THERM-A-GAP™ GEL 50VT Reliability Report

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Executive Summary

THERM-A-GAP™ GEL 50VT is a high performance, one-component, silicone, dispensable thermal interface gel material with 5.2 W/m-K thermal conductivity. It was developed to conduct heat from electronics to heat sinks or enclosures and perform reliably in vertical, high vibration, and harsh environments. 50VT is meant to support mission critical applications that rely on consistent thermal performance over the course of hundreds or thousands of cycles and many years of continuous operation. THERM-A-GAP™ GEL 50VT requires no mixing or curing and is designed for easy application and rework. It can be dispensed at various bond line thicknesses to take up gaps created by assembly or manufacturing tolerances. This document outlines the examination of the thermal reliability of this high-performance gap filler after being subjected to long-term environmental aging under dry heat, heat & humidity conditions, and temperature cycling from -40°C to 125°C.

The thermal performance of THERM-A-GAP™ GEL 50VT 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. After 1000-hour dwell at 125°C, 1000 hours at 85°C/85% relative humidity, and 1000 temperature cycles from -40°C to 125°C, there was no statistically significant increase in impedance according to one-way ANOVA with the Tukey method for multiple comparisons. The mean value for thermal impedance decreased slightly for each aging treatment, indicating an improvement in thermal performance. This improvement can likely be attributed to enhanced wetting at the interface between the gel and the reliability fixture.

Based on these results, THERM-A-GAP™ GEL 50VT 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 gel. 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 of GEL 50VT dispensed and compressed 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 rather can be used as a proxy to measure changes to thermal performance over time as a result of aging under various test conditions.

2.0 Long-Term Aging

2.1. Purpose

Long term aging was performed on GEL 50VT between aluminum nitride substrates to evaluate the thermal performance reliability over time. The material was subjected to an extended dwell time of 1000-hrs at 125ºC, prolonged temperature cycling from -40°C to 125°C, and long-term heat and humidity aging at 85ºC/85% relative humidity. Three samples were prepared for each long-term aging criteria.

2.2. Materials

2.2.1. Eighteen 1” x 1” x 0.040” 316 stainless-steel coupons
2.2.2. PTFE shims, 0.040” thick
2.2.3. Eighteen clamps
2.2.4. Russells Humidity Chamber GD-16-3-3-AC
2.2.5. Sun Electronics Systems PTL-001 Temperature Cycling System
2.2.5. Blue-M B-2730-Q Oven

2.3. Sample Preparation

2.3.1. GEL 50VT was dispensed onto the center of a stainless-steel coupon.
2.3.2. The 0.040” PTFE shims were placed at each corner of the test plates.
2.3.3. A second stainless-steel coupon was placed on top of the dispensed material.
2.3.4. Two clamps were placed onto the assembly to hold the substrate at a constant thickness.
2.3.5. The above procedure was performed for all 9 sample assemblies.

2.4. Test Procedure

2.4.1. The assemblies were removed from their clamps and 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 50 PSI per ASTM D5470.

2.4.3. After testing each assembly, the silicone oil was gently removed from the outside surfaces and the clamps were place back onto the assemblies.

2.4.4. Three 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.

2.4.4.3. Temperature cycling: thermal cycling chamber from -40°C to 125°C; 10°C/min ramp; 15-minute dwell.

2.4.5. After 500 hours of exposure to the aging conditions, the samples were removed from their respective environments, allowed to equilibrate to room temperature for at least 2 hours, and retested for thermal impedance.

2.4.6. Once tested, the samples were returned to their respective aging environments and the aging intervals were repeated until the samples had been subjected to a total of 1000 hours of dry heat or heat/humidity aging, or 1000 temperature cycles.

2.5. Results

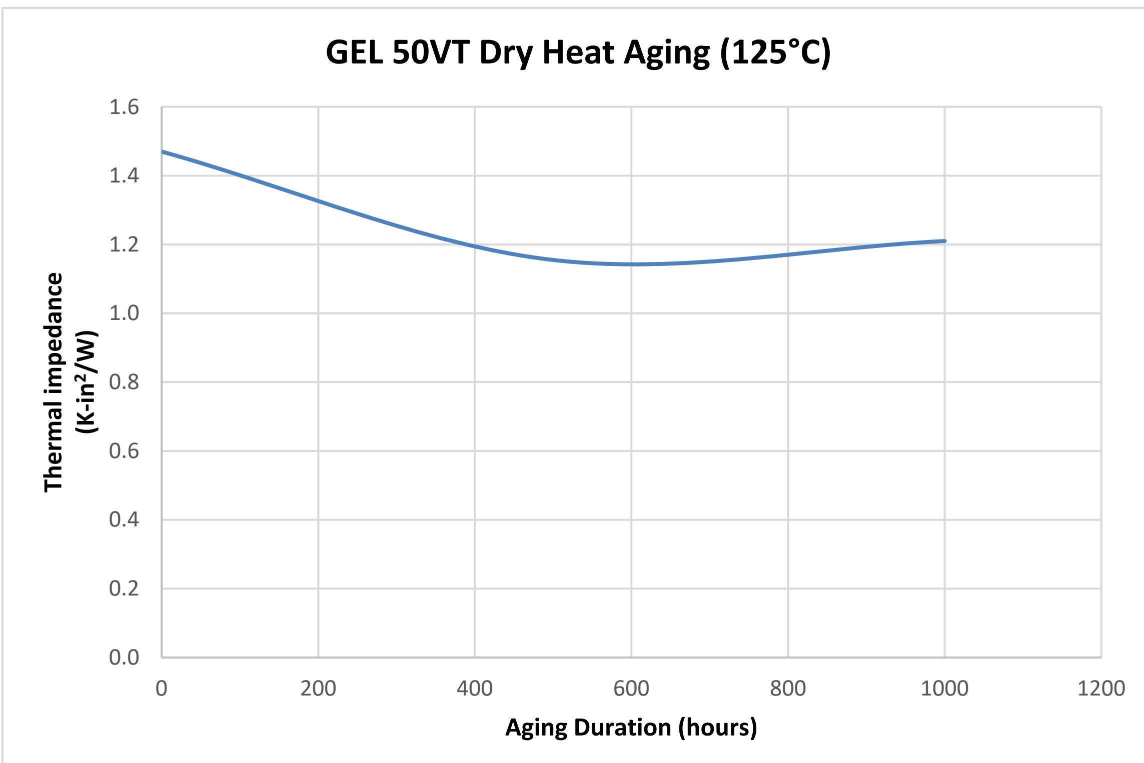

Figure 1: Thermal Impedance versus Time – Dry heat aging at 125℃

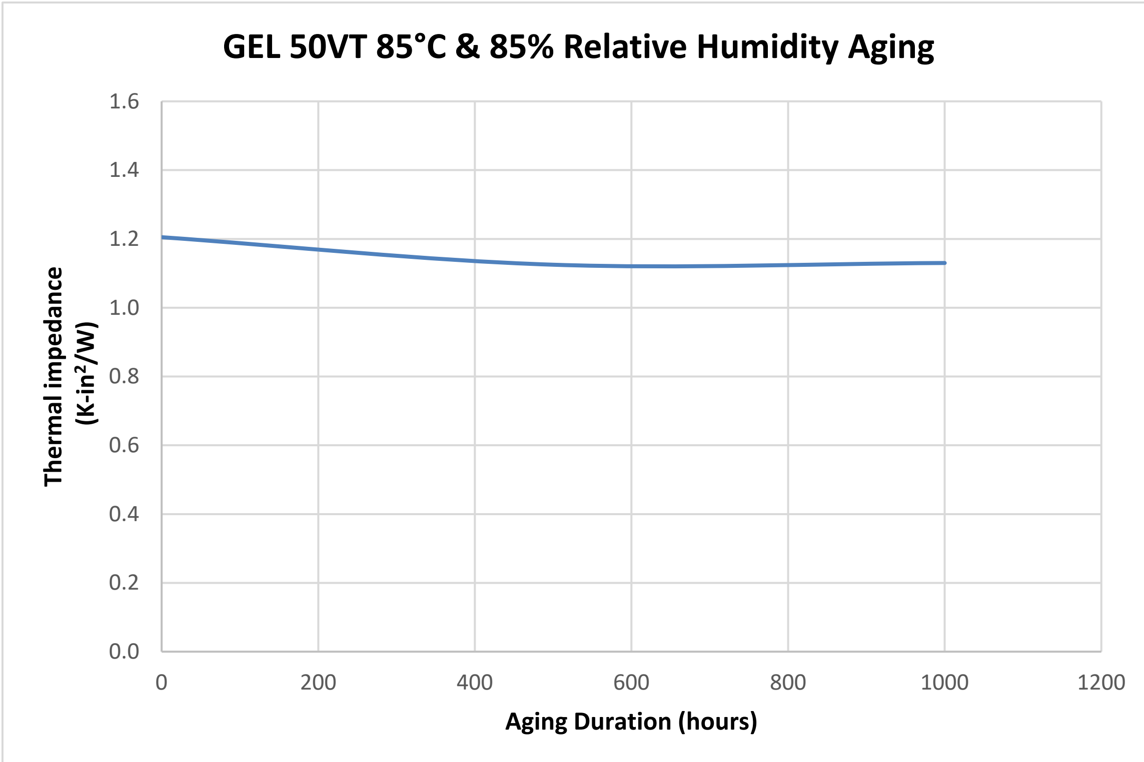

Figure 2: Thermal Impedance versus Time – Heat & Humidity aging at 85%RH and 85℃

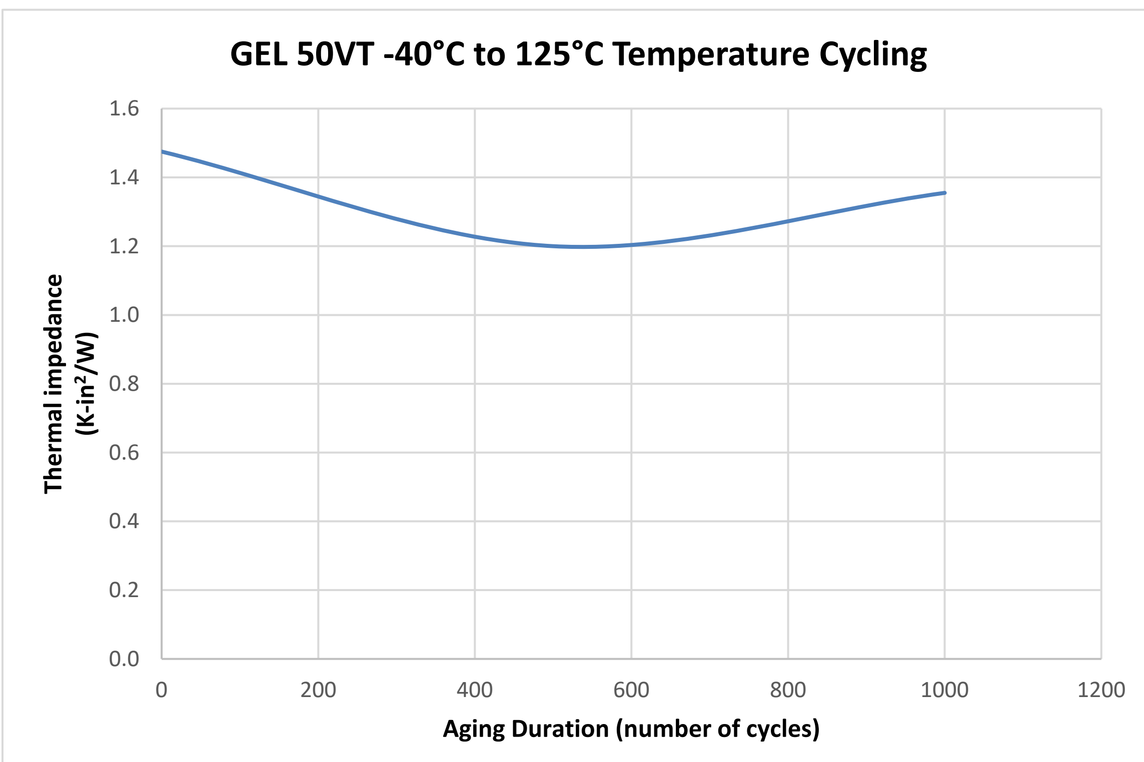

Figure 3: Thermal Impedance versus Time – Temperature cycling between -40℃ and 125℃

GEL 50VT Aging Condition	Initial Thermal Impedance (K*in^2/W)	Thermal Impedance @500h or cycles (K*in^2/W)	Percentage Change at 500 hrs or cycles	Thermal Impedance @1000h or cycles (K*in^2/W)	Percentage Change at 1000 hrs or cycles
125°C - 1	1.470	1.140	-22.4%	1.200	-18.4%
125°C - 2	1.470	1.170	-20.4%	1.220	-17.0%
Average	1.470	1.155	-21.4%	1.210	**-17.7%**
85%/85°C - 1	1.210	1.150	-5.0%	1.120	-7.4%
85%/85°C - 2	1.200	1.100	-8.3%	1.140	-5.0%
Average	1.143	1.083	-6.6%	1.153	**-6.2%**
-40 to 125°C-1	1.450	1.200	-17.2%	1.310	-9.7%
-40 to 125°C-2	1.500	1.200	-20.0%	1.400	-6.7%
Average	1.475	1.200	-18.6%	1.355	**-8.1%**

Table 1: Raw data of thermal aging testing

3.0 Compression vs Deflection

3.1. Purpose

This test is intended to provide data on the compressive load on substrates relative to the deflection percentage of THERM-A-GAP™ GEL 50VT. Compressive load or compression forces are of concern due to the fragile nature of some heat generating components that cannot operate effectively under constant or high load values.

3.2. Materials

3.2.1. TA.HD*plus*C Texture Analyzer.

3.2.2. Small sample of GEL 50VT.

3.3. Test Procedure

3.3.1. A 1" x 1" (25.4mm x 25.4mm) sample of GEL 50VT with a height of 0.080" (2.0mm) was dispensed onto a 1" x 1" (25.4mm x 25.4mm) test plate.

3.3.2. The upper compression plate was lowered onto the sample at a rate of 0.025 inches per minute. The plate was lowered until the gel sample was deflected to 70% of its original height

3.3.3. A force plate embedded into the lower probe measured the load as the sample was deflected and the values were recorded.

3.4. Results

GEL 50VT had a deflection of up to 60% the original sample height at a compressive load of less than four pounds per square inch (PSI).

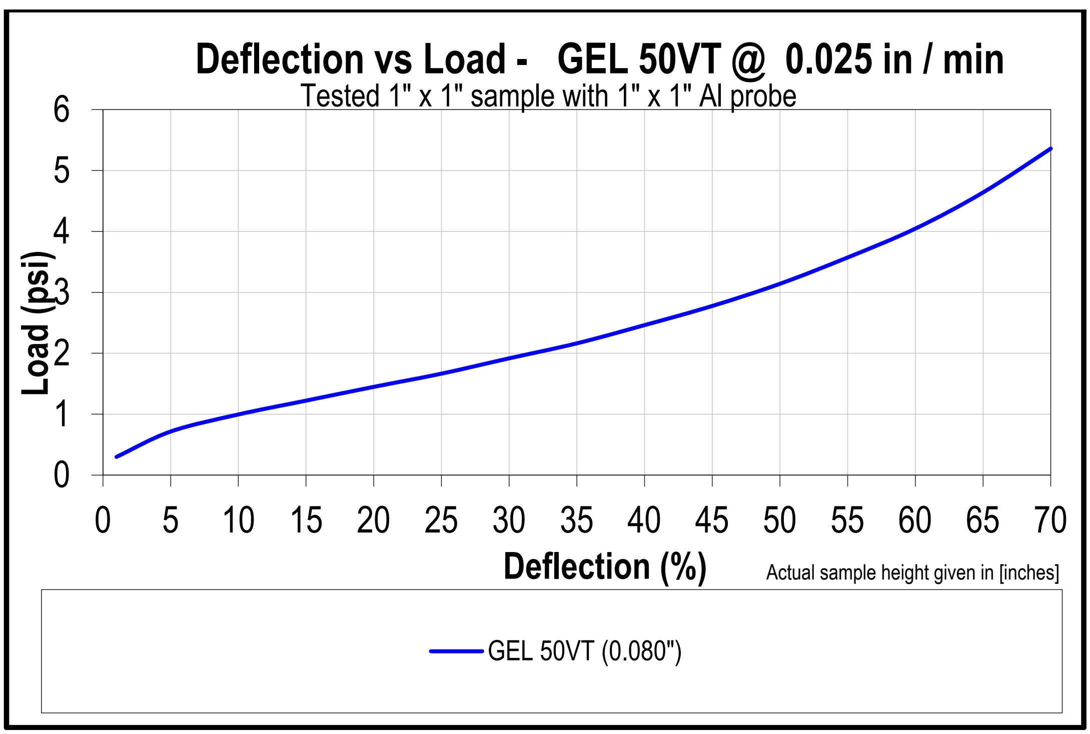

Figure 4: Compression force versus sample deflection percentage

4.0 Automotive Testing

4.1 Purpose

This testing was conducted to evaluate the performance of THERM-A-GAP™ GEL 50VT under conditions that simulate thermal shock, power cycling, and vibration conditions that may be present in automotive applications. The testing in this section aligns with the procedures presented in standard GMW 3172 – General Specifications for Electrical/Electronic Components – Environmental/Durability.

4.2 Materials

4.2.1. 178 mm x 178 mm sapphire glass test plate with screw holes
4.2.2. Aluminum test plate with 25 mm x 25 mm emboss and screw holes
4.2.3. PTFE shims, 1 mm thickness
4.2.4. Analysis Tech Thermal Interface Material Tester
4.2.5. Espec Thermal Shock Chamber
4.2.6. Espec Thermal Cycling Chamber
4.2.7. Vibration tester

4.3 Sample Preparation

4.3.1. Samples of GEL 50VT were dispensed onto the center of aluminum test plates.
4.3.2. The 1.0 mm PTFE shims were placed on the aluminum test plate, centered on the screw holes.
4.3.3. The sapphire glass test plate was placed on top of the material.
4.3.4. Screws were inserted at the corners of the substrates and tightened to achieve desired 1.0 mm gap thickness.

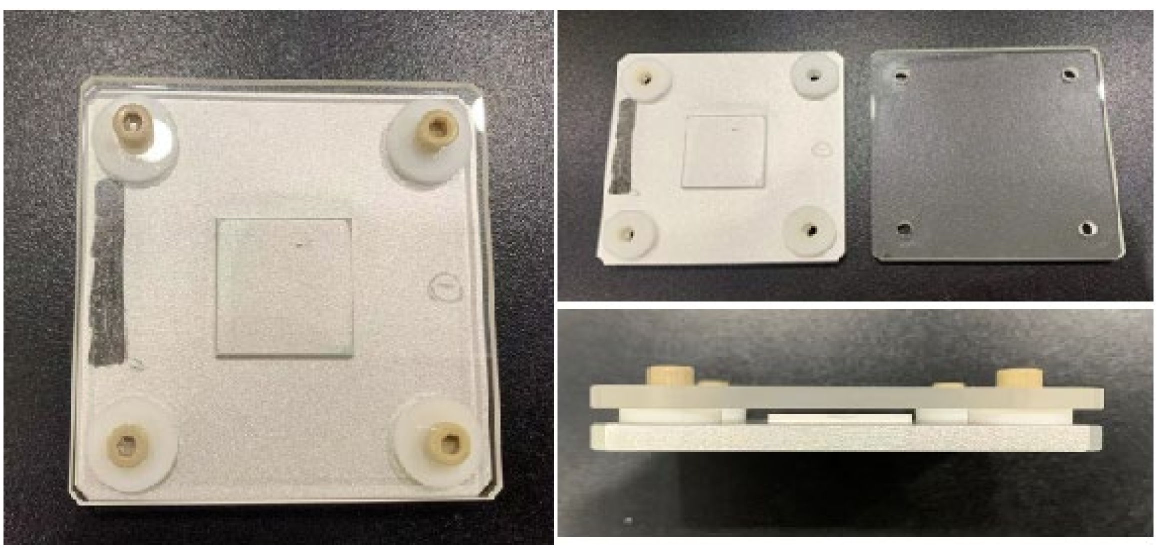

Figure 5: Test plates and assembled fixture for automotive testing

4.4 Test Procedure

4.4.1. Initial Thermal Impedance Testing

4.4.1.1. Sample fixtures were tested for thermal impedance per ASTM D5470 at 30 psi. The thermal impedance was recorded as R_0.

4.4.2. Thermal Shock Air-to-Air (TS)

4.4.2.1. After initial thermal impedance measurement, sample fixtures were placed into the Espec thermal shock chamber.

4.4.2.2. The test chamber was run through thermal cycling from -40°C to 85°C with a dwell time at high temperature and low temperature of 15 minutes.

4.4.2.3. The number of cycles was determined by GMW 3172 9.4.2. Table 33 according to Code Letter for Temperature of A, B, C, and D [632 cycles]. This is shown in Table 2 of this report.

4.4.2.4. The fixtures were removed from the thermal shock chamber for two hours. Thermal impedance was measured per ASTM D5470 at 30 psi and recorded as R_1.

4.4.3. Power Temperature Cycling (PTC)

4.4.3.1. After recording R_1, the test fixtures were placed into the Espec thermal cycling chamber.

4.4.3.2. The test chamber was run through power cycling from -40°C to 125°C with a 11ºC/minute ramp and decline as a dwell time of 15 minutes at the high temperature and low temperature.

4.4.3.3. The number of cycles was determined by GMW 3172 9.4.2. Table 33 according to Code Letter for Temperature of A, B, C, and D [211 cycles]. This is shown in Table 2 of this report.

4.4.3.4. The fixtures were removed from the thermal cycling chamber for two hours. Thermal impedance was measured per ASTM D5470 at 30 psi and recorded as R_2.

4.4.4. Random Vibration

4.4.4.1. After recording R_2, the test fixtures were placed into the vibration chamber.

4.4.4.2. The vibration testing parameters were set per IEC 60068-2-64 with the power spectral density (PSD) and frequencies set per Table 3.

4.4.4.3. The effective acceleration for the vibration testing was 19.6 m/s^2 or 2.0 GRMS. Testing was completed in 3 directions with 8 hours per direction.

4.4.4.4. The fixtures were removed from the vibration chamber. Thermal impedance was measured per ASTM D5470 at 30 psi and recorded as R_3.

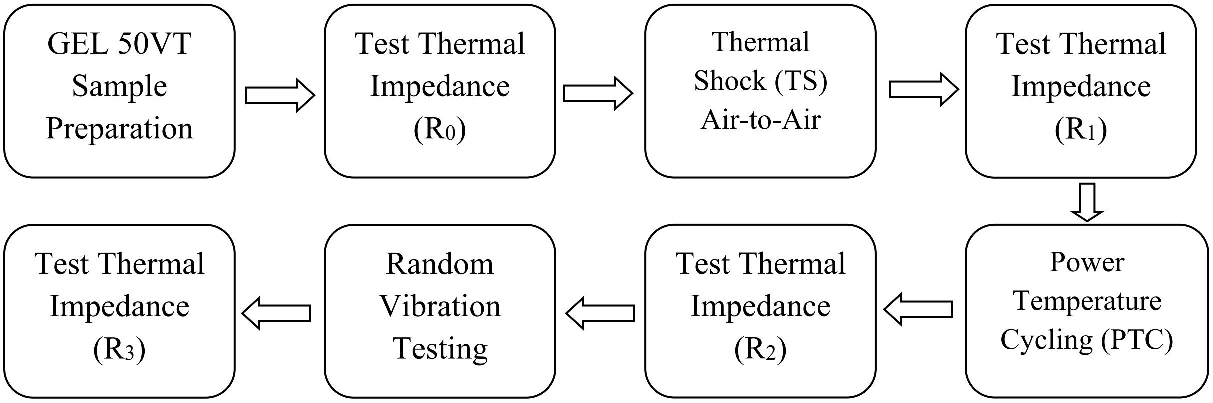

Figure 6: Automotive Testing Procedure

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

Table 2: GMW 3172 9.4.2 Table 33 – Thermal Shock and Power Thermal Cycling guidance

Frequency	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

Table 3: Frequency and Power Spectral Density test parameters

4.5 Results

Sample	Initial Thermal Impedance [R_0] ($K*in^2/W$)	Impedance post Thermal Shock [R_1] ($K*in^2/W$)	Impedance post Power Temp Cycling [R_2] ($K*in^2/W$)	Impedance post Random Vibration [R_3] ($K*in^2/W$)	Impedance Change post Vibration
1	0.804	0.809	0.814	0.811	0.87%
2	0.806	0.804	0.809	0.811	0.62%
3	0.811	0.810	0.820	0.817	0.74%
Average	**0.807**	**0.808**	**0.814**	**0.813**	**0.74%**

Table 4: Results of thermal impedance change post automotive testing

Figure 7: Automotive Testing Results after 3 Environmental Aging Tests

GEL 50VT demonstrates superior stability of thermal properties in automobile test environments, as its thermal impedance is not impacted by thermal shock, temperature cycling and vibration testing in such conditions. No cracking or sliding was observed after long term reliability aging**.**

5.0 Results

THERM-A-GAP™ GEL 50VT is a one-component, fully-cured, dispensable thermal compound. The thermal performance of GEL 50VT was measured after exposure to multiple accelerated aging conditions. The aging treatments featured in this study 1000 hours of dry heat aging at 125°C, 1000 hours of heat and humidity aging at 85°C and 85% relative humidity, and 1000 temperature cycles between -40°C and 125°C. There was no statistically significant increase in the thermal impedance of the sample assemblies for any of the aging treatments according to one-way ANOVA with the Tukey method for multiple comparisons.

The mean impedance values after dry heat aging at 125°C, heat and humidity aging, and temperature cycling decreased by 17.7%, 6.2%, and 8.1%, respectively. A decrease in impedance represents improved thermal performance, and this phenomenon may be attributed to enhanced wetting at the interface between the thermal compound and the substrate.

6.0 Conclusion

The results of this study provide evidence that GEL 50VT maintains reliability after long-term aging. This reliability report presents the test results of GEL 50VT under controlled lab conditions. We strongly recommend the testing of thermal materials under application specific conditions to understand how the material will perform in a given environment.