Fermilab

Particle Physics Division

Mechanical Department Engineering Note

Number: MD-ENG-255 Date: 11/15/2010

Project: CMS Pixel Detector Mechanical Upgrade

Project Internal Reference:

Title: Thermal Testing on Thermflow Adhesive Tape

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Key Words: Thermal, Testing, Adhesive

Abstract/Summary:

A phase-change thermally conductive tape with a claimed lower thermal resistance was tested according to the ASTM D 5470 Standard. Results were found not quite agreeable.

Thermal Testing on Thermflow Adhesive Tape

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7/7/2010

Introduction:

Chomerics is a leading global manufacturer of EMI (electromagnetic interference) shielding materials. Many kinds of adhesives are developed for this industry and one of the attractive product appears to be the thermally conductive tape – Thermflow. Thermflow is basically a phase-change thermal interface material combining the consistency and ease of use of elastomeric pads with the low thermal impedance of thermal grease. Heating to about 50 ~ 60C is needed for curing so that the adhesive will be molten and hence fills up the tiny irregular voids at the interface effectively. This will result a lower thermal resistance path and thus maximizes heat sink. LHCb has tried to use it on its VELO silicon sensors and is satisfied on its performance. However, a thermal test on the Thermflow tape to measure the thermal properties has not been done. An attempt to measure the thermal properties on this material and compare to what the manufacturer's data was thus conducted.

Samples Preparation:

Free samples of Thermflow T710 and T725 were received. Their typical properties were as shown in Table 1. LHCb uses T710 because of lower phase change temperature. The Thermflow tape came with the release liner and carrier strip. After cutting the tape in right size (1 1/8" x 1/2"), the release liner and carried strip were carefully removed and attached to the cleaned surface of the brass calorimeters. Weights corresponding to 10, 25 and 50 psi on the calorimeter cross-sectional area were then applied on top. The whole set up was then heated up to 60C inside an oven for at least 30 minutes then let cooled gradually at room temperature. Excess adhesive that oozed out from the interface was trimmed off and the whole sample was ready for testing.

	Typical Properties	T710 with PSA	T725
Physical	Color	Light gray / off-white	Pink
	Carrier	2 mil Fiberglass	None - Free Film
	Standard Thicknesses, mm (in)	0.138 (0.0055)	0.125 (0.005)
	Specific Gravity	1.15	1.1
	Phase Transition Temperature, °C	45	55
	Weight Loss, 125°C for 48 Hours	<0.5%	<0.5%
Thermal	Thermal Impedance @ 70°C, °C-cm²/W (°C-in²/W)		
	@ 69 kPa (10 psi)	1.48 (0.23)	0.71 (0.11)
	@ 172 kPa (25 psi)	1.03 (0.16)	0.39 (0.06)
	@ 345 kPa (50 psi)	0.77 (0.12)	0.26 (0.04)

Table 1 Properties of Thermflow Tape for Testing

Apparatus:

The thermal tests were conducted using the technique described by the ASTM D5470 , Standard Test Method for Thermal Transmission Properties of Thermally Conductive Electrical Insulation Materials. Referring to this testing standard, two brass calorimeters with dimensions 1 1/8” x 1/2” were used. The end surfaces were machining-finished in order to get a smooth square cut. Two holes on each calorimeter were drilled and they were used to embed the RTDs completely. In addition, a glass fudicial was glued on each bar, and the distance between the calorimeters was measured using Coordinate Measuring Machine (CMM) 3 times in order to calculate the adhesive thickness. The calorimeter assembly was housed within a machined high density foam under CMM and its corresponding picture around the interface were shown in Figure 1 and 2.

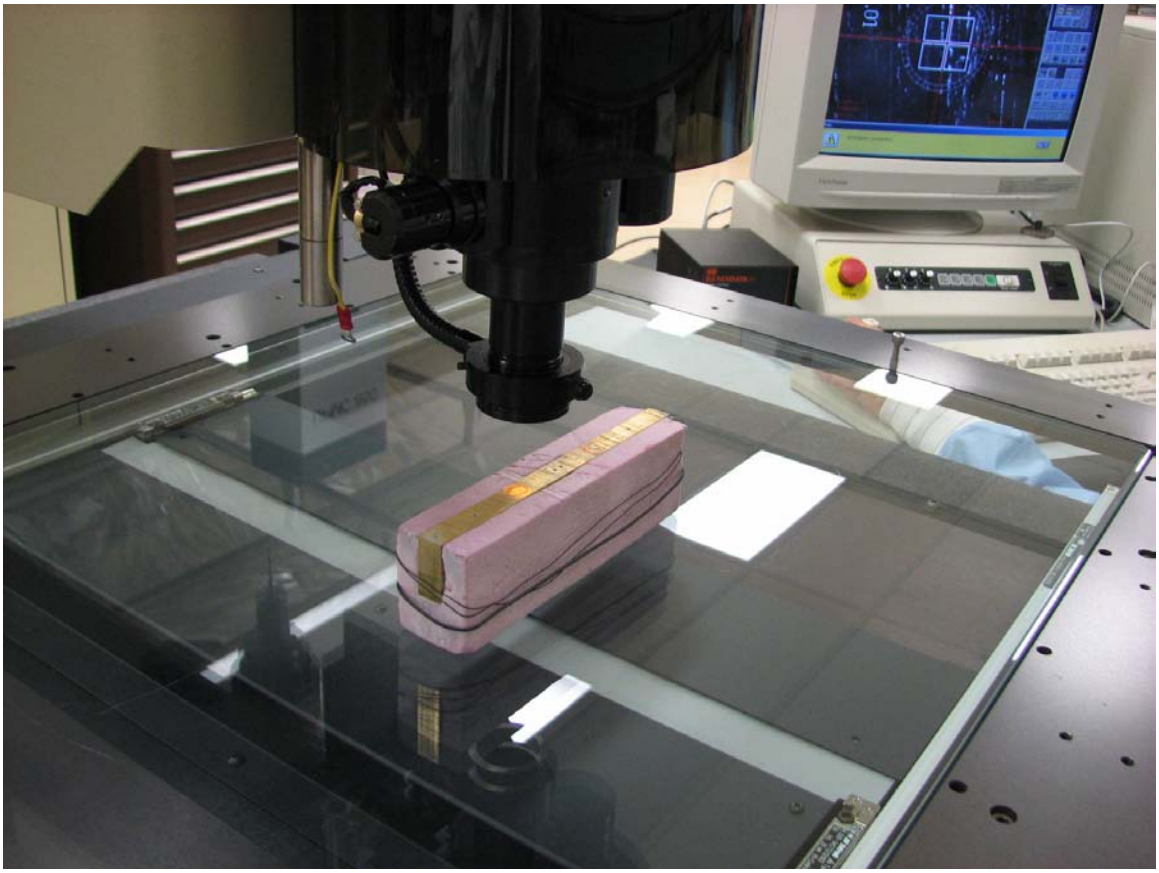

Figure 1 Calorimeter Assembly on CMM Table

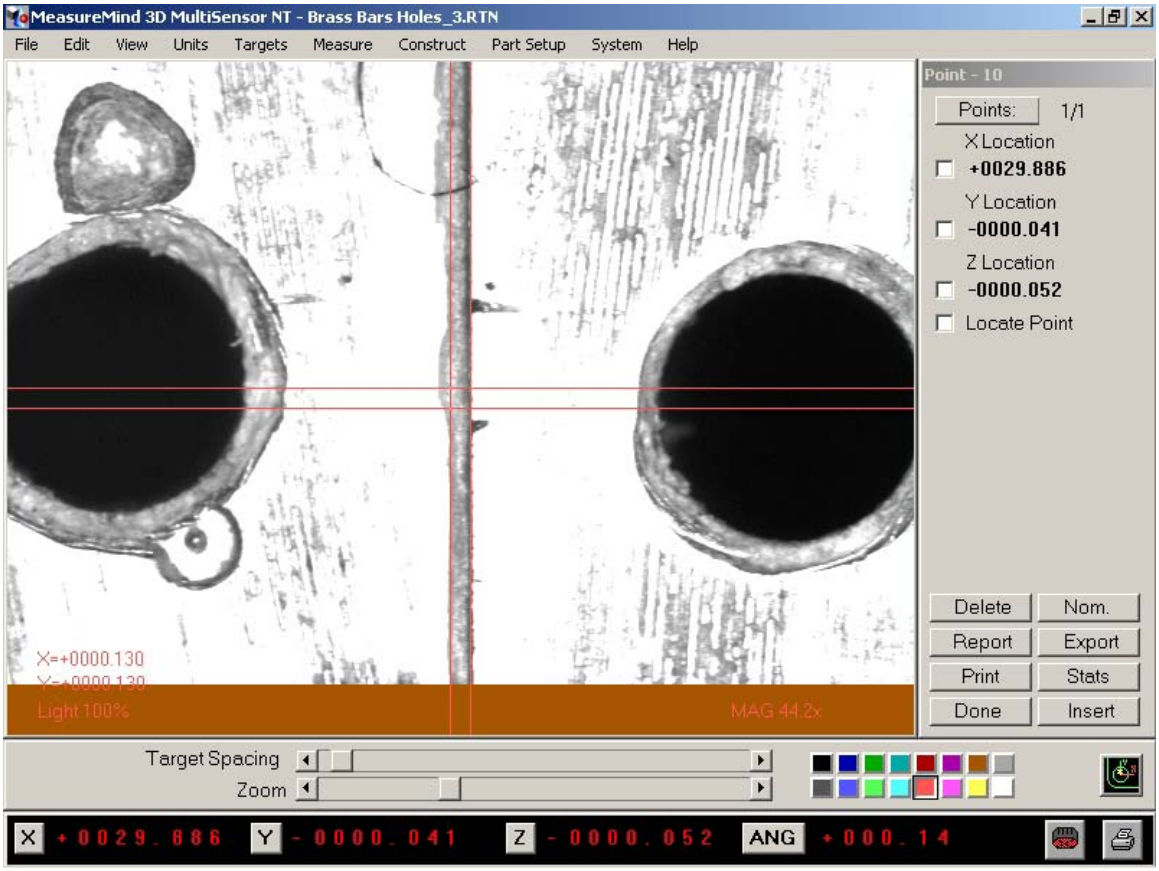

Figure 2 Image of Tape Interface and Near By Drilled Holes

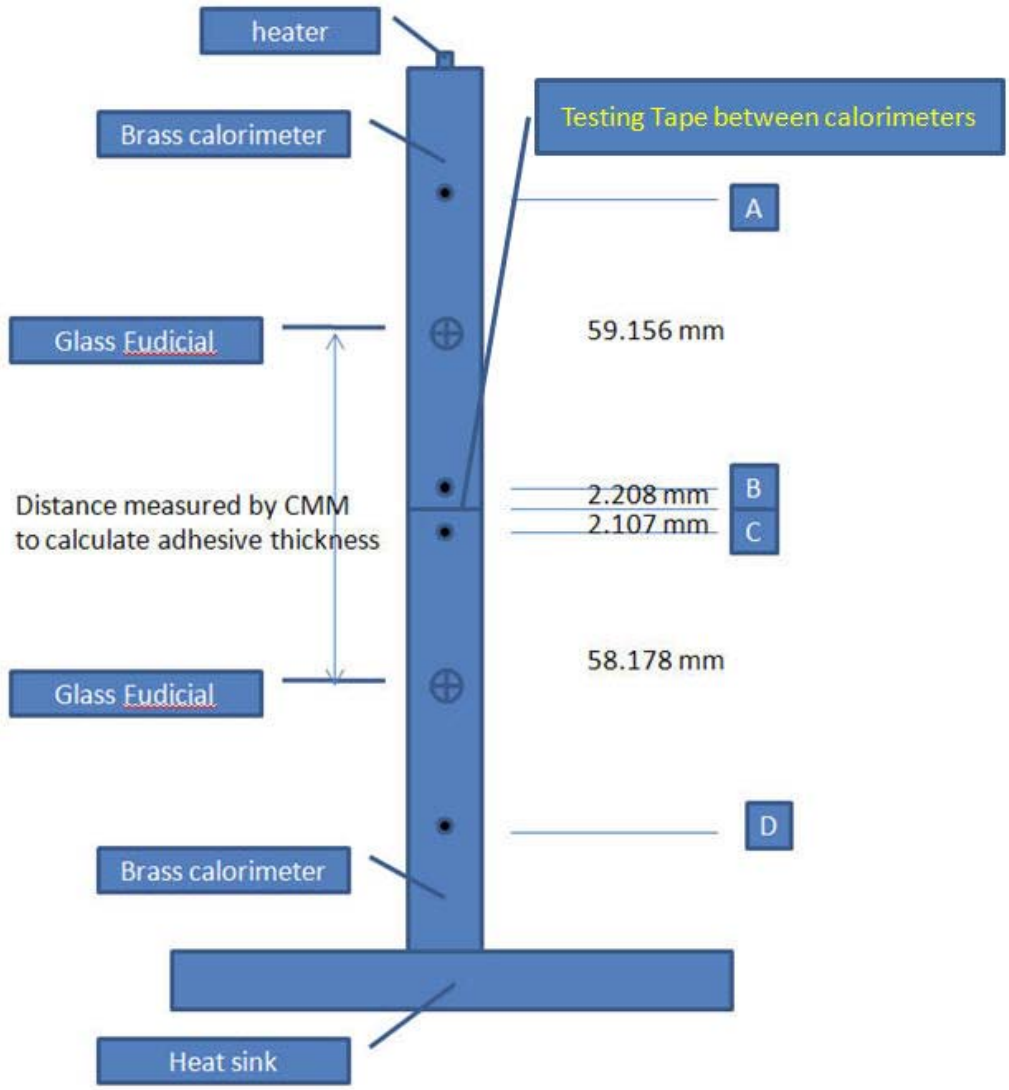

Figure 3 Basic Test Set Up

As shown in Figure 3, these two calorimeters were then stacked up vertically after the adhesive tape was glued in between. A 50-ohm resistance heater was glued on top of the calorimeter assembly while the bottom was kept in contact with a heat sink surface which was cooled by a chiller. After all four RTDs were inserted carefully in their hole positions, the whole setup was thermally insulated to minimize the impact from the environment as shown in Figure 4. Similar weights corresponding to 10, 25 and 50 psi on the calorimeter cross-sectional area were then carefully applied on the top surface of the upper calorimeter. Since this was an unstable setup with so many weights on top of a small surface, a safety plate being hung from the

ceiling was used. This safety plate was carefully set with no tension on the rope so that all weights were basically applied on the calorimeter assembly.

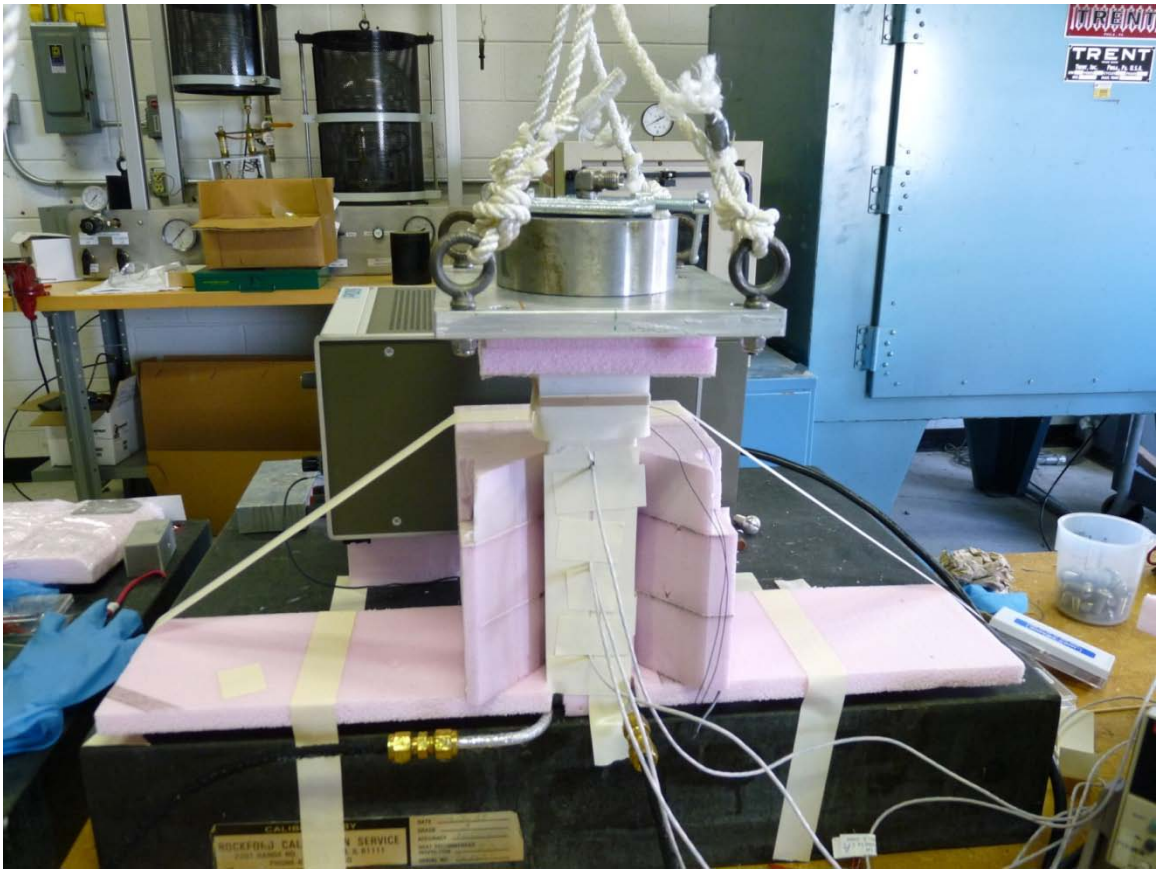

Figure 4 Test Set Up with Insulation and Weight on Top

Test:

The RTD's measurements were made with 4 wire configuration in order to eliminate any error from the lead wire resistance. Before the test, all RTDs were immersed in the chiller bath and calibrated. As shown in Table 1, it appeared that only the RTD that was located near the end of cold plate was about 0.6C lower than the others and needed to be adjusted. The actual resistance of the heater was also measured. Constant voltage of 12.54 V was supplied by a Hewlett-Packard 6114A precision power supply and the RTD's temperature were recorded by a Keithley 2700 multi-meter system with a module 7702 connecting to all RTDs. After all the temperatures readings were stable at equilibrium with 2 sets of data taken at 5 minute intervals differed by less than +/- 0.1C, last set of temperature readings was used for further calculations. The thermal gradients dT/dL of the upper and

lower calorimeters was then computed. As shown in Figure 5, the temperatures at interface were then derived using a mean dT/dL by extrapolations. The corresponding thermal properties of the adhesive tape were then calculated. Tests were repeated with and without the weights on top to verify if significant differences would be resulted.

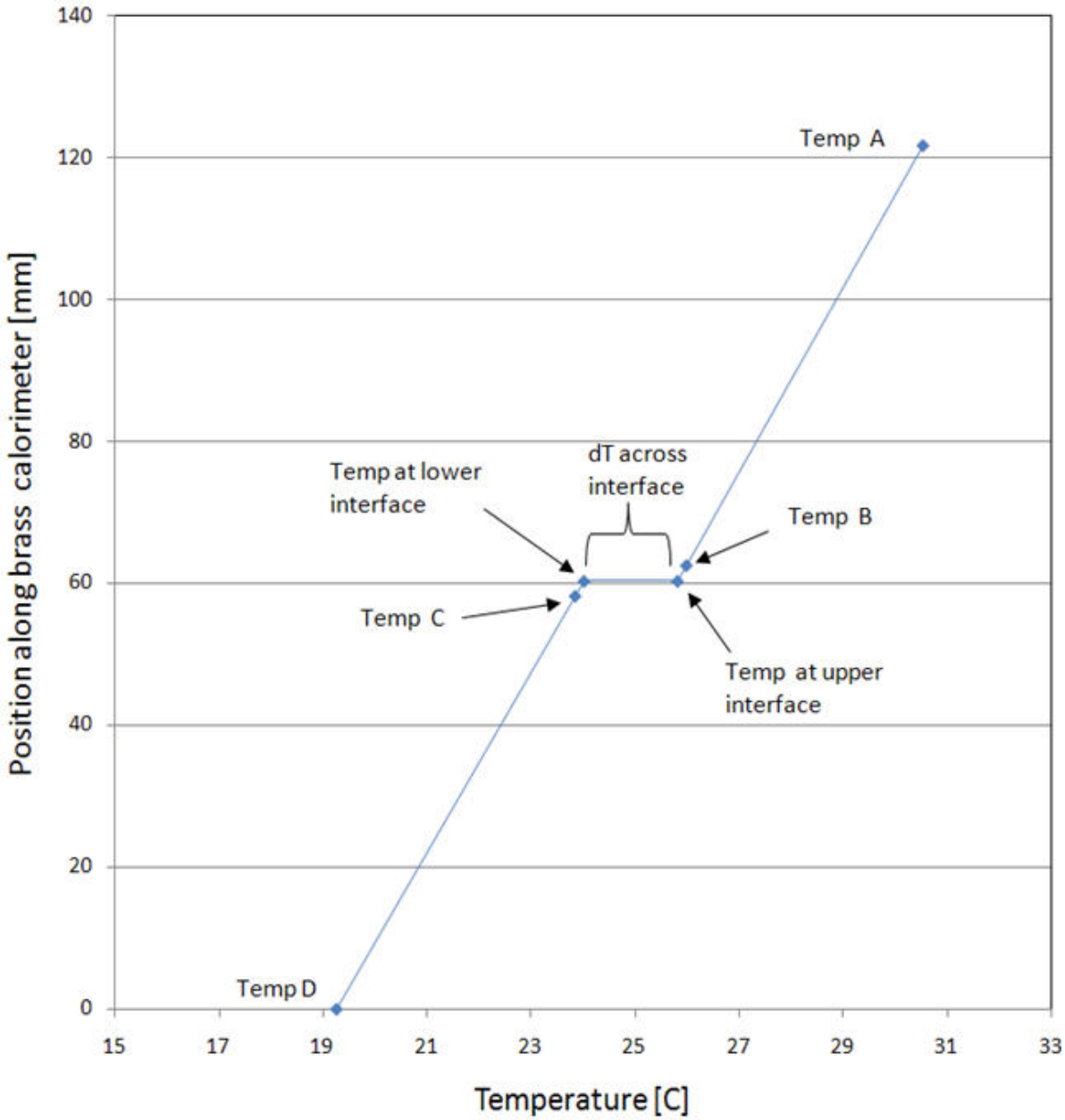

Figure 5 Computation of the Temperature Gradient across Interface

Chiller temp	18	20	22	24	26	28	30	32	
RTD A	18.15	20.17	22.12	24.11	26.06	28.02	30.01	32	
RTD B	18.14	20.17	22.12	24.11	26.05	28.02	30	32	
RTD C	18.14	20.17	22.12	24.11	26.06	28.02	30.01	32	
RTD D	18.08	20.12	22.05	24.05	26	27.95	29.95	31.94	
RTD ROOM	18.1	20.15	22.09	24.06	26.03	27.98	29.98	32	
Median	18.14	20.17	22.12	24.11	26.05	28.02	30	32	
Delta temp	18	20	22	24	26	28	30	32	Adjustment
RTD A	-0.01	0	0	0	-0.01	0	-0.01	0	0
RTD B	0	0	0	0	0	0	0	0	0
RTD C	0	0	0	0	-0.01	0	-0.01	0	0
RTD D	0.06	0.05	0.07	0.06	0.05	0.07	0.05	0.06	0.06
RTD ROOM	0.04	0.02	0.03	0.05	0.02	0.04	0.02	0	0.025

Table 2 Calibration Results of RTDs

The thermal impedance (R) and conductivity (k) are calculated from the following equations:

$$R = A * \Delta T / Q \quad \textit{and}$$
$$k = t/R$$

where:

- *R is the calculated thermal impedance in °C*mm2/W*
- *ΔT is the temperature difference across the sample thickness, in °C*
- *A is the cross-sectional area of the calorimeter, in mm2*
- *Q is the thermal power (voltage*current), in watts*
- *k is the thermal conductivity in W/mm°C*
- *t is the thickness of the sample in mm*

The results of the test were shown in Table 3.

Summary of Thermflow Test

Heat resistance, ohm	51
Current, A	0.242
DC Voltage supplied, V	12.49
Power, W	3.02
Area of calorimeter brass bar, mm^2	363.22
Distance btw RTD A & B, upper calorimeter, mm	58.16
Distance btw RTD C & D, lower calorimeter, mm	58.18
Distance btw RTD B & interface, mm	2.21
Distance btw RTD C & interface, mm	2.14

T725 Thermflow

Curing P, psi	10	25	50	10	25	50
Testing P, psi	0	0	0	10	25	50
Temp, room	24.79	26.49		24.35	26.76	
Temp at A, C	30.54	30.01	29.83	30.06	29.66	29.71
Temp at B, C	25.99	25.31	25.25	25.47	24.94	25.11
Temp at C, C	23.85	23.36	24.28	23.33	23.12	24.11
Temp at D, C	19.26	18.62	19.67	18.66	18.32	19.470
Temp at interface, upper =	25.82	25.13	25.08	25.29	24.76	24.93
Temp at interface, lower =	24.02	23.53	24.45	23.50	23.29	24.28
Temp drop acroos interface	1.80	1.60	0.63	1.79	1.47	0.65
Calculated thermal k of upper brass calorimeter	106.37	102.97	105.67	105.44	102.54	105.21
Calculated thermal k of lower brass calorimeter	105.48	102.14	105.02	103.68	100.87	104.35
Thermal impedance, calculated, C*cm^2/W	2.161	1.919	0.753	2.156	1.763	0.787
*Thermal impedance, claimed, C*cm^2/W*	*0.71*	*0.39*	*0.26*	*0.71*	*0.39*	*0.26*
Adhesive thickness, mm	0.084	0.055	0.012	0.084	0.055	0.012
Calculated apparent thermal k, W/mK =	0.390	0.285	0.155	0.391	0.310	0.148

T710 Thermflow

Curing P, psi	10	25	50	10	25	50
Testing P, psi	0	0	0	10	25	50
Temp, room	26.35	24.95	23.8	27.43	25.28	22.67
Temp at A, C	30.2	31.8	29.25	30.18	29.95	29.39
Temp at B, C	25.52	27.25	24.58	25.48	25.3	24.66
Temp at C, C	23.86	25.51	22.7	23.83	23.54	22.87
Temp at D, C	19	20.91	17.95	18.93	18.75	18.07
Temp at interface, upper =	25.34	27.08	24.40	25.31	25.12	24.48
Temp at interface, lower =	24.04	25.68	22.87	24.00	23.71	23.04
Temp drop acroos interface	1.30	1.40	1.53	1.31	1.41	1.43
Calculated thermal k of upper brass calorimeter	103.41	106.37	103.63	102.97	104.08	102.32
Calculated thermal k of lower brass calorimeter	99.62	105.25	101.93	98.81	101.08	100.87
Thermal impedance, calculated, C*cm^2/W	1.559	1.680	1.836	1.577	1.691	1.723
*Thermal impedance, claimed, C*cm^2/W*	*1.48*	*1.03*	*0.77*	*1.48*	*1.03*	*0.77*
Adhesive thickness, mm	0.025	0.035	0.030	0.025	0.035	0.030
Calculated apparent thermal k, W/mK =	0.163	0.208	0.162	0.161	0.207	0.172

Table 3 Test Results of T725 and T710 Thermflow

Discussion and Conclusion:

All the computed results of the thermal impedance were higher than what the vendor claimed. Any possible errors in this experiment could be made were carefully checked and none of them could be that huge to create such discrepancies. For instances, all the results with weights on top or not during the data taking phase were not much different. All RTDs were calibrated and they were basically agreed with each other so any error due to temperature measurement was unlikely either. Based on the voltage and current measurements, the power input was 3.02 W. It basically agreed with the resistance that was measured before the experiment. Theoretically speaking, it was possible that a small quantity of this heat amount generated from the heater might leak to the surrounding although insulation materials were used, but it would not help in getting a lower value of thermal

impedance even if some compensation amount was used in the computation. The CMM measurements were very accurate, any error larger than 10 microns was unlikely and this would not lead to any significant changes in calculating the thermal impedances. To compute the thermal conductivity values, the thickness of the tape is needed. Since the tape was very thin, this measurement is thus very sensitive in obtaining the thermal conductivity results. It should be noted that this number calculated using the above-mentioned equations included the thermal resistances at the interfaces, therefore, it would be just the apparent thermal conductivity and the true value of thermal conductivity of the tape would be somewhat higher than this.