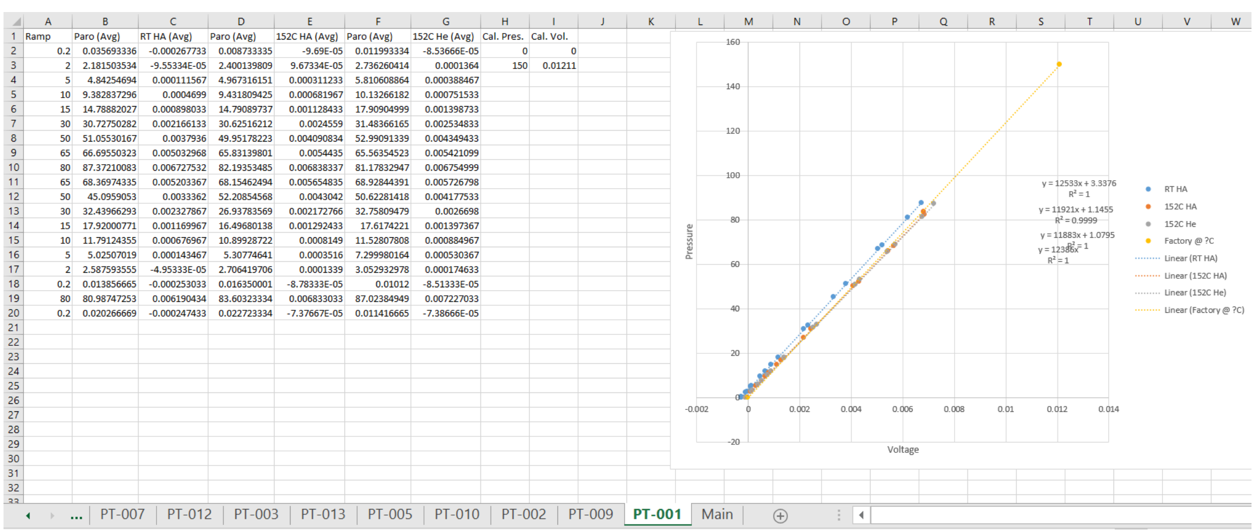
Table 1. PTs specifications on stainless steel manifold.

Name	Port Designation	Pressure Range (psia)	Mass (g) with wiring
Measurement Specialties XPC10 #2	PT-009	0 to 150	42.30
Tecsis XPMF03 #2	PT-010	0 to 100	29.44
GP50 7900 #2 (amplified)	PT-013	0 to 100	78.92
MEMScap SP81 R #2	PT-012	0 to 145	10.04
MEMScap SP80 D #2	PT-014	0 to 145	12.30

Table 2. PTs specifications on aluminum manifold.

The trade study is comprised of two types of test cycles, a thermal vacuum cycle and a full test cycle. Typically, a thermal vacuum cycle is run four times per week and a full test cycle is run once per week. The thermal vacuum cycle consists of heating the manifolds to operating temperatures and allowing them to thermally soak for about one and a half hours. The thermal cycles are important as is it replicates the numerous thermal cycles the LAVA subsystem will undergo. In addition, the manifolds are brought to operating temperature to consistently induce thermal stress onto the PTs and to investigate how the wear effects the PT's repeatability. Additional background on the trade study purpose and test setup can be found in the previous trade study report[1].

The full test cycle consists of ramping through pressure steps, as seen below in Figure 2 column "A", via manual adjustments of the pressure source (house air or helium) to create calibration curves for each PT. To accurately read the pressure within the manifolds, a calibrated Paroscientific pressure standard is used. Using LabVIEW system design software paired with Data Acquisition (DAQ) cards, we record the raw voltage output values from the PTs and the pressure readings from the Paroscientific pressure sensor in Microsoft Excel spreadsheets. Although we record test data from thermal vacuum cycles in case of any anomalies, we are mainly concentrated on processing and analyzing the data from the full test cycles. We use Microsoft Excel macros to process and plot the raw data. An example of the processed data is shown below in Figure 2.



Ramp	Paro (Avg)	RT HA (Avg)	Paro (Avg)	152C HA (Avg)	Paro (Avg)	152C He (Avg)	Cal. Pres.	Cal. Vol.
0.2	0.035693336	-0.000267733	0.008733335	-9.69E-05	0.011993334	-8.53666E-05	0	0
2	2.181503534	-9.55334E-05	2.400139809	9.67334E-05	2.736260414	0.0001364	150	0.01211
5	4.84254694	0.000111567	4.967316151	0.000311233	5.810608864	0.000388467		
10	9.382837296	0.0004699	9.431809425	0.000681967	10.13266182	0.000751533		
15	14.78882027	0.000898033	14.79089737	0.001128433	17.90904999	0.001398733		
30	30.72750282	0.002166133	30.62516212	0.0024559	31.48366165	0.002534833		
50	51.05530167	0.0037936	49.95178223	0.004090834	52.99091339	0.004349433		
65	66.69550323	0.005032968	65.83139801	0.0054435	65.56354523	0.005421099		
80	87.37210083	0.006727532	82.19353485	0.006838337	81.17832947	0.006754999		
65	68.36974335	0.005203367	68.15462494	0.005654835	68.92844391	0.005726798		
50	45.0959053	0.0033362	52.20854568	0.0043042	50.62281418	0.004177533		
30	32.43966293	0.002327867	26.93783569	0.002172766	32.75809479	0.0026698		
15	17.92000771	0.001169967	16.49680138	0.001292433	17.6174221	0.001397367		
10	11.79124355	0.000676967	10.89928722	0.0008149	11.52807808	0.000884967		
5	5.02507019	0.000143467	5.30774641	0.0003516	7.299980164	0.000530367		
2	2.587593555	-4.95333E-05	2.706419706	0.0001339	3.052932978	0.000174633		
0.2	0.013856665	-0.000253033	0.016350001	-8.78333E-05	0.01012	-8.51333E-05		
80	80.98747253	0.006190434	83.60323334	0.006833033	87.02384949	0.007227033		
0.2	0.020266669	-0.000247433	0.022723334	-7.37667E-05	0.011416665	-7.38666E-05		

Figure 2. Processed data for PT-001 from Test 25.

At each pressure step, we aim to acquire about 90 seconds' worth of data at a rate of one data point per second. This time duration is sufficient for the system to stabilize and to gather enough reliable data points at each step. Columns B and C list average pressure readings from the Paroscientific and average voltage readings from the PTs, respectively, for the room temperature (RT) house air (HA) cycle. Note the multiple tabs along the bottom of the spreadsheet for each PT. The same pattern follows for the next four columns for 152C HA and 152C He. The macro sifts through raw data and averages 30 data points out of the 90 at every pressure step. Again, the values listed in columns B, D and F are averages. The macro averages using the following two requirements: 1) skip the first 30 points at each pressure step to reach the more stable region of data, and 2) do not average until 30 sequential pressure data points are within 0.1psia of each other. Next, the macro plots data sets at each environmental condition by voltage versus pressure. By plotting the experimental data sets for each environmental condition, we are able to characterize each PT using its trend lines (calibration curve) and R^2 (correlation coefficient) values. Available factory calibration curves are plotted for comparison between experimental trend lines, however they are not entirely helpful as they do not always specify the environmental conditions at which the calibration curves were made.

B. Results and Discussion

The results are reflective of 25 full test cycles performed over the course of five months. Upon processing the raw data using Excel macros, we were left with trend lines for each test cycle in each test environment for all of the pressure sensors. The data for PT-001 Measurement Specialties in the stainless steel manifold at 152C Helium is shown below and represents one data set, but for ease of explanation is separated into four tables (Tables 3-6).

PT-001 Measurement Specialties (SS) 152C He

Test#	Slope (psia/V)	Intercept (psia)	R^2
Factory	12386	-	1
1	11772	0.6791	1
2	11820	0.2544	0.9996
3	-	-	-
4	11768	0.3496	1
5	-	-	-
6	11764	0.0643	1
7	11761	-0.0414	1
8	11761	-0.2843	1
9	11773	-0.4704	1
10	11769	-0.1253	1
11	11769	0.0647	1
12	11765	0.2504	1
13	11770	0.5007	1
14	-	-	-
15	11775	1.0364	1
16	11772	1.1477	1
17	11762	0.0535	1
18	11789	0.0797	1
19	11790	0.2291	1
20	11806	0.7983	1
21	11830	0.8718	1
22	11885	0.9048	1
23	11781	1.165	1
24	11942	0.7318	1
25	11883	1.0795	1

Table 3. Trend lines from plotting experimental data

3 psia	10 psia	65 psia
3	10	65
3.530	10.183	62.457
3.117	9.797	62.284
-	-	-
3.200	9.851	62.106
-	-	-
2.914	9.562	61.800
2.807	9.454	61.679
2.564	9.211	61.436
2.381	9.035	61.313
2.725	9.377	61.637
2.915	9.567	61.827
3.100	9.749	61.991
3.351	10.003	62.268
-	-	-
3.888	10.543	62.830
3.999	10.652	62.926
2.902	9.550	61.779
2.935	9.598	61.947
3.085	9.748	62.101
3.658	10.330	62.755
3.737	10.423	62.954
3.783	10.500	63.276
4.018	10.677	62.990
3.624	10.373	63.402
3.958	10.673	63.440

Table 5. Pressure outputs based on factory curve voltages at 3, 10, 65 psia

Range	181	1.6354	0.0004
Average	11795.77273	0.424518182	0.999982
SD	47.47145728	0.479190046	8.33E-05
%RSD	0.402444659	112.8785684	0.008332

Table 4. Statistical data of trend lines

1.637338	1.641858905	2.127164654
1.637	9.947990431	62.3270878
0.484617	0.498082082	0.634148931
29.59785	5.006861294	1.017453171

Table 6. Statistical data of theoretical pressures

To view test data for RT HA, 152C HA, and the rest of 152C He, refer to the "Appendix".

Table 3 shown above contains the collection of all trend lines separated into test, slope, intercept, and R^2 values. Table 4 contains the range, average, standard deviation (SD), and percent relative standard deviation (%RSD) for the trend lines in Table 3. Table 5 contains theoretical pressures with respect to the experimental trend lines (will go into more depth in upcoming sections). Table 6 contains the range, average, SD, and %RSD of the theoretical pressures.

Making any sort of selection based on linearity is difficult since all of the sensors displayed R^2 values that were more or less indicative of straight lines. However, by analyzing the range, average and standard deviation of the slope and intercept data for each sensor over the five months, we were able to identify the top contenders.

One issue when comparing several types of PTs is the varying output range from each sensor. Depending on the scale of the output, a small deviation in the calibration curve can mean a large pressure variation. In an attempt to translate the deviations into percentages for easier comparison across the multiple sensors, we tried using percent relative standard deviation (%RSD). While %RSD was helpful, it was difficult to interpret and translate into practical meaning. The %RSD values were not useful when dealing with very small numbers. In order to "quantify" the deviation in numbers that we can compare and understand in terms of pressure, we used the factory calibration curve for each individual sensor to determine the theoretical voltage outputs at low (3psia), medium (10psia) and high (65psia) pressures. Given that each trend line represents a line function, $y = mx+b$, with "y" being output pressure, "m" being slope, "x" being voltage and "b" being the intercept, we were able to back calculate the expected voltage by plugging in fixed output pressures (3, 10 and 65 psia). Using the expected voltages obtained from the factory curves, we plugged them into all of the experimental calibration curves for Tests 1-25 and were able to compute theoretical pressure values. Although this method does not precisely indicate how accurate a sensor may be, it does provide a good idea of how much a sensor is drifting over time.

The following tables, 7 and 8, show the top two candidates: PT-001 Measurement Specialties and PT-002 Tecsis with 152C Helium in the stainless steel manifold.

PT-001 Measurement Specialties (SS) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	181	1.6354	0.0004	1.637338	1.641858905	2.127164654
Average	11795.77273	0.424518182	0.999982	1.637	9.947990431	62.3270878
SD	47.47145728	0.479190046	8.33E-05	0.484617	0.498082082	0.634148931
%RSD	0.402444659	112.8785684	0.008332	29.59785	5.006861294	1.017453171

Table 7. Data analysis table of PT-001

PT-002 Tecsis (SS) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	487	2.6632	0.0004	2.568181	2.384861535	1.059901936
Average	18465.22727	-0.247504545	0.999964	2.568	10.30605402	64.91927729
SD	140.746365	0.706328181	8.81E-05	0.679222	0.627015225	0.229498985
%RSD	0.762223843	-285.3798826	0.008814	26.44761	6.083950504	0.353514387

Table 8. Data analysis table of PT-002

Based on %RSD and the ranges of the theoretical pressures at 3, 10, and 65 psia, Measurement Specialties is the clear winner. However, this was dismissed when we took additional factors into account. Since minimizing mass is a driving requirement, the Tecsis units are 13 grams lighter and preferable to the Measurement Specialties units. Although Measurement Specialties produced slightly better results, there were not any distinguishable trends in its drift over time, as shown in Figure 3 below. On the contrary, Tecsis shows a predictable and consistent drift throughout the entire testing period, as shown in Figure 4 below. Tecsis also shows consistency in its counterpart sensor, PT-010, shown in Figure 6, being tested in the aluminum manifold; this produced data very similar to the stainless-steel sensor. It is important to have this consistency because it allows us to account for its drift more easily during flight if we cannot recalibrate. As a result, the team down selected Tecsis as the best option for ETU testing.

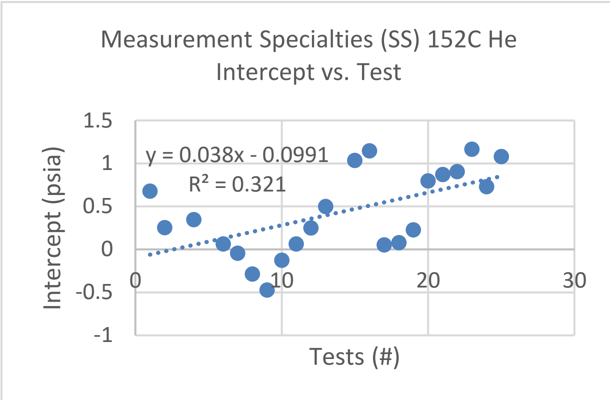


Figure 3. Test # vs Intercept plot for PT-001; notice the random pattern in the drift.

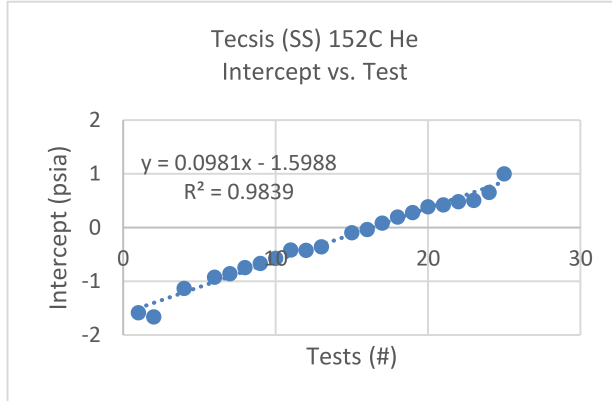


Figure 4. Test # vs Intercept plot for PT-002; notice the predictable pattern in the drift.

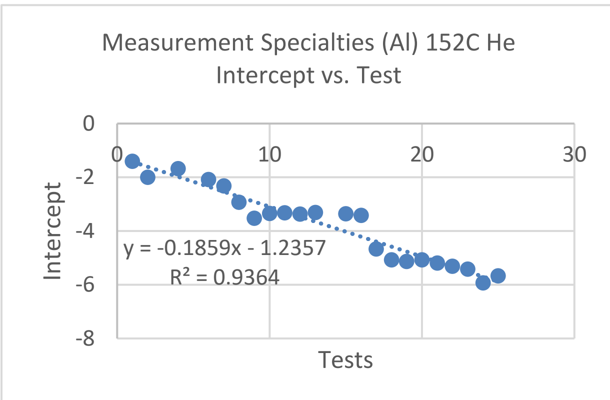


Figure 5. Test # vs Intercept plot for PT-009; notice differing trend from its counterpart, PT-001.

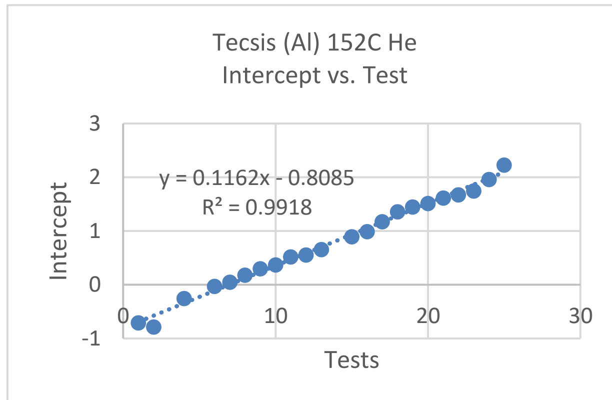


Figure 6. Test # vs Intercept plot for PT-010; notice consistent trend with its counterpart, PT-002.

C. Additional Findings

Throughout the trade study, there were several occasions when the system leak rate fell out of tolerance. Our standard procedure for trouble shooting a leak consists of pressurizing the system with helium or house air and using Snoop, a soapy leak check fluid, or a helium detector to find the source of the leak. Ports on the manifolds without sensors are plugged using special bolts with Viton O-rings shown in Figure 7. Over time, due to the constant fluctuation of temperature during thermal cycling, the O-rings expand and contract. This constant change is observed to result in wear, eventually causing the O-ring to lose its seal.

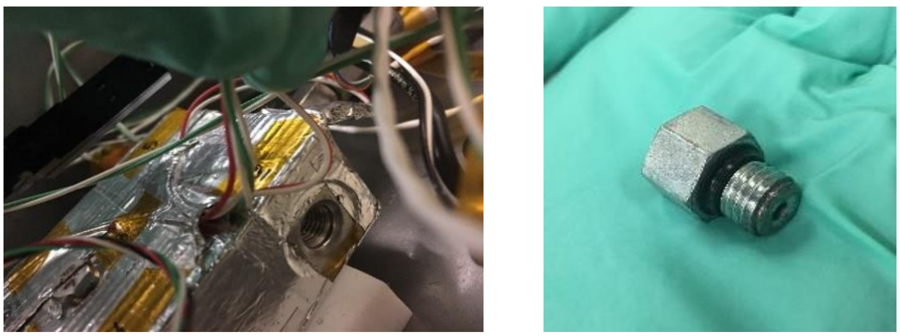


Figure 7. The left shows an empty port and the right shows the matching Viton O-ring plug.

As previously mentioned, the MEMScap PTs were an addition we made late into the trade study. Although the test manifolds were designed to accommodate various port sizes, they could not support the MEMScap sensors without an adapter. We used 4mm to 10-32 Beswick compression fittings to integrate the MEMScap sensors to the manifolds. As a result of the fitting extension, the MEMScap sensors were further away from the heat traced manifolds compared to the other sensors. This was a concern since the MEMScap PTs would likely experience lower steady-state temperatures compared to the others. We ran two full test cycles following the MEMScap integration to verify that there were no unexpected anomalies. As expected, the MEMScap sensors experienced significantly lower temperatures at steady state, roughly 30C below the 152C target needed to adequately thermally stress the sensors. To minimize heat loss to radiation and conduction, and to increase the steady-state temperatures of the MEMScap PTs, we added aluminum and fiberglass insulation shown in Figures 8 and 9. We also installed rope heaters around the base of the bell jar. After two thermal cycle tests, we saw a favorable increase in the steady-state temperatures of the MEMScap PTs without impacting the temperatures of the others.

Figure 8. Insulation around and in between PTs.

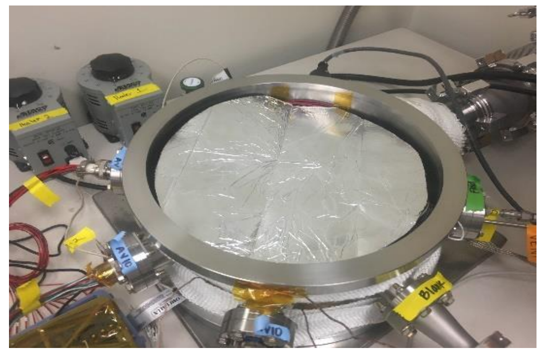


Figure 9. Aluminum & fiberglass cover and rope heaters around base.

III. Conclusion and Future Work

As a critical component of the LAVA subsystem, important calculations will rely on the measurements the PTs output. It is vital to select a sensor that is capable of producing accurate readings while surviving high temperature cycling under vacuum. As a result, six different models of sensors were tested in three environmental conditions, RT HA, 152C HA, and 152C He, to sufficiently down select the sensor that will proceed to integrated testing in the ETU. From this trade study, we found that He does not have a significant affect in pressure readings compared to HA. Furthermore, we observed that the PTs in contact with the stainless steel manifold generally drifted less over time in comparison to the aluminum manifold.

The MEMScap sensors have successfully survived two full test cycles, but it is difficult to judge their performance this early on. With limited time remaining in the trade study, we have decided to run additional partial tests with only the 152C He pressure cycle to acquire more data points. The MEMScap sensors are significantly lighter than the other candidates in the trade study. Our goal is to gather enough data to decide whether MEMScap can be used as a strong backup option for ETU testing. Furthermore, given that there is enough time in the design cycle prior to the payload Preliminary Design Review, additional experimental changes will be made to further stress the sensors. Knowing that the sensors have successfully survived 25 full test cycles without encountering any anomalies, it will be beneficial to see how the sensors react to higher operating temperatures and longer exposure to helium.

	Name	Range for 3psia	Range for 10psia	Range for 65 psia	Mass (g) with wiring
PT-002	Tecsis (SS)	2.568	2.384	1.059	29.44
PT-010	Tecsis (Al)	2.912	2.718	1.324	29.44
PT-001	Measurement Specialties (SS)	1.637	1.641	2.127	42.30
PT-009	Measurement Specialties (Al)	4.538	4.545	4.603	42.30
PT-005	GP 50 7900 (SS)	17.75	17.19	18.09	78.92
PT-013	GP 50 7900 (Al)	3.886	4.536	9.967	78.92
PT-007	GP 50 189 (SS)	12.73	12.71	12.56	14.35

Table 9. Summary of important aspects for PT down selection, and listed by increasing mass; PT-007 is separated since it is not a contender for the FSS manifold.

Ultimately, Tecsis has proved itself to be the best sensor for ETU integration and testing. As a reiteration, GP 50 189 was tested for its potential use in the high pressure gas manifold, and due to its high pressure range, was not considered to be a contender for the FSS manifold. Measurement Specialties, a close second, drifted less over time than Tecsis, but only by a very small fraction that is not worth losing the opportunity of having a lighter unit. It is also important to note that Tecsis is the only unit to provide consistency across varying manifold materials. Over the duration of 42 thermal cycles and 25 test cycles in high temperature and helium, the Tecsis sensors experienced drift no more than 3 psia since the first test, five months ago. Overall, Tecsis has provided strong stability and consistency, and is the lightest option among its contenders. In the following months, multiple Tecsis sensors will undergo extended vacuum testing for accuracy and to identify any potential compatibility issues within the full ETU system.

Appendix

Room Temperature House Air

Data sets contain experimental trend lines, and theoretical pressures. As shown in the data sets, several tests do not have data points. This is because the affected tests did not pass the leak rate tolerance of 0.1 psia per 30 seconds due to test setup leaks, or test conductor errors.

PT-001 Measurement Specialties (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
1	12335	3.2612	1
2	12334	2.6773	1
3	-	-	-
4	12339	2.5297	1
5	-	-	-
6	12337	2.0807	1
7	12347	1.3911	1
8	12335	1.8035	1
9	12354	0.7899	1
10	12343	1.3887	1
11	12328	1.2123	1
12	12527	1.9261	0.999
13	12348	2.3537	1
14	-	-	-
15	12345	3.7852	1
16	12356	4.2871	1
17	12377	2.0202	1
18	12375	2.027	1
19	12380	2.1683	1
20	12409	2.9029	1
21	12441	3.1912	1
22	12697	3.2925	1
23	-	-	-
24	12558	3.3968	1
25	12533	3.3376	1
Factory	12386	-	1

PT-009 Measurement Specialties (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
1	11320	2.7593	1
2	11318	1.922	1
3	-	-	-
4	11324	2.395	1
5	-	-	-
6	11324	1.8459	1
7	11338	1.4257	1
8	11321	1.7675	1
9	11340	0.025	1
10	11326	0.808	1
11	11312	0.4968	1
12	11496	1.2536	0.9989
13	11331	1.4839	1
14	-	-	-
15	11330	2.9118	1
16	11337	3.2829	1
17	11347	1.1984	1
18	11330	1.0582	1
19	11326	1.0292	1
20	11339	1.408	1
21	11332	1.5529	1
22	11354	1.5693	1
23	-	-	-
24	11343	1.5923	1
25	11346	1.2504	1
Factory	11450	2E-14	1

PT-002 Tecsis (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
1	18386	1.8347	0.9998
2	18371	2.4193	0.9998
3	-	-	-
4	18378	2.6179	0.9998
5	-	-	-
6	18388	2.6127	0.9999
7	18407	1.8976	1
8	18349	3.0765	0.9998
9	18382	2.8405	0.9999
10	18336	3.133	0.9998
11	18360	3.0721	0.9999
12	18615	3.1875	0.999
13	18343	3.264	0.9999
14	-	-	-
15	18308	3.5369	0.9998
16	18324	3.5918	0.9998
17	18396	3.5943	0.9998
18	18310	3.6334	0.9997
19	18312	3.7256	0.9997
20	18333	3.7761	0.9998
21	18309	3.7833	0.9998
22	18344	3.8335	0.9998
23	-	-	-
24	18310	4.2382	0.9997
25	18315	4.1693	0.9998
Factory	18596	-0.6283	1

PT-010 Tecsis (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
1	19030	-0.0349	0.9998
2	19028	0.9182	0.9998
3	-	-	-
4	19028	0.7147	0.9998
5	-	-	-
6	19053	0.8872	0.9999
7	19079	0.3079	1
8	19017	1.3589	0.9998
9	19049	1.0758	0.9999
10	19005	1.3015	0.9998
11	19010	1.4374	0.9999
12	19289	1.2977	0.9989
13	19010	1.4208	0.9998
14	-	-	-
15	18988	1.5558	0.9998
16	19007	1.5349	0.9998
17	19048	1.6351	0.9998
18	18994	1.5959	0.9997
19	18996	1.6929	0.9997
20	19015	1.717	0.9998
21	18987	1.7657	0.9997
22	19014	1.7997	0.9998
23	-	-	-
24	19008	2.0746	0.9997
25	19012	2.0581	0.9998
Factory	19295	-0.7445	1

PT-005 GP50 7900 (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
1	19.933	-3.1251	1
2	19.953	-3.7139	1
3	-	-	-
4	19.923	-5.8777	1
5	-	-	-
6	19.92	-6.6878	1
7	19.963	-8.1197	1
8	19.956	-8.3101	1
9	19.972	-11.18	1
10	19.969	-11.473	1
11	19.946	-12.391	1
12	20.207	-12.811	0.9987
13	19.981	-12.896	1
14	-	-	-
15	20.021	-14.086	0.9999
16	19.986	-14.037	1
17	19.764	-14.162	0.9999
18	20.007	-14.41	1
19	20.004	-14.421	1
20	20.012	-14.532	1
21	20.009	-14.572	1
22	19.946	-14.507	1
23	-	-	-
24	20.01	-13.341	1
25	20.019	-13.585	1
Factory	19.97	-2.1024	

PT-013 GP50 7900 (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
1	20.163	0.1194	0.9993
2	20.161	0.0095	0.9994
3	-	-	-
4	20.105	-0.3051	0.9997
5	-	-	-
6	20.082	-0.4334	0.9997
7	20.064	-0.6424	0.9998
8	20.044	-0.7506	0.9999
9	19.957	-1.3381	1
10	19.937	-1.4898	1
11	19.921	-1.4052	1
12	20.217	-2.0944	0.9989
13	19.935	-2.0481	1
14	-	-	-
15	19.946	-3.2229	1
16	19.948	-3.4356	1
17	19.886	-3.7033	1
18	19.947	-4.1162	1
19	19.946	-4.185	1
20	19.953	-4.4165	1
21	19.941	-4.5083	1
22	19.928	-4.5662	1
23	-	-	-
24	19.964	-4.8458	1
25	19.975	-4.9588	1
Factory	19.973	-1.8488	1

PT-007 GP50 189 (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
1	588174	142.89	0.9913
2	572055	114.62	1
3	-	-	-
4	587069	114.34	0.9973
5	-	-	-
6	587613	109.52	0.9977
7	571520	100.98	1
8	572966	102.72	1
9	573072	92.335	1
10	573885	91.378	1
11	580176	92.819	0.998
12	590314	95.676	0.9956
13	574712	86.522	1
14	-	-	-
15	567773	84.166	0.9981
16	575511	88.749	1
17	613129	82.821	0.9974
18	575918	143.06	1
19	574946	133.19	0.9996
20	576714	128.32	1
21	576117	126.72	1
22	591419	125.12	0.9962
23	-	-	-
Factory	574713	365.27	1

PT-003 MEMScap SP81 R (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	541.1	3.4167	0.9776
25	479.3	4.0967	1
Factory	-	-	-

PT-012 MEMScap RP81 R (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	644.9	-9.963	0.9756
25	562.51	-7.5548	1
Factory	-	-	-

PT-007 MEMScap SP80 D (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	724.87	-24.079	0.9468
25	566.89	-17.063	1
Factory	-	-	-

PT-014 MEMScap SP80 D (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	648.42	-11.049	0.9721
25	553.7	-8.1141	1
Factory	-	-	-

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Data Analysis Summary Chart for All PTs in 152C He

PT-001 Measurement Specialties (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	369	3.4972	0.001
Average	12399.90476	2.467761905	0.999952
SD	95.57490444	0.895285561	0.000213
%RSD	0.770771278	36.27925203	0.021297

PT-009 Measurement Specialties (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	184	3.2579	0.0011
Average	11339.71429	1.573147619	0.999948
SD	36.46021035	0.760256123	0.000234
%RSD	0.321526711	48.32706823	0.023427

PT-002 Tecsis (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	307	2.4035	0.001
Average	18360.7619	3.230390476	0.999776
SD	65.03032608	0.653968375	0.000187
%RSD	0.354180978	20.24425157	0.018752

PT-010 Tecsis (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	302	2.1095	0.0011
Average	19031.7619	1.338804762	0.999762
SD	61.76599832	0.524203732	0.000206
%RSD	0.324541672	39.15460619	0.020586

PT-005 GP50 7900 (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	0.443	11.4469	0.0013
Average	19.9762381	-11.34468095	0.999929
SD	0.075070066	3.676234974	0.000276
%RSD	0.37579681	-32.40492165	0.027629

PT-013 GP50 7900 (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	0.331	5.0782	0.0011
Average	20.00095238	-2.492228571	0.999843
SD	0.091745235	1.752766445	0.00029
%RSD	0.458704334	-70.32928139	0.029048

PT-007 GP50 189 (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	45356	60.239	0.0087
Average	580162.2632	108.2076842	0.998484
SD	10372.46363	19.51804914	0.002212
%RSD	1.78785562	18.03758142	0.221511

PT-003 MEMScap SP81 R (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	61.8	0.68	0.0224
Average	510.2	3.7567	0.9888
SD	30.9	0.34	0.0112
%RSD	6.056448452	9.050496446	1.132686

PT-012 MEMScap SP81 R (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	82.39	2.4082	0.0244
Average	603.705	-8.7589	0.9878
SD	41.195	1.2041	0.0122
%RSD	6.823697004	-13.74716003	1.235068

PT-007 MEMScap SP80 D (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	157.98	7.016	0.0532
Average	645.88	-20.571	0.9734
SD	78.99	3.508	0.0266
%RSD	12.22982597	-17.05313305	2.73269

PT-014 MEMScap SP80 D (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	94.72	2.9349	0.0279
Average	601.06	-9.58155	0.98605
SD	47.36	1.46745	0.01395
%RSD	7.879413037	-15.31537173	1.414736

152C House Air

Data sets contain experimental trend lines, and theoretical pressures.

PT-001 Measurement Specialties (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	11754	1.0054	1	3.852	10.495	62.689
2	11761	0.6861	1	3.535	10.181	62.406
3	-	-	-	-	-	-
4	11756	0.569	1	3.416	10.060	62.263
5	-	-	-	-	-	-
6	11754	0.305	1	3.152	9.795	61.988
7	11754	0.168	1	3.015	9.658	61.851
8	11749	-0.0045	1	2.841	9.481	61.653
9	11756	-0.2215	1	2.626	9.270	61.472
10	11761	0.0605	1	2.909	9.556	61.781
11	11762	0.2506	1	3.099	9.747	61.976
12	11844	0.0368	0.9986	2.906	9.599	62.192
13	11754	0.7022	1	3.549	10.192	62.386
14	-	-	-	-	-	-
15	11766	1.2883	1	4.138	10.788	63.035
16	11760	1.441	1	4.289	10.936	63.156
17	11762	0.2303	1	3.079	9.727	61.956
18	11775	0.2551	1	3.107	9.762	62.049
19	11779	0.3861	1	3.239	9.896	62.201
20	11798	0.9698	1	3.827	10.495	62.884
21	11820	1.0932	1	3.956	10.636	63.123
22	11923	0.9158	1	3.804	10.542	63.486
23	11773	1.3711	1	4.223	10.876	63.154
24	11916	0.908	1	3.794	10.529	63.442
25	11921	1.1455	0.9999	4.033	10.770	63.705
Factory	12386	-	1	-	-	-

PT-009 Measurement Specialties (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	10730	-0.91	0.9999	1.901	8.461	60.003
2	10728	-1.4949	0.9999	1.316	7.875	59.406
3	-	-	-	-	-	-
4	10730	-1.3777	1	1.434	7.993	59.535
5	-	-	-	-	-	-
6	10727	-1.808	1	1.003	7.561	59.088
7	10722	-2.0367	1	0.773	7.327	58.831
8	10715	-2.5098	0.9999	0.298	6.848	58.318
9	10718	-3.1843	1	-0.376	6.176	57.660
10	10732	-3.0913	1	-0.279	6.282	57.833
11	10722	-3.053	1	-0.244	6.311	57.814
12	10806	-3.5312	0.9986	-0.700	5.906	57.813
13	10717	-3.0257	1	-0.218	6.334	57.813
14	-	-	-	-	-	-
15	10735	-3.031	0.9999	-0.218	6.345	57.910
16	10739	-3.0887	0.9999	-0.275	6.290	57.875
17	10708	-4.4253	0.9999	-1.620	4.927	56.362
18	10722	-4.8477	1	-2.038	4.516	56.020
19	10723	-4.9158	1	-2.106	4.449	55.957
20	10733	-4.8814	1	-2.069	4.492	56.048
21	10728	-4.9425	0.9999	-2.132	4.427	55.959
22	10756	-5.2766	1	-2.458	4.117	55.784
23	10732	-5.1817	0.9999	-2.370	4.191	55.742
24	10735	-5.6839	1	-2.871	3.692	55.257
25	10736	-5.4893	1	-2.676	3.887	55.457
Factory	11450	2E-14	1	-	-	-

PT-002 Tecsis (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	18666	-1.452	1	2.190	9.216	64.423
2	18623	-1.2253	0.9999	2.408	9.418	64.498
3	-	-	-	-	-	-
4	18585	-0.9106	0.9999	2.716	9.711	64.679
5	-	-	-	-	-	-
6	18552	-0.7156	0.9999	2.904	9.888	64.757
7	18527	-0.6464	0.9999	2.968	9.942	64.738
8	18511	-0.5374	0.9999	3.074	10.042	64.791
9	18461	-0.455	0.9999	3.147	10.096	64.697
10	18456	-0.3117	0.9999	3.289	10.237	64.823
11	18433	-0.1613	0.9999	3.435	10.374	64.892
12	18552	-0.5824	0.9986	3.037	10.021	64.891
13	18386	-0.088	0.9999	3.499	10.420	64.799
14	-	-	-	-	-	-
15	18353	0.1496	0.9999	3.730	10.639	64.920
16	18338	0.2304	0.9999	3.808	10.711	64.948
17	18327	0.3098	0.9999	3.886	10.784	64.989
18	18270	0.4439	0.9999	4.009	10.886	64.922
19	18278	0.5274	0.9999	4.094	10.974	65.033
20	18280	0.6056	0.9999	4.172	11.053	65.119
21	18250	0.6941	0.9999	4.255	11.125	65.101
22	18305	0.4742	1	4.046	10.936	65.076
23	18224	0.7409	0.9998	4.297	11.157	65.056
24	18228	0.9174	0.9999	4.474	11.335	65.247
25	18219	1.2789	0.9999	4.834	11.692	65.577
Factory	18596	-0.6283	1	-	-	-

PT-010 Tecsis (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	19374	-0.7467	1	3.013	10.041	65.264
2	19342	-0.5413	1	3.212	10.229	65.360
3	-	-	-	-	-	-
4	19295	-0.2108	1	3.534	10.533	65.530
5	-	-	-	-	-	-
6	19260	0.0039	1	3.741	10.728	65.626
7	19238	0.0785	1	3.812	10.791	65.625
8	19219	0.2144	1	3.944	10.916	65.697
9	19178	0.2999	1	4.022	10.979	65.642
10	19152	0.4827	1	4.199	11.147	65.737
11	19141	0.5985	1	4.313	11.257	65.815
12	19256	0.2196	0.9987	3.956	10.942	65.828
13	19090	0.7491	1	4.454	11.379	65.792
14	-	-	-	-	-	-
15	19046	0.9755	1	4.671	11.581	65.868
16	19029	1.0862	1	4.779	11.682	65.921
17	19017	1.24	0.9999	4.930	11.829	66.034
18	18961	1.4212	1	5.101	11.979	66.024
19	18960	1.5128	1	5.192	12.070	66.112
20	18943	1.599	0.9999	5.275	12.147	66.141
21	18917	1.7378	0.9999	5.409	12.271	66.191
22	18949	1.671	1	5.348	12.222	66.233
23	18882	1.8514	0.9999	5.516	12.365	66.185
24	18897	2.0522	0.9999	5.719	12.575	66.437
25	18882	2.3629	0.9999	6.027	12.877	66.697
Factory	19295	-0.7445	1	-	-	-

PT-005 GP50 7900 (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	20.049	-3.181	1	1.942	8.969	64.187
2	20.026	-3.9164	1	1.200	8.220	63.374
3	-	-	-	-	-	-
4	20.046	-7.0055	1	-1.884	5.143	60.352
5	-	-	-	-	-	-
6	20.043	-8.092	1	-2.971	4.055	59.256
7	19.994	-9.9613	1	-4.853	2.156	57.222
8	19.995	-10.318	1	-5.209	1.800	56.868
9	19.926	-14.263	0.9999	-9.172	-2.187	52.692
10	20.049	-14.873	1	-9.750	-2.723	52.495
11	19.971	-15.964	1	-10.861	-3.861	51.142
12	20.193	-16.992	0.9988	-11.833	-4.754	50.860
13	19.968	-16.89	1	-11.788	-4.789	50.206
14	-	-	-	-	-	-
15	20.049	-18.995	1	-13.872	-6.845	48.373
16	20.049	-19.264	1	-14.141	-7.114	48.104
17	19.841	-19.636	0.9998	-14.567	-7.612	47.033
18	20.049	-20.181	1	-15.058	-8.031	47.187
19	20.047	-20.273	1	-15.151	-8.124	47.088
20	20.051	-20.543	1	-15.420	-8.392	46.832
21	20.029	-20.757	0.9998	-15.640	-8.619	46.544
22	20.052	-20.801	1	-15.678	-8.649	46.577
23	20.047	-20.992	1	-15.870	-8.843	46.369
24	20.042	-19.584	1	-14.463	-7.438	47.760
25	20.045	-19.855	1	-14.733	-7.707	47.499
Factory	19.97	-2.1024	1	-	-	-

PT-013 GP50 7900 (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	21.899	4.1443	0.9838	9.461	17.136	77.439
2	21.913	4.1876	0.9825	9.507	17.187	77.529
3	-	-	-	-	-	-
4	21.723	4.087	0.9848	9.361	16.974	76.793
5	-	-	-	-	-	-
6	21.748	3.9404	0.9839	9.220	16.842	76.730
7	21.627	3.8488	0.9858	9.099	16.679	76.233
8	21.547	3.9392	0.9863	9.170	16.722	76.056
9	21.269	3.4789	0.9898	8.642	16.097	74.665
10	21.251	3.4166	0.9889	8.576	16.024	74.543
11	21.215	3.096	0.9905	8.246	15.682	74.102
12	21.276	2.7859	0.9865	7.951	15.408	73.996
13	21.007	3.0733	0.9921	8.173	15.536	73.383
14	-	-	-	-	-	-
15	20.677	2.5152	0.9943	7.535	14.782	71.720
16	20.55	2.4253	0.9949	7.414	14.616	71.205
17	20.486	2.0419	0.9959	7.015	14.195	70.608
18	20.362	1.66	0.997	6.603	13.740	69.811
19	20.338	1.5528	0.9972	6.490	13.618	69.623
20	20.25	1.3209	1	6.237	13.334	69.097
21	20.167	1.3114	0.998	6.207	13.275	68.810
22	20.222	0.9966	0.9982	5.906	12.993	68.679
23	20.129	0.699	0.9986	5.586	12.640	68.070
24	20.068	0.8174	0.9987	5.689	12.723	67.984
25	20.045	0.6745	0.9988	5.541	12.566	67.764
Factory	19.973	-1.8488	1	-	-	-

PT-007 GP50 189 (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	559885	-84.687	0.9995	-437.610	-430.791	-377.210
2	546906	-81.663	0.9982	-426.405	-419.744	-367.405
3	-	-	-	-	-	-
4	559984	-85.981	0.9999	-438.967	-432.146	-378.556
5	-	-	-	-	-	-
6	560992	-88.215	0.9997	-441.836	-435.003	-381.316
7	548518	-86.999	0.998	-432.757	-426.076	-373.583
8	547722	-87.748	0.9979	-433.004	-426.333	-373.916
9	538952	-88.78	0.9967	-428.508	-421.944	-370.366
10	561088	-93.7	0.9998	-447.381	-440.547	-386.851
11	547968	-91.042	0.9979	-436.453	-429.779	-377.339
12	567119	-96.774	0.9986	-454.257	-447.350	-393.076
13	549701	-92.555	0.9978	-439.059	-432.363	-379.757
14	-	-	-	-	-	-
15	563862	-96.108	0.9997	-451.538	-444.670	-390.709
16	562253	-95.999	0.9997	-450.415	-443.567	-389.759
17	532768	-92.51	0.9953	-428.340	-421.851	-370.865
18	553626	-94.353	0.9982	-443.331	-436.588	-383.606
19	555837	-95.59	0.9992	-445.962	-439.191	-385.998
20	564662	-99.998	0.9999	-455.932	-449.055	-395.017
21	560007	-102.59	0.9973	-455.590	-448.769	-395.177
22	560705	-102.92	0.9999	-456.360	-449.531	-395.871
23	563951	-113.65	0.9999	-469.136	-462.267	-408.297
Factory	574713	365.27	1	-	-	-

PT-003 MEMScap SP81 R (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	570.17	3.781	1
25	574.38	3.804	1
Factory	-	-	-

PT-012 MEMScap SP81 R (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	668.71	-8.8979	1
25	671.9	-8.9196	1
Factory	-	-	-

PT-007 MEMScap SP80 D (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	676.59	-21.121	1
25	684.7	-21.413	1
Factory	-	-	-

PT-014 MEMScap SP80 D (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	661.76	-9.6475	1
25	668.93	-9.7188	1
Factory	-	-	-

Data Analysis Summary Chart for All PTs in 152C HA

PT-001 Measurement Specialties (SS)

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	174	1.6625	0.0014	1.6634688	1.665729	2.232897
Average	11790.81818	0.616445455	0.999932	1.663	10.13592	62.49301
SD	56.05568365	0.484799264	0.000291	0.4892145	0.500798	0.640898
%RSD	0.475418099	78.64430829	0.029139	29.409295	4.940829	1.025552

PT-009 Measurement Specialties (Al)

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	98	4.7739	0.0014	4.77259	4.769533	4.745516
Average	10731.54545	-3.53575	0.9999	4.305	5.836779	57.38569
SD	18.90581265	1.440453528	0.000288	1.4398328	1.43845	1.430789
%RSD	0.176170457	-40.73968826	0.028765	33.446449	24.64458	2.493286

PT-002 Tecsis (SS)

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	447	2.7309	0.0014	2.643685	2.475423	1.153365
Average	18401.09091	-0.032431818	0.999845	2.425	10.48447	64.908
SD	138.1527182	0.708960048	0.000274	0.6824182	0.631311	0.243348
%RSD	0.750785477	-2186.001549	0.027428	28.136607	6.021387	0.374912

PT-010 Tecsis (Al)

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	492	3.1096	0.0013	3.0141246	2.835642	1.433279
Average	19092.18182	0.848081818	0.999914	2.815	11.47909	65.89814
SD	155.9418995	0.852355603	0.000268	0.8224309	0.76656	0.335837
%RSD	0.816784069	100.5039355	0.026851	29.216698	6.677883	0.50963

PT-005 GP50 7900 (SS) 152C HA

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	0.352	17.811	0.0012	17.811511	17.81221	17.81772
Average	20.0255	-15.56078182	0.999923	17.070	-3.42475	51.72811
SD	0.062749683	5.688411255	0.000252	5.688098	5.687742	5.687903
%RSD	0.313348896	-36.55607618	0.025216	33.321734	-166.078	10.99577

PT-013 GP50 7900 (Al) 152C HA

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	1.868	3.5131	0.0175	3.9665901	4.621274	9.765218
Average	20.89859091	2.546045455	0.992114	3.967	14.94394	72.49276
SD	0.648956691	1.221807283	0.005826	1.3760816	1.599926	3.37548
%RSD	3.105265298	47.98843168	0.58719	34.691802	10.70618	4.656299

PT-007 GP50 189 (SS) 152C HA

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	34351	31.987	0.0046	29.527484	29.31122	27.77187
Average	555325.3	-93.5931	0.998655	-441.5192	-434.765	-381.695
SD	9002.98079	7.266811611	0.001254	9.366593	9.271707	8.540104
%RSD	1.621208468	-7.764259984	0.125527	-2.121446	-2.13258	-2.23742

PT-003 MEMScap SP81 R (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	4.21	0.023	0
Average	572.275	3.7925	1
SD	2.105	0.0115	0
%RSD	0.367830152	0.303230059	0

PT-012 MEMScap SP81 R (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	3.19	0.0217	0
Average	670.305	-8.90875	1
SD	1.595	0.01085	0
%RSD	0.23795138	-0.121790375	0

PT-007 MEMScap SP80 D (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	8.11	0.292	0
Average	680.645	-21.267	1
SD	4.055	0.146	0
%RSD	0.595758435	-0.686509616	0

PT-014 MEMScap SP80 D (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	7.17	0.0713	0
Average	665.345	-9.68315	1
SD	3.585	0.03565	0
%RSD	0.538818207	-0.368165318	0

152C Helium

Data sets contain experimental trend lines, and theoretical pressures.

PT-001 Measurement Specialties (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	11772	0.6791	1	3.530	10.183	62.457
2	11820	0.2544	0.9996	3.117	9.797	62.284
3	-	-	-	-	-	-
4	11768	0.3496	1	3.200	9.851	62.106
5	-	-	-	-	-	-
6	11764	0.0643	1	2.914	9.562	61.800
7	11761	-0.0414	1	2.807	9.454	61.679
8	11761	-0.2843	1	2.564	9.211	61.436
9	11773	-0.4704	1	2.381	9.035	61.313
10	11769	-0.1253	1	2.725	9.377	61.637
11	11769	0.0647	1	2.915	9.567	61.827
12	11765	0.2504	1	3.100	9.749	61.991
13	11770	0.5007	1	3.351	10.003	62.268
14	-	-	-	-	-	-
15	11775	1.0364	1	3.888	10.543	62.830
16	11772	1.1477	1	3.999	10.652	62.926
17	11762	0.0535	1	2.902	9.550	61.779
18	11789	0.0797	1	2.935	9.598	61.947
19	11790	0.2291	1	3.085	9.748	62.101
20	11806	0.7983	1	3.658	10.330	62.755
21	11830	0.8718	1	3.737	10.423	62.954
22	11885	0.9048	1	3.783	10.500	63.276
23	11781	1.165	1	4.018	10.677	62.990
24	11942	0.7318	1	3.624	10.373	63.402
25	11883	1.0795	1	3.958	10.673	63.440
Factory	12386	-	1	3	10	65

PT-009 Measurement Specialties (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	10749	-1.399	1	1.417	7.989	59.622
2	10793	-2.0008	0.9996	0.827	7.425	59.270
3	-	-	-	-	-	-
4	10745	-1.6715	1	1.144	7.713	59.326
5	-	-	-	-	-	-
6	10740	-2.0769	1	0.737	7.303	58.893
7	10739	-2.3174	1	0.496	7.062	58.646
8	10736	-2.9315	1	-0.119	6.445	58.015
9	10747	-3.5202	1	-0.704	5.866	57.489
10	10743	-3.3458	1	-0.531	6.037	57.641
11	10741	-3.3224	1	-0.508	6.058	57.653
12	10737	-3.3689	1	-0.556	6.008	57.584
13	10745	-3.3144	1	-0.499	6.070	57.683
14	-	-	-	-	-	-
15	10739	-3.3616	1	-0.548	6.017	57.602
16	10745	-3.4123	1	-0.597	5.972	57.586
17	10729	-4.6614	1	-1.850	4.709	56.246
18	10726	-5.0777	1	-2.267	4.290	55.812
19	10726	-5.1372	1	-2.327	4.230	55.753
20	10731	-5.0756	1	-2.264	4.296	55.843
21	10748	-5.1911	1	-2.375	4.196	55.824
22	10746	-5.3144	1	-2.499	4.071	55.689
23	10734	-5.4192	1	-2.607	3.955	55.516
24	10737	-5.9344	1	-3.121	3.443	55.018
25	10736	-5.6693	1	-2.856	3.707	55.277
Factory	11450	2E-14	1	3	10	65

PT-002 Tecsis (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	18726	-1.5833	1	2.070	9.119	64.504
2	18781	-1.662	0.9996	2.002	9.072	64.619
3	-	-	-	-	-	-
4	18651	-1.1335	1	2.506	9.526	64.689
5	-	-	-	-	-	-
6	18610	-0.924	1	2.707	9.712	64.754
7	18591	-0.8558	1	2.772	9.770	64.755
8	18571	-0.743	1	2.880	9.871	64.797
9	18535	-0.6658	1	2.951	9.928	64.747
10	18521	-0.5717	1	3.042	10.014	64.792
11	18502	-0.4146	1	3.195	10.160	64.882
12	18483	-0.4228	1	3.183	10.141	64.807
13	18463	-0.3546	1	3.248	10.198	64.804
14	-	-	-	-	-	-
15	18420	-0.0975	1	3.496	10.430	64.910
16	18405	-0.0342	1	3.557	10.485	64.920
17	18382	0.0852	1	3.672	10.591	64.958
18	18353	0.1966	1	3.777	10.686	64.967
19	18358	0.282	0.9999	3.864	10.774	65.070
20	18336	0.3873	0.9999	3.965	10.867	65.098
21	18332	0.4232	1	4.000	10.901	65.120
22	18322	0.4806	1	4.055	10.952	65.142
23	18294	0.5047	0.9999	4.074	10.960	65.067
24	18305	0.6569	0.9999	4.228	11.119	65.258
25	18294	1.0012	1	4.571	11.457	65.564
Factory	18596	-0.6283	1	3	10	65

PT-010 Tecsis (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	19403	-0.7102	1	3.055	10.094	65.399
2	19464	-0.787	0.9996	2.990	10.051	65.530
3	-	-	-	-	-	-
4	19326	-0.2553	1	3.495	10.506	65.591
5	-	-	-	-	-	-
6	19284	-0.0275		3.715	10.710	65.676
7	19264	0.0452	1	3.783	10.772	65.681
8	19244	0.1757	1	3.910	10.891	65.743
9	19205	0.298	1	4.025	10.992	65.732
10	19194	0.3681	1	4.093	11.056	65.765
11	19169	0.5184	1	4.238	11.192	65.830
12	19150	0.5534	1	4.270	11.217	65.800
13	19122	0.655	1	4.366	11.303	65.807
14	-	-	-	-	-	-
15	19079	0.8937	1	4.596	11.517	65.899
16	19060	0.9876	1	4.686	11.601	65.928
17	19030	1.1747	1	4.868	11.771	66.013
18	18999	1.3555	1	5.042	11.935	66.088
19	19001	1.4484	1	5.136	12.029	66.188
20	18976	1.5099	1	5.192	12.076	66.164
21	18968	1.6114	1	5.292	12.173	66.238
22	18949	1.671	1	5.348	12.222	66.233
23	18921	1.7458	1	5.418	12.281	66.213
24	18939	1.9607	1	5.636	12.506	66.489
25	18929	2.2288	1	5.902	12.769	66.723
Factory	19295	-0.7445	1	3	10	65

PT-005 GP50 7900 (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	20.033	-3.1475	1	1.971	8.993	64.167
2	20.12	-4.1613	0.9996	0.979	8.032	63.445
3	-	-	-	-	-	-
4	20.032	-6.9796	1	-1.861	5.160	60.331
5	-	-	-	-	-	-
6	20.031	-8.0741	1	-2.956	4.065	59.233
7	20.033	-9.9941	1	-4.876	2.146	57.320
8	20.035	-10.369	1	-5.250	1.773	56.952
9	20.039	-14.4	1	-9.280	-2.256	52.934
10	20.038	-14.881	1	-9.761	-2.737	52.450
11	20.039	-16.066	1	-10.946	-3.922	51.268
12	20.05	-16.491	1	-11.368	-4.340	50.880
13	20.045	-17.04	1	-11.918	-4.892	50.314
14	-	-	-	-	-	-
15	19.991	-19.047	0.9999	-13.939	-6.932	48.126
16	20.049	-19.319	1	-14.196	-7.169	48.049
17	19.972	-19.851	0.9999	-14.748	-7.747	47.258
18	19.931	-20.067	1	-14.975	-7.988	46.904
19	19.938	-20.194	0.9999	-15.100	-8.111	46.801
20	19.93	-20.397	0.9999	-15.305	-8.319	46.571
21	19.935	-20.618	0.9999	-15.525	-8.537	46.367
22	19.933	-20.673	0.9999	-15.580	-8.593	46.305
23	19.925	-20.871	0.9999	-15.780	-8.796	46.080
24	19.925	-19.503	0.9999	-14.412	-7.428	47.448
25	19.937	-19.75	0.9999	-14.656	-7.668	47.242
Factory	19.97	-2.1024	1	3	10	65

PT-013 GP50 7900 (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	22.042	4.0541	0.9821	9.405	17.130	77.828
2	21.971	4.1482	0.9785	9.482	17.182	77.684
3	-	-	-	-	-	-
4	21.817	4.1519	0.9818	9.448	17.095	77.172
5	-	-	-	-	-	-
6	21.736	4.0937	0.9837	9.370	16.988	76.843
7	21.655	3.8805	0.9846	9.138	16.727	76.359
8	21.551	4.009	0.9852	9.241	16.794	76.139
9	21.334	3.4267	0.9886	8.606	16.083	74.831
10	21.329	3.3074	0.9886	8.485	15.961	74.695
11	21.215	3.1653	0.9901	8.316	15.751	74.171
12	21.151	3.1665	0.9906	8.301	15.714	73.958
13	21.069	3.0915	0.9909	8.206	15.590	73.609
14	-	-	-	-	-	-
15	20.745	2.4183	0.9942	7.455	14.725	71.851
16	20.624	2.2861	0.9947	7.293	14.521	71.314
17	20.416	2.2069	0.9961	7.163	14.319	70.538
18	20.363	1.8	0.9967	6.743	13.880	69.954
19	20.361	1.5764	0.9971	6.519	13.655	69.724
20	20.272	1.3591	0.9977	6.280	13.385	69.209
21	20.265	1.119	0.9979	6.039	13.141	68.945
22	20.216	1.0375	0.9982	5.945	13.030	68.700
23	20.145	0.7052	0.9986	5.596	12.656	68.130
24	20.138	0.7455	0.9986	5.634	12.692	68.147
25	20.051	0.7511	0.9987	5.619	12.646	67.861
Factory	19.973	-1.8488	1	3	10	65

PT-007 GP50 189 (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
1	559352	-83.421	0.9996	-436.008	-429.195	-375.665
2	561875	-83.786	0.9994	-437.964	-431.120	-377.349
3	-	-	-	-	-	-
4	559666	-85.553	0.9998	-438.338	-431.521	-377.961
5	-	-	-	-	-	-
6	559920	-87.566	0.9997	-440.511	-433.691	-380.107
7	560566	-88.923	0.9998	-442.275	-435.448	-381.802
8	561272	-89.858	0.9996	-443.655	-436.819	-383.105
9	562138	-92.441	0.9999	-446.784	-439.938	-386.141
10	561601	-93.162	0.9997	-447.167	-440.327	-386.581
11	561550	-92.997	0.9998	-446.970	-440.130	-386.390
12	561570	-94.75	0.9997	-448.735	-441.895	-388.153
13	561622	-94.368	0.9998	-448.386	-441.546	-387.798
14	-	-	-	-	-	-
15	551001	-93.458	0.9944	-440.781	-434.070	-381.339
16	560923	-95.162	0.9998	-448.739	-441.907	-388.227
17	549913	-95.301	0.9976	-441.938	-435.240	-382.614
18	544853	-93.903	0.9977	-437.351	-430.714	-378.572
19	546796	-94.531	0.9977	-439.204	-432.544	-380.215
20	546856	-96.358	0.9976	-441.068	-434.408	-382.074
21	546189	-98.911	0.9975	-443.201	-436.548	-384.278
22	547330	-100.09	0.9973	-445.099	-438.433	-386.053
23	545581	-109.22	0.9968	-453.127	-446.481	-394.269
Factory	574713	365.27	1	3	10	65

PT-003 MEMScap SP81 R (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	572.11	3.7637	1
25	575.75	3.789	1
Factory	-	-	-

PT-012 MEMScap SP81 R (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	669.14	-8.8701	1
25	671.52	-8.8878	1
Factory	-	-	-

PT-007 MEMScap SP80 D (SS)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	674.06	-20.971	0.9999
25	681.93	-21.256	0.9999
Factory	-	-	-

PT-014 MEMScap SP80 D (Al)

Test#	Slope (psia/V)	Intercept (psia)	R^2
24	661.79	-9.6117	1
25	668.08	-9.676	1
Factory	-	-	-

Data Analysis Summary Chart for All PTs in 152C He

PT-001 Measurement Specialties (SS) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	181	1.6354	0.0004	1.637338	1.641858905	2.127164654
Average	11795.77273	0.424518182	0.999982	1.637	9.947990431	62.3270878
SD	47.47145728	0.479190046	8.33E-05	0.484617	0.498082082	0.634148931
%RSD	0.402444659	112.8785684	0.008332	29.59785	5.006861294	1.017453171

PT-009 Measurement Specialties (Al) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	67	4.5354	0.0004	4.538544	4.545880349	4.603522271
Average	10741.45455	-3.7965	0.999982	4.265	5.584683009	57.18118956
SD	13.07227209	1.372134839	8.33E-05	1.373787	1.377665879	1.409352327
%RSD	0.121699273	-36.14210034	0.008332	32.21073	24.66864953	2.464713201

PT-002 Tecsis (SS) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	487	2.6632	0.0004	2.568181	2.384861535	1.059901936
Average	18465.22727	-0.247504545	0.999964	2.568	10.30605402	64.91927729
SD	140.746365	0.706328181	8.81E-05	0.679222	0.627015225	0.229498985
%RSD	0.762223843	-285.3798826	0.008814	26.44761	6.083950504	0.353514387

PT-010 Tecsis (Al) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	543	3.0158	0.0004	2.91198	2.717898492	1.324007618
Average	19121.63636	0.791877273	0.999981	2.912	11.4392872	65.942293
SD	157.2379625	0.833202011	8.52E-05	0.803074	0.746835017	0.315163048
%RSD	0.822303905	105.2185786	0.008519	27.57826	6.52868491	0.477937654

PT-005 GP50 7900 (SS) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	0.195	17.7235	0.0004	17.75109	17.78895114	18.08639731
Average	19.99822727	-15.54061818	0.999941	16.760	-3.421111635	51.65662998
SD	0.056179042	5.639235467	8.87E-05	5.649792	5.664302435	5.779377807
%RSD	0.280920108	-36.28707302	0.008873	33.71094	-165.5690617	11.18806591

PT-013 GP50 7900 (Al) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	1.991	3.4467	0.0202	3.886294	4.53612248	9.966794162
Average	20.93027273	2.568177273	0.991509	3.886	14.98487058	72.62092926
SD	0.659825058	1.232435744	0.006373	1.389124	1.616537808	3.421306189
%RSD	3.15249145	47.98873337	0.642774	35.74419	10.78779959	4.711184811

PT-007 GP50 189 (SS) 152C He

	Slope (psia/V)	Intercept (psia)	R^2	3 psia	10 psia	65 psia
Range	17285	25.799	0.0055	12.73128	12.71214415	12.56179955
Average	555528.7	-93.18795	0.99866	-442.726	-435.947883	-382.6873411
SD	6855.937289	5.7689341	0.001458	4.084001	4.049297869	3.822634361
%RSD	1.23412837	-6.190643854	0.145949	-0.92247	-0.928849073	-0.998892294

PT-003 MEMScap SP81 R (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	3.64	0.0253	0
Average	573.93	3.77635	1
SD	1.82	0.01265	0
%RSD	0.317111843	0.334979544	0

PT-012 MEMScap SP81 R (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	2.38	0.0177	0
Average	670.33	-8.87895	1
SD	1.19	0.00885	0
%RSD	0.177524503	-0.099673948	0

PT-007 MEMScap SP80 D (SS)

	Slope (psia/V)	Intercept (psia)	R^2
Range	7.87	0.285	0
Average	677.995	-21.1135	0.9999
SD	3.935	0.1425	0
%RSD	0.580387761	-0.674923627	0

PT-014 MEMScap SP80 D (Al)

	Slope (psia/V)	Intercept (psia)	R^2
Range	6.29	0.0643	0
Average	664.935	-9.64385	1
SD	3.145	0.03215	0
%RSD	0.472978562	-0.333373082	0

Reference

[1]Oltman, S., "LAVA PT Trade Study," NASA NIFS Report, 2016.