MINCO

Test Report
No. 1877

NASA/NASDA QUALIFICATION TESTING ON MINCO'S POLYIMIDE-INSULATED THERMOFOIL™ HEATERS

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1. Purpose

To qualify Minco heaters for use in space flight applications in Japan. Qualification testing will be per a combination of NASA and NASDA test specifications as previously agreed upon by Japan Machinery and Minco.

Thirty-one units of the each of the models in Table 1 were tested as described in the Testing Flowchart. These units were manufactured for testing only.

2. Applicable Documents

NASA S-311-P-079, rev. (D)
NASDA-QTS-1040

3. Heater Material

Test heaters were constructed with polyimide insulation. See Table 1 for heater characteristics including size, final resistance, internal adhesive, and conditioning amps and volts.

Table 1 - Heater Characteristics

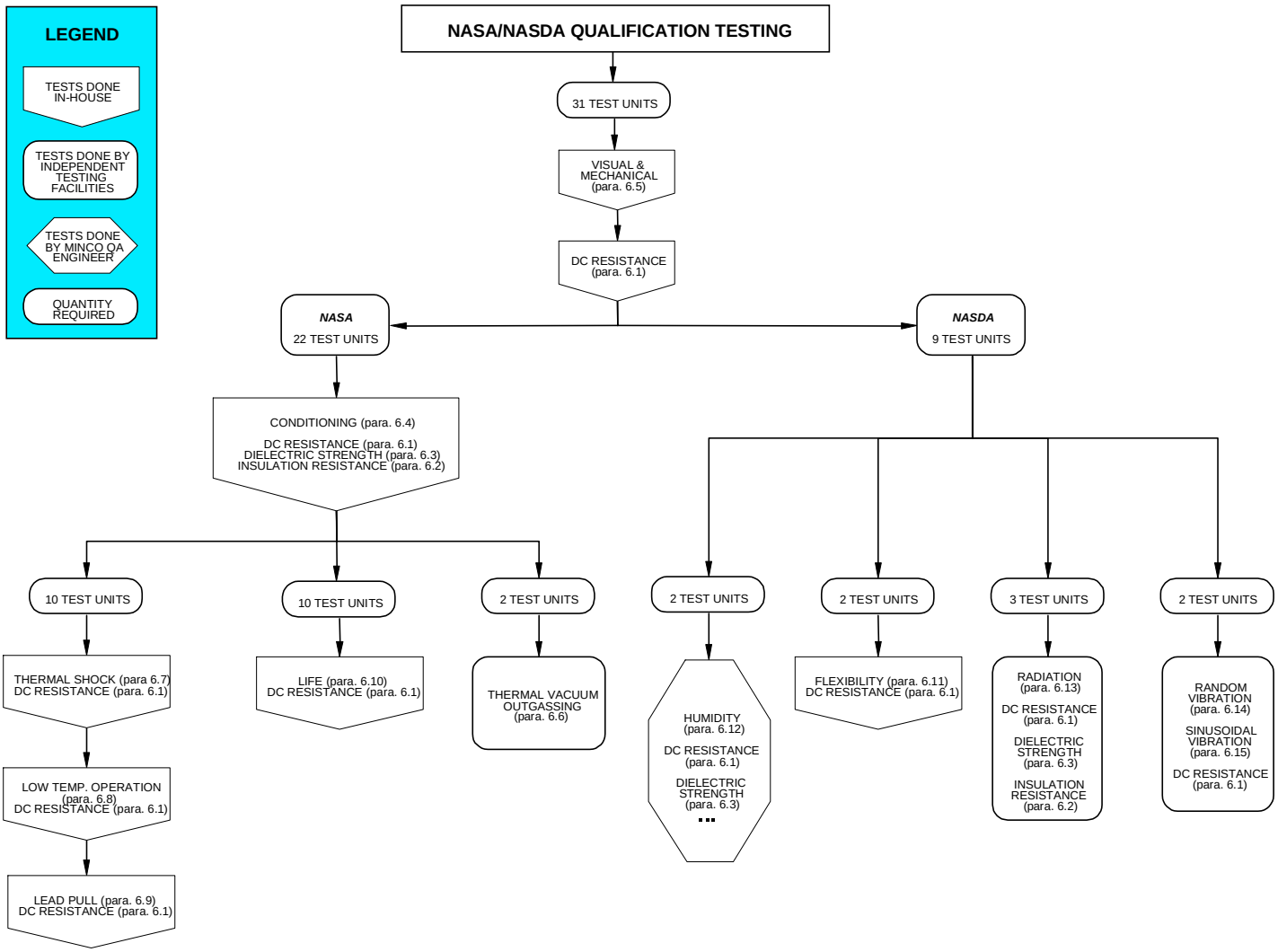
Model Number	Heater Size	Final Resistance	Internal Adhesive	Conditioning	
				Volts	Amps
HK20602	.880 x .880	.82Ω	WA	1.0	1.230
HK20603	.880 x .880	670.00Ω	WA	28.8	0.043
HK20604	11.00 x 20.00	321.00Ω	WA	120.0	0.373
HK20605	11.00 x 20.00	91800.00Ω	WA	120.0	0.001
HK20606	.880 x .880	.82Ω	FEP	1.2	1.456
HK20607	.880 x .880	420.00Ω	FEP	27.0	0.064
HK20608	11.00 x 20.00	321.00Ω	FEP	120.0	0.374
HK20609	11.00 x 15.00	4500.00Ω	FEP	120.0	0.026

4. Inspection Procedures

Each inspection consists of viewing the units under a microscope for the purpose of observing any flaws as determined by the internal workmanship specification. Units are inspected at various intervals during fabrication so that any rejectable units are identified and removed before further work is done on them.

After in-process inspections, units are subjected to a final verification prior to qualification testing. At this time any units which are rejectable per the internal workmanship specification are removed. Qualification testing and inspections are performed as indicated on the Testing Flowchart. After all testing is complete, Final Inspection is performed on all units to identify any non-conforming units and to determine results of testing.

Testing Flowchart



6. Testing Procedure

6.1 DC Resistance: This test was performed as indicated in Section 4.7.5 of NASA S-311-P-079, which specifies MIL-STD-202, Method 303. Resistance was measured at 25°C ± 5°C (room temperature measurement) using a calibrated digital multimeter (DMM) with ±0.2% minimum accuracy.

6.2 Insulation Resistance: This test was performed as indicated in Section 4.7.4 of NASA S-311-P-079, which specifies MIL-STD-202, Method 302, Test Condition B. Insulation resistance was measured between element and outer surfaces. See paragraph 7.1 for performance requirements.

6.3 Dielectric Withstanding Voltage: This test was performed as indicated in Section 4.7.3 of NASA S-311-P-079, which specifies MIL-STD-202, Method 301. Dielectric strength of each unit was checked between element and outer surfaces. See paragraph 7.2 for performance requirements.

6.4 Conditioning: This test was performed as indicated in Section 4.7.2 of NASA S-311-P-079. The units were suspended in still air while voltage per Table 1 was applied continuously to each element for 168 hours +48/-0 hours. See paragraph 7.3 for performance requirements.

6.5 Visual and Mechanical Inspection: This test was performed as indicated in Section 4.7.1 of NASA S-311-P-079. Materials, design, construction, physical dimensions, marking, and workmanship of the unit are inspected. See paragraph 7.4 for performance requirements. (WA is an exception to Section 3.2.1.4 of NASA S-311-P-079 Specification.)

6.6 Thermal Vacuum Outgassing: This test was performed as indicated in Section 4.7.10 of NASA S-311-P-079, which specifies ASTM-E595. See paragraph 7.5 for performance requirements.

6.7 Thermal Shock: This test was performed as indicated in Section 4.7.7 of NASA S-311-P-079, which specifies MIL-STD-202, Method 107, Test Condition D, with the exception of a high temperature limit of 200°C. Each unit was subjected to five cycles, consisting of:

1. 30 minutes at -65°C/-5°C
2. 5 minutes max at 25°C +10/-5°C
3. 30 minutes at 150°C* +5/-0°C
4. 5 minutes max at 25°C +10/-5°C

* 200°C for Kapton/FEP units

See paragraph 7.6 for performance requirements.

6.8 Low Temperature Operation: This test was performed as indicated in Section 4.7.8 of NASA S-311-P-079. The unmounted units were placed for one hour in a chamber cooled to -65°C while voltage (see Table 1) was applied to each unit for 45 minutes. Units were returned to 25°C +5/-0°C within 15 minutes of removal from power. See paragraph 7.7 for performance requirements.

6.9 Lead Pull Strength: This test was performed as indicated in Section 4.7.6 of NASA S-311-P-079, which specifies MIL-STD-202, Method 211, Test Condition A. A 3 pound axial pull was applied to each leadwire. See paragraph 7.8 for performance requirements.

6.10 Life: This test was performed as indicated in Section 4.7.9 of NASA S-311-P-079. Voltage (see Table 1) was applied continuously to each unit for 1000 hours with unit suspended in still air. See paragraph 7.9 for performance requirements.

6.11 Flexibility: This test was performed as indicated in Section 4.6.9 of NASDA-QTS-1040. Each unit was bent to a 0.030” minimum radius on both directions, per sketch shown below. See paragraph 7.10 for performance requirements.

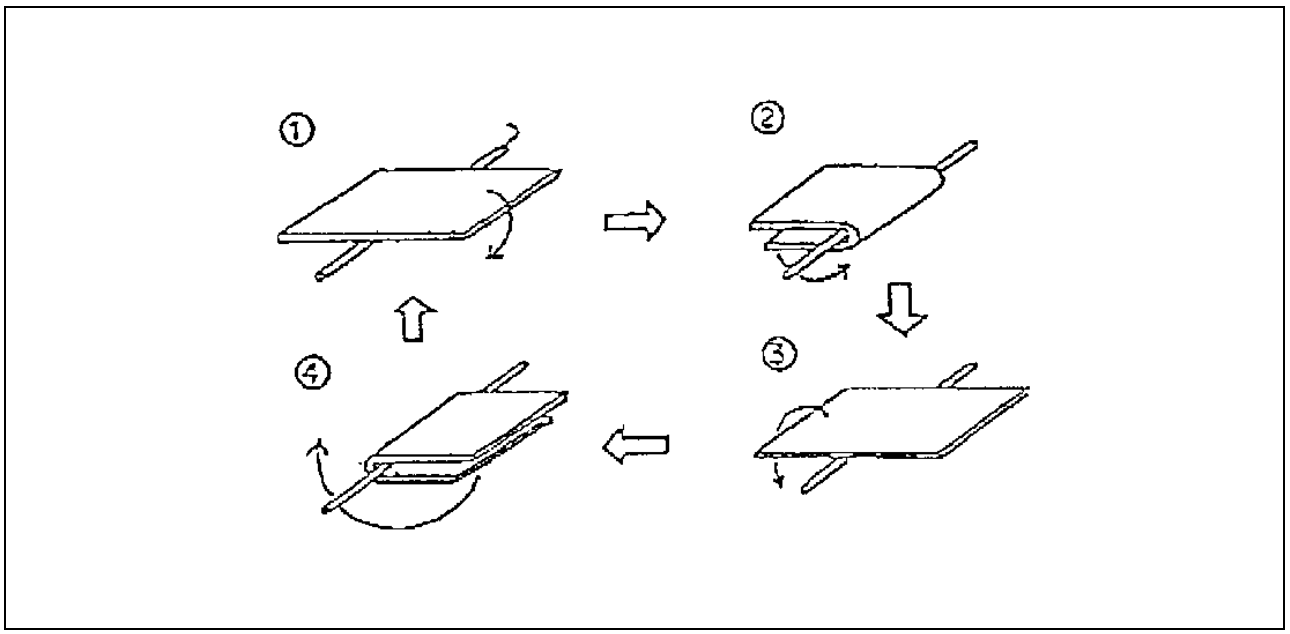


Figure 1 - Flexibility Test

6.12 Humidity: This test was performed as indicated in Section 4.6.8 of NASDA-QTS-1040. Unmounted units were placed in a climate test box hold at 40°C ± 2°C and a relative humidity of 90 - 95% for 90 hours. See paragraph 7.11 for performance requirements.

6.13 Radiation: This test was performed as indicated in Section 4.6.10 of NASDA-QTS-1040. Each unit was mounted and exposed to gamma radiation (Cobolt 60) under atmospheric conditions at a level of from 0.5×10^6 to 1×10^6 rads for one hour. Total radiation exposure shall not be less than 1.0×10^6 rads. See paragraph 7.12 for performance requirements.

6.14 Random Vibration: This test was performed as indicated in Section 4.6.12 of NASDA-QTS-1040. Each unit was vibrated in three-dimensions for 840 seconds at the frequencies listed in the following chart. See paragraph 7.13 for performance requirements.

Table 2 - Random Vibration Testing

Frequency	Power Spectrum
10 - 30 Hz	0.1 G^2/Hz
30 -70 Hz	+6 dB/oct
70 - 80 Hz	0.5 G^2/Hz
80 - 100 Hz	+10 dB/Oct
100 - 1200 Hz	1.05 G^2/Hz
1200 - 2000 Hz	-3 dB/oct

Note: G(rms) = 43 G

6.15 Sinusoidal Vibration: This test was performed as indicated in Section 4.6.13 of NASDA-QTS-1040. Each unit was vibrated in three-dimensions for one full cycle at the frequencies listed in the following chart. See paragraph 7.14 for performance requirements.

Table 3 - Sinusoidal Vibration

Frequency	Power
5 - 15 Hz	20 G (O-P)
15 - 25 Hz	25 G
25 - 70 Hz	40 G
70 - 100 Hz	15 G
100 - 2000 Hz	5 G

Note: 1) for 5 - 39.5 Hz, an amplitude of 12.7 mm shall be used.

2) Rate shall be 2 oct/min

7. Performance Requirements

7.1 Insulation Resistance: After testing per paragraph 6.2, the insulation resistance of the unit must measure 1,000 megohms minimum at 500 volts DC and must not decrease.

7.2 Dielectric Withstanding Voltage: After testing per paragraph 6.3, each unit must withstand 500 volts rms at 60 Hz for 1 minute with 1 mA maximum leakage current.

7.3 Conditioning: After testing per paragraph 6.4, the units shall exhibit no mechanical damage including blistering, delamination, or bubbles. The change in DCR shall not exceed ±1%, the insulation resistance shall not decrease and DWV leakage current shall not exceed one mA.

7.4 Visual and Mechanical Inspection: After testing per paragraph 6.5, the units shall be examined to verify that the materials, design, construction, physical dimensions, marking, and workmanship are in accordance with the internal workmanship specification.

7.5 Thermal Vacuum Outgassing: After testing per paragraph 6.6, units must meet outgassing requirements of 1.0% total mass loss (TML) maximum and 0.1% collected volatile condensable materials (CVMC) maximum.

7.6 Thermal Shock: After testing per paragraph 6.7, units shall exhibit no mechanical damage. The change in DCR shall not exceed ±1%.

7.7 Low Temperature Operation: After testing per paragraph 6.8, units shall exhibit no mechanical damage. The change in DCR between the initial and final measurement at 25°C shall not exceed ±1%, the insulation resistance shall not decrease and DWV leakage current shall not exceed one mA.

7.8 Lead Pull Strength: After testing per paragraph 6.9, the units shall exhibit no damage as a result of this test. The change in DCR shall not exceed ±1%.

7.9 Life: After testing per paragraph 6.10, the change in DCR between the initial and final measurement at 25°C shall not exceed ±1%.

7.10 Flexibility: After testing per paragraph 6.11, units must not show evidence of mechanical damage (including breakage of heater element, failure of insulation materials or cracking). The change in DCR shall not exceed ±1%.

7.11 Humidity: After testing per paragraph 6.12, units must not show evidence of mechanical damage (including blistering, delamination or bubbles). The change in DCR shall not exceed ±1%, the insulation resistance shall not decrease and DWV leakage current shall not exceed one mA.

7.12 Radiation: After testing per paragraph 6.13, units must not show evidence of mechanical damage (including blistering, delamination or bubbles). The change in DCR shall not exceed ±1%, the insulation resistance shall not decrease and DWV leakage current shall not exceed one mA.

7.13 Random Vibration: After testing per paragraph 6.14, units must no show evidence of mechanical damage (including blistering, delamination, or bubbles) as a result of this test. The change in DCR shall not exceed ±1%.

7.14 Sinusoidal Vibration: After testing per paragraph 6.15, units must not show damage (including blistering delamination or bubbles). The change in DCR shall not exceed ±1%.

8. Results and Discussion

All of the qualification tests were performed at Minco except for the Thermal Vacuum Outgassing, Radiation, and Vibration tests, which were performed by independent testing facilities. Results are summarized in Table 4.

8.1 Conditioning: 22 units from each model were tested per paragraph 6.4. All but 3 units met the performance requirements of paragraph 7.3. These 3 units were rejected for Insulation Resistance failure after Conditioning: 2 from HK20604 and 1 from HK20605 (NASA S-311-P-079 allows for 2 rejects per model per lot tested maximum).

8.2 Visual and Mechanical Inspection: Units from paragraph 8.1 were subjected to inspections as indicated in paragraph 6.5. All units met the performance requirements of paragraph 7.4. The rejected units from paragraph 8.1 were not subjected to this inspection.

8.3 Thermal Shock: 10 units from paragraph 8.2 were tested per paragraph 6.7. All units met the performance requirements of paragraph 7.6.

8.4 Low Temperature Operation: The same 10 units from paragraph 8.3 were tested per paragraph 6.8. All units met the performance requirements of paragraph 7.7.

8.5 Dielectric Withstanding Voltage: The same 10 units from paragraph 8.4 were tested per paragraph 6.3. All units met the performance requirements of paragraph 7.2.

8.6 Insulation Resistance: The same 10 units from paragraph 8.5 were tested per paragraph 6.2. All units met the performance requirements of paragraph 7.1.

8.7 Lead Pull Strength: The same 10 units from paragraph 8.6 were tested per paragraph 6.9. All units met the performance requirements of paragraph 7.8.

8.8 Life: 10 units from paragraph 8.2 were tested per paragraph 6.10. All units met the performance requirements of paragraph 7.9.

8.9 Thermal Vacuum Outgassing: 2 units from paragraph 8.1 were sent to an independent testing facility to be tested per paragraph 6.6. All units met the performance requirements of paragraph 7.5.

8.10 Flexibility: 2 units were tested per paragraph 6.11. Both units met the performance requirements of paragraph 7.10.

8.11 Humidity: 2 units were tested per paragraph 6.12. Both units met the performance requirements of paragraph 7.11.

8.12 Radiation: 3 units were sent out to an independent testing facility to be tested per paragraph 6.13. All units met the performance requirements of paragraph 7.12.

8.13 Random Vibration: 2 units were sent out to an independent testing facility to be tested per paragraph 6.14. Both units met the requirements of paragraph 7.13.

8.14 Sinusoidal Vibration: The same 2 units from paragraph 8.13 were tested per paragraph 6.15 at the same facility. Both units met the performance requirements of paragraph 7.14.

Table 4 - Testing Summary

Required Tests	Models							
	HK20602	HK20603	HK20604	HK20605	HK20606	HK20607	HK20608	HK20609
Conditioning	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Thermal Shock	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Low Temp. Operation	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Dielectric	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Insulation Resistance	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Lead Pull	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Life	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
T. V. Outgassing	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Flexibility	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Humidity	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Radiation	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Random Vibration	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Sinusoidal Vibration	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

9. Conclusion

After testing, all units remained intact and appeared to have incurred no visible evidence of degradation as a result of these tests, **with the following exceptions:**

- Units subjected to Thermal Vacuum Outgassing test (intended to be destructive test).
- Darkening of the WA units after Life test as expected (cosmetic).

This testing has shown that Minco's polyimide-insulated Thermofoil™ heaters conform to the specifications specified by both NASA and NASDA that are listed herein. This testing has also confirmed that these heaters are suitable for Space Flight use under the conditions specified by both NASA and NASDA herein.

Appendix A – Cross-Sectional Figure of Heater Unit