# THERM-A-GAP™ PAD 60 Test Report

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**Executive Summary**

THERM-A-GAP™ PAD 60 is a soft, highly reliable, high-performance 6.0 W/m-K thermally conductive pad.

This document outlines the examination of the thermal reliability of this silicone-based gap filler pad after being subjected to long-term environmental aging.

The thermal performance of THERM-A-GAP™ PAD 60 was examined after being subjected to multiple environmental stress tests. The thermal impedance of the aged samples did not experience a significant increase after any of the treatments studied.

Samples were subjected to 1000-hour dwell at 125°C, 1000-hour dwell at 85°C/85% relative humidity, and a combined stress of thermal shock at -40°C to 80°C, thermal cycling at -40°C to 80°C, and random vibration frequencies equivalent to 2.0 GRMS. In all cases, there was no statistically significant increase in impedance according to one-way ANOVA with the Tukey method for multiple comparisons.

Based on these results, THERM-A-GAP™ PAD 60 demonstrates the ability to withstand long-term aging without a reduction in thermal performance.

## 1.0 Introduction

The purpose of this document is to examine the thermal reliability of this high-performance thermal pad. Samples of production-scale batches were subjected to long-term aging conditions, and the thermal performance was measured over time.

Successful survival of long-term aging is demonstrated by a lack of statistically significant increase in thermal impedance of the reliability fixtures after the full aging duration. The reliability fixtures comprise PAD 60 sandwiched between two stainless-steel coupons, with thickness set by PTFE spacers.

It is worth noting that the exact impedance value of the reliability fixture is not representative of the impedance value of the thermal interface material itself, but it can be used to measure changes to thermal performance over time.

## 2.0 Long-Term Aging – Thermal Impedance

### 2.1. Purpose

Long-term aging was performed on PAD 60 between stainless-steel substrates to evaluate the reliability of thermal performance over time. The material was subjected to an extended dwell time of 1000 hours at 125°C, and long-term heat and humidity aging at 85°C and 85% relative humidity.

### 2.2. Materials

2.2.1. 1” x 1” x 0.040” 316 stainless-steel coupons.
2.2.2. PTFE spacers, 0.040” thick.
2.2.3. LongWin9389 Thermal Impedance Tester
2.2.4. THERM-A-GAP™ PAD 60 at 0.100” thickness

### 2.3. Sample Preparation

2.3.1. Samples were cut to 1” x 1” squares and installed onto the center of the stainless-steel coupons.
2.3.2. The 0.040” PTFE shims were placed at each corner of the coupon and fastened into place to maintain of 1mm gap.
2.3.3. The above procedure was performed for all four sample assemblies.

### 2.4. Test Procedure

2.4.1. One drop of 500 cSt silicone oil was applied by pipette to the outside of each stainless-steel substrate.
2.4.2. The samples were tested initially for thermal impedance at 50°C and 20 psi per ASTM D5470.
2.4.3. After testing each assembly, the silicone oil was gently removed from the surfaces.

2.4.4. Four assemblies were subjected to each aging condition:

2.4.4.1. Dry heat aging: oven at 125°C.

2.4.4.2. Heat/humidity aging: humidity chamber at 85°C, 85% relative humidity.

2.4.5. After 500 hours of dry heat or heat/humidity aging the samples were removed from their respective environments, allowed to equilibrate at room temperature for at least two hours, and re-tested for thermal impedance.

2.4.6. Once tested, the samples were returned to their respective aging environments and the tested again after the samples were subjected to a total of 1000 hours of dry heat or heat/humidity aging.

## 2.5. Results

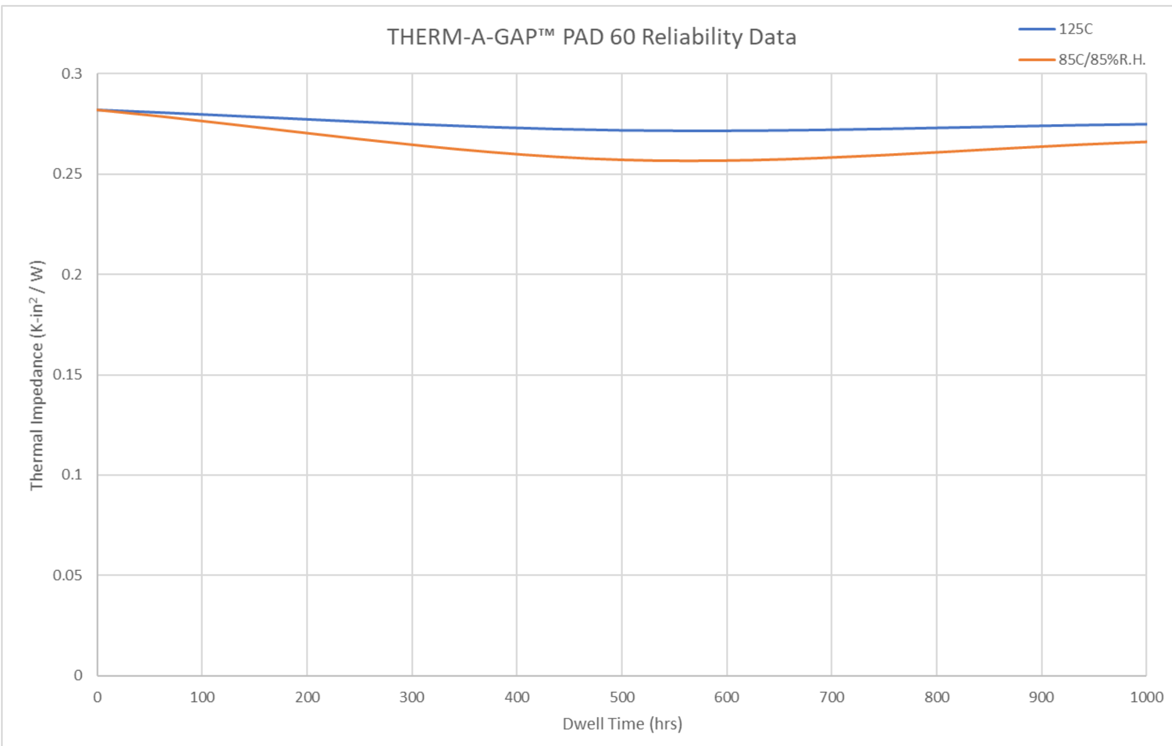



*Figure 1: Dry heat aged and heat & humidity aged thermal impedance versus time*

| | Thermal Impedance (K-in$^2$/ W ) | | |
|---|---|---|---|
| | Initial | 500hrs | 1000hrs |
| 125°C | 0.282 | 0.272 | 0.275 |
| 85°C/85%R.H. | 0.282 | 0.257 | 0.266 |

*Table 1: Thermal Impedance Results (average)*

## 3.0 Long Term Aging - Compression-Deflection Force

### 3.1. Purpose

This test is intended to provide data on the deflection force recorded from compressing THERM-A-GAP™ PAD 60 after it is subjected to long-term aging.

### 3.2. Materials

3.2.1. TA-XT Plus Texture Analyzer

3.2.2. 0.5” diameter THERM-A-GAP™ PAD 60 disks at 0.100” thickness

### 3.3. Test Procedure

3.3.1. Four 0.5” diameter disks of THERM-A-GAP™ PAD 60 were subjected to each stress environment, as detailed in section 2.0.

3.3.2. The samples were tested initially for compression-deflection, up to a 70% deflection rate, using a 0.025 in/min compression speed.

3.3.3. The samples were tested again at 1000 hours for their respective stress environments.

### 3.4. Results

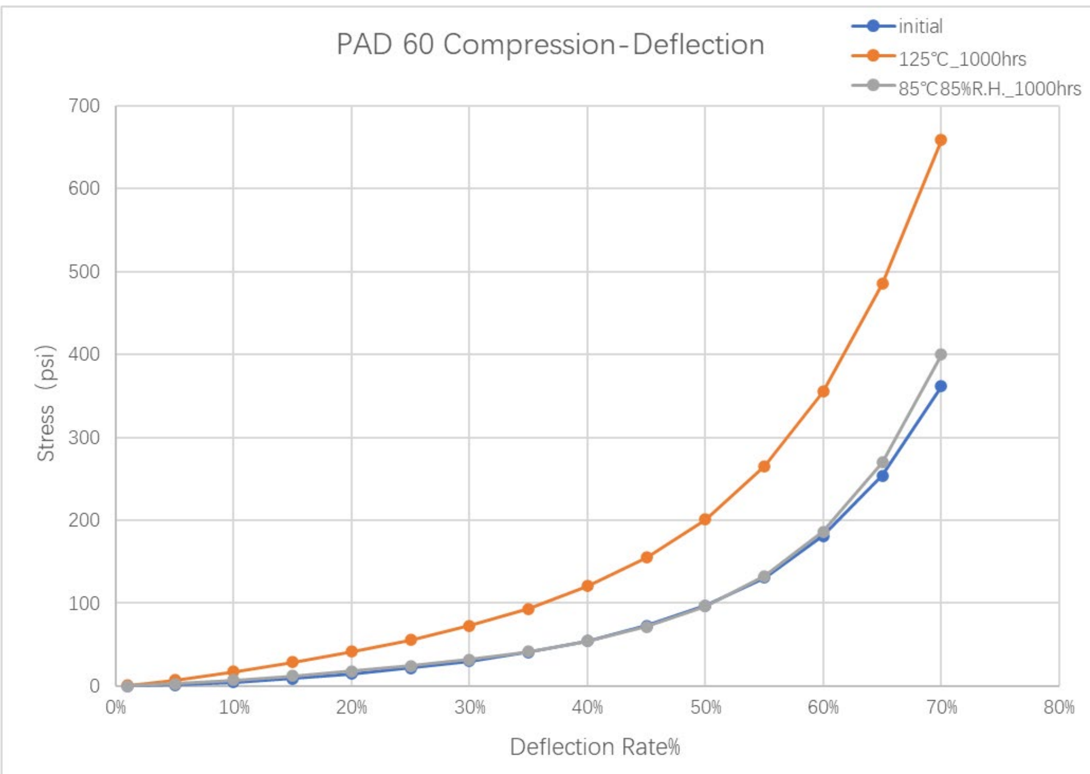



*Figure 2: Compression-deflection curves for THERM-A-GAP™ PAD 60 after long-term aging.*

## 4.0 Total Mass Loss

### 4.1. Purpose

This test is intended to provide data on the volatile silicone content of THERM-A-GAP™ PAD 60. Volatile silicone is of concern due to its ability to migrate and cause problems in electronics applications. The material was tested by thermogravimetric analysis (TGA) and by an independent outside laboratory.

### 4.2. Materials

4.2.1. TA Instruments Thermogravimetric Analyzer.
4.2.2. Small sample of PAD 60.

### 4.3. Test Procedure

4.3.1. A small amount of PAD 60 was placed onto a TGA test aluminum dish.
4.3.2. The sample was subjected to 125° C for three hours in a nitrogen environment and the sample weight loss was recorded.

### 4.4. Results

PAD 60 experienced a total mass loss of 0.034 % after a 3-hour dwell at 125°C.

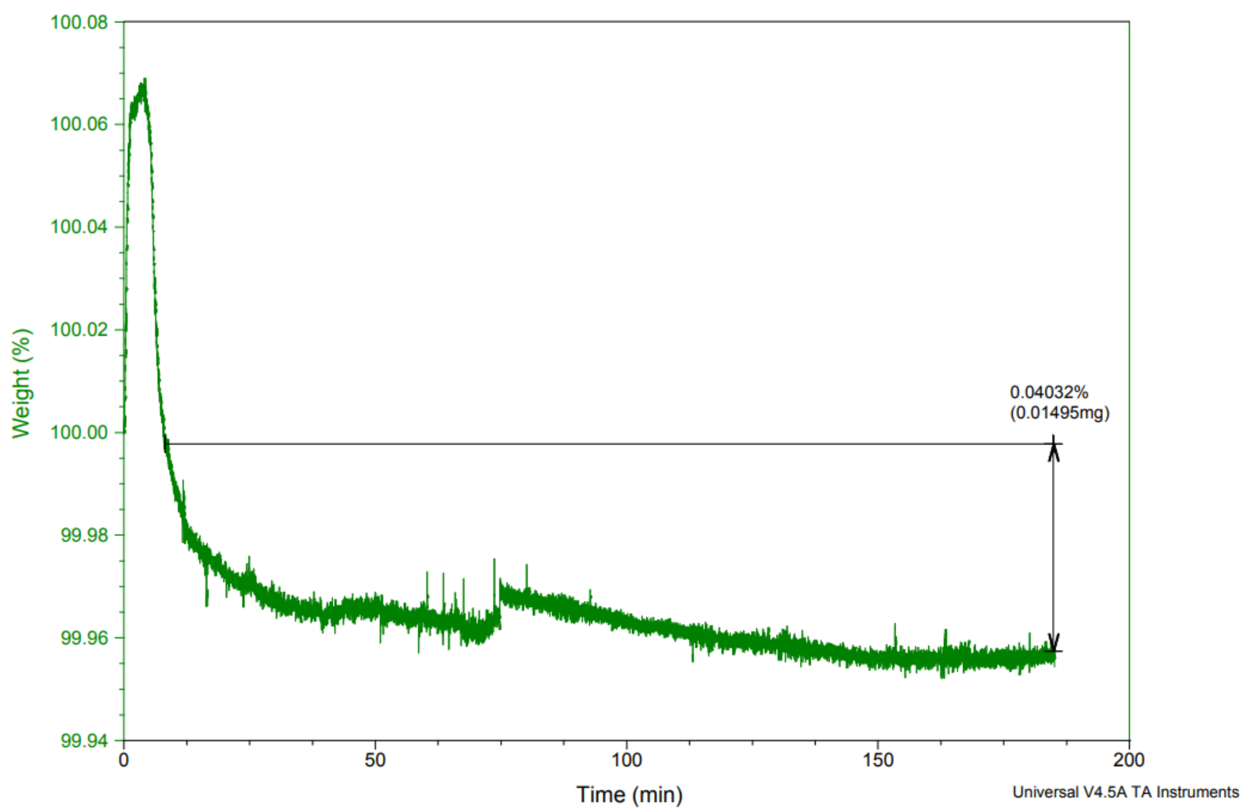



*Figure 3: Thermogravimetric Analysis of PAD 60 at 125°C for 3 hours*

The National Aeronautics & Space Administration (NASA) criteria for low-volatility materials limits the total mass loss (TML) to 1.0% and collected volatile condensable material (CVCM) to 0.10%.

| Outgassing Results | |
|---|---|
| % Total mass loss | 0.05 |
| % CVCM | 0.02 |

*Table 2: Independent laboratory outgassing test results*

Based on the independent laboratory results, PAD 60 passes the NASA outgassing criteria for low-volatility material.

## 5.0 Thermal Shock, Thermal Cycling & Random Vibration Testing

### 5.1. Purpose

This test is intended to provide data on the long-term aging and durability of THERM-A-GAP™ PAD 60 when subjected to Air-to-Air Thermal Shock (TS), followed by Power Thermal Cycling (PTC), and finishing with Random Vibration.
These test methods adhere to the GMW3172 specification for Electronical/Electronic (E/E) components for passenger or commercial vehicles and trucks based on mounting location.

### 5.2. Materials

5.2.1. Espec Thermal Shock Chamber
5.2.2. Power Temperature Cycle Chamber
5.2.3. Vibration Chamber
5.2.4. LongWin9389 Thermal Impedance Tester
5.2.5. THERM-A-GAP PAD 60 at 0.100” thickness

### 5.3. Sample Preparation

5.3.1. Three samples were prepared according to IEC 60068-2-64 with a set gap thickness of 0.040”.

### 5.4. Test Procedure

5.4.1. The three samples were tested initially for thermal impedance at 50°C and 20 psi per ASTM D5470.

5.4.2. *Thermal Shock Air-to-Air Testing:* Samples were subjected to the below settings (see Figure 4 for additional details):

- Temperature Min / Max: -40°C / 85°C
- Dwell Time: 15 minutes
- Number of Cycles: 632

5.4.3. After being subjected to the above settings, the samples were tested again for thermal impedance.

5.4.4. *Power Temperature Cycle Testing:* Samples were then subjected to the below settings (see Figure 5 for additional details):

- Temperature Min / Max: -40°C / 85°C
- Dwell Time: 15 minutes
- Ramp Rate: 1°C/min
- Number of Cycles: 211

5.4.5. After being subjected to the above settings, the samples were tested again for thermal impedance.

5.4.6. *Random Vibration Frequency Testing:* Samples were subjected to the settings detailed in Figure 7. These settings were performed for the X, Y and Z direction – each for 8 hours – for an effective acceleration of 19.6 $m/s^2$ = 2.0 GRMS.

5.4.7. After being subjected to the above settings, the samples were tested again for thermal impedance. The results can be seen on

## 5.5. Results

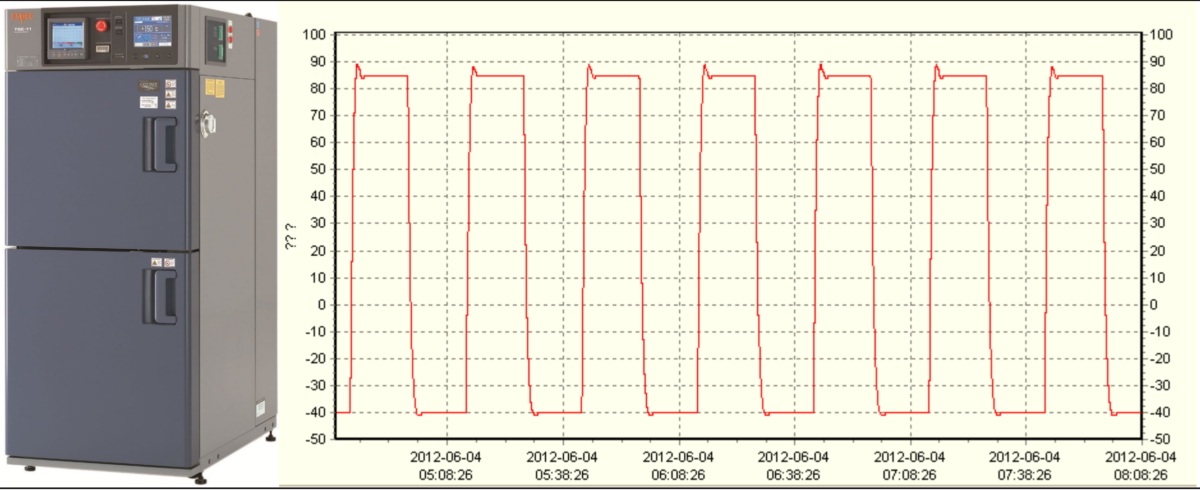



*Figure 4: Espec thermal shock chamber and temperature curve.*

*Thermal Shock Air-to-Air (TS) transfers samples from one oven to another with a set amount of time in each oven. This rapid transfer (~30 second transfer time) allows samples to quickly reach the desired temperature.*

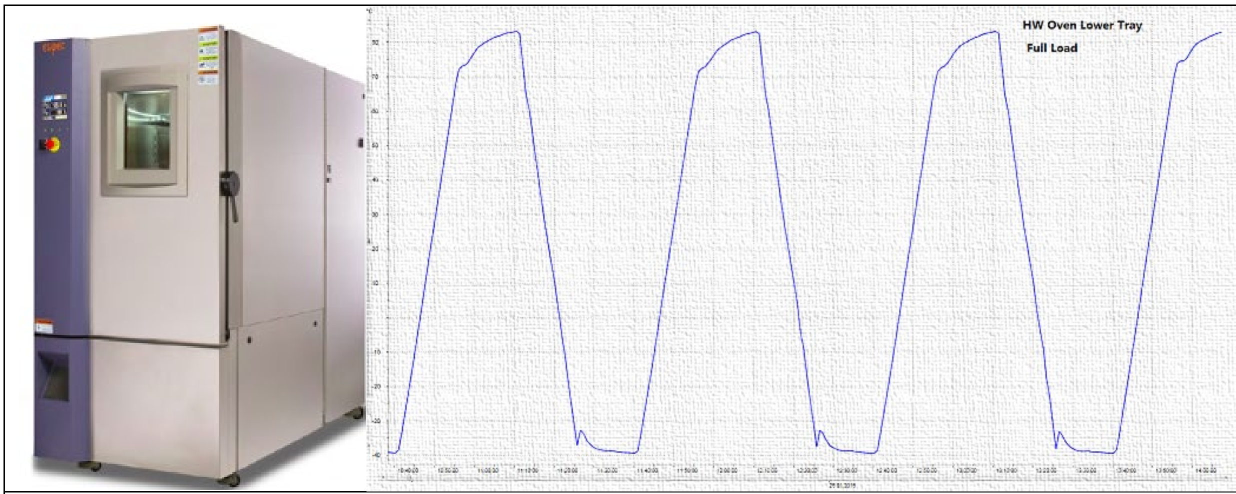
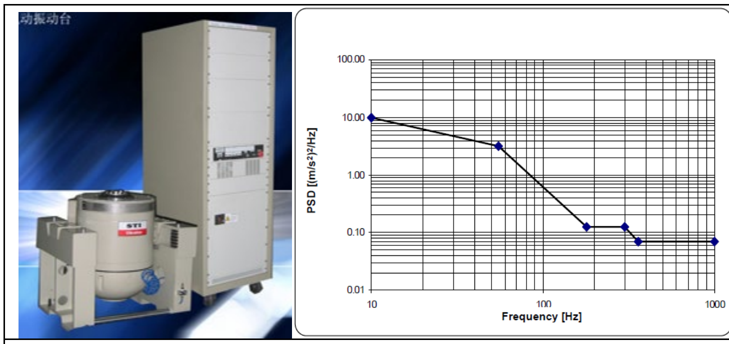



*Figure 5: Espec temperature cycling chamber and temperature curve.*

*Power Temperature Cycle (PTC) is a single-oven chamber that ramps the internal temperature up/down at a specified speed to a set min/max temperature.*

| Code Letter For Temperature | Location In The Vehicle | Combined Number of TS + PTC Cycles | Number Of TS Cycles | Number Of PTC Cycles |
|---|---|---|---|---|
| A, B, C, and D | Inside the passenger compartment, luggage compartment, or attached to the exterior of the vehicle but not under the hood or above the exhaust system | 843 | 632 | 211 |
| E and F | Under the hood of the vehicle | 1236 | 927 | 309 |
| G, H, and I | Attached to or inside the engine (total cycles = 2248) | 1248 | 1000 | 248 |
| | | Cyclic Humidity and Constant Humidity | | |
| | | 1000 | 1000 | 0 |

*Figure 6: Number of TS and PTC cycles Per GMW 3172 9.4.2 Table 33.*




| Fre-quency | Power Spectral Density | |
|---|---|---|
| 10 Hz | 9.9069 $(m/s^2)^2/Hz$ | = 0.1032 $G^2/Hz$ |
| 55 Hz | 3.2245 $(m/s^2)^2/Hz$ | = 0.0336 $G^2/Hz$ |
| 180 Hz | 0.1238 $(m/s^2)^2/Hz$ | = 0.0013 $G^2/Hz$ |
| 300 Hz | 0.1238 $(m/s^2)^2/Hz$ | = 0.0013 $G^2/Hz$ |
| 360 Hz | 0.0695 $(m/s^2)^2/Hz$ | = 0.0007 $G^2/Hz$ |
| 1000 Hz | 0.0695 $(m/s^2)^2/Hz$ | = 0.0007 $G^2/Hz$ |

*Figure 7: Vibration equipment, test parameters and profile settings*

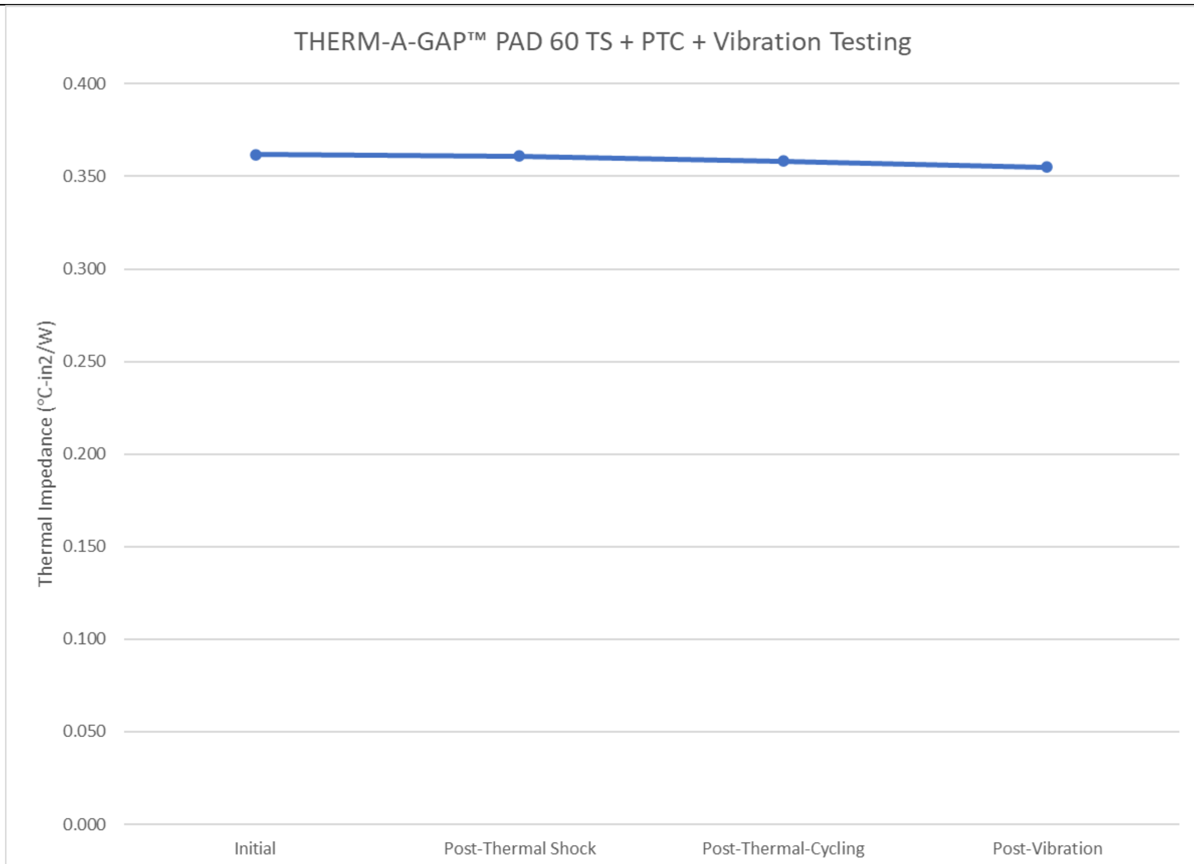



*Figure 8: PAD 60 Thermal Shock, Thermal Cycling and Random Vibration Test Results*

| | Initial | Post-Thermal Shock | Post-Thermal-Cycling | Post-Vibration |
|---|---|---|---|---|
| Thermal Impedance ( -in2/W) | 0.362 | 0.361 | 0.358 | 0.355 |

*Figure 9: Thermal Impedance results (average)*

Note: The exact impedance value of the reliability fixture is not representative of the impedance value of the thermal interface material itself, but it can be used to measure changes to thermal performance over time.

## 6.0 Results

To summarize the above results, THERM-A-GAP™ PAD 60 is highly reliable after long-term aging in multiple environments.

The mean impedance values after dry heat aging, heat and humidity aging, and thermal shock + thermal cycling + random vibration aging saw a decrease of 2.5%, 5.7% and 1.9% from initial.

A decrease in thermal impedance indicates an improved thermal performance post-stress. This can likely be attributed to an enhanced wetting at the interface between the thermal pad and the substrate.

In addition, the physical and chemical properties of the pad remained unchanged as we see an outgassing result of 0.04% and minimal change in deflection force within the compression ranges recommended for application.

The results of this study provide evidence that PAD 60 maintains reliability after long-term aging.