Thermoelectric Cooler Reliability Report

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Moscow, March 20th, 2003

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1 Introduction

This Section contains a description of the background of the testing, a brief overview of the contents of this Report, and a Notice of Confidentiality.

1.1 Background

RMT Ltd., in order to provide advanced information about the reliability of our thermoelectric coolers (TECs), has performed testing selected modules according to recognized specifications in the military and telecommunications industries.

One particular thermoelectric cooler type was selected for the testing, the 1ML series (used in fiber optic communications).

For the 1ML series, the 1ML06-023-09 was selected. As TECs with between 12 and 35 couples are commonly used in fiber optic applications, a 23-coupled TEC was chosen. As for the chose of the element geometry (which determines the cooling power as well as the operating power), the chosen geometry has elements that are 0.6 mm x 0.6 mm and 0.95 mm in height. The 0.95 mm was chosen as a height in order to give us close to typical-case results for the 1ML series.

The TE modules have metallized cold and hot sides for soldering applied in some tests.

RMT Ltd will continue to perform testing in future, and will provide updates as they become available. For more information concerning the testing, please contact RMT Ltd at 53 Leninskij prosp Moscow 119991 Russia, or by call +7-095-132-6817, or e-mail rmtcom@dol.ru .

1.2 Contents of This Report

Sections 2 through 10 contain detailed information regarding the multiple types of testing conducted on the selected modules. For each test, the purpose of the test, test methods, test equipment used, test data, test results, and conclusions are described.

1.3 Notice of Confidentiality

This Report and all of its contents are to be treated as confidential information. The Report may not be reproduced, or may the information contained within be divulged to third parties, without the prior written consent of RMT Ltd.

2 Methods

2.1 General

Methods used for testing reported herein are based on military standards and Telcordia requirements.

2.2 Military Standards

Military standards (abbreviated in the singular as "MIL-STD") were originally developed for defense and aerospace related organizations, but lately these standards have been adopted by many commercial and industrial companies ranging from those using thermoelectric for telecommunications to those using them for medical applications. Thermoelectric modules, being typically comprised of a small circuit of Peltier elements, are tested using MIL-STD 883 for microcircuits.

2.3 Telcordia Requirements

Telcordia, whose requirements are referenced in this report, is a company that provides technical analysis, testing, and consulting services to product suppliers and service providers in the communications market. Telcordia's GR-468 CORE is their generic reliability assurance requirement.

3 Power Cycle Testing

3.1 Purpose of Test

The purpose of this test was to determine the resistance of the parts to thermal/electrical stresses generated by sudden cycling between “on” and “off” conditions.

3.2 Test Method Used

The basic test method employed was MIL-SDT-883E, Method 1006, Intermittent Life, Condition B.

A total of 10 TE modules were prepared by first recording the pre-test resistance of each TE module.

Every TE module has been soldered onto copper plates. The copper bases with the TE modules were then mounted onto heat sink using thermally conductive grease as an interface material. The heat sink with mounted TE modules was placed into oven.

The wires from the test TE modules were run to a power supply controlled by a programmable controller.

Prior to the test, the resistance of each TE module was recorded.

The oven temperature was then set to keep the parts at 70^{o}C. The programmable controller cycled the thermoelectric modules between the “on” and “off” conditions for 1000 hours.

3.3 Test Equipment Details

The following test equipment was used to conduct this test.

DX3065 Z-Meter (ACR, Z, time constant), S/N 20-0012

DX2050 Programmable Time Controller

HERAEUS Power Controller KRGU.UI-45-7785

HERAEUS Oven HEP 2, S/N 8903510

3.4 Test Parameters

The TE modules were run at maximum current (I_{max}) according to specification on the TE modules, which was specified as 1.8 Amps at a duty cycle of 5 min on and 5 min off.

The ambient temperature was set at 70^{o}C, and the parts were tested for 1000 hrs to meet the requirements of the intermittent life test.

3.5 Test Data

Table 3.1-1. Resistance Data for TEC 1ML06-023-09 Power Cycling Test (dated 28/02/03)

Module #	Before	After	Change
A1	1.255	1.301	3.67%
A2	1.304	1.339	2.68%
A3	1.249	1.285	2.88%
A4	1.232	1.264	2.56%
A5	1.263	1.299	2.85%
A6	1.269	1.286	1.34%
A7	1.248	1.262	1.12%
A8	1.267	1.298	2.45%
A9	1.305	1.341	2.76%
A10	1.256	1.269	1.04%
Average	1.265	1.294	2.33%

Table 3.1-1 shows the data from the test of the TEC 1ML06-023-09 part. The before and after resistances in Ohms are shown. as well as the calculated change value.

3.6 Test Results

A total of 10 parts were selected for the purpose of this report. Telcordia provides a suggested passing criterion for such a test in GR-468 CORE of less than 5% change in resistance. All parts tested met the suggested criterion, with the average change value of 2.33% for the TEC 1ML06-023-09.

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4 Temperature Cycling

4.1 Purpose of Test

The purpose of this test was to determine the resistance of the parts to alternate exposure to extremes of high and low temperatures.

4.2 Test Method Used

The basic test method employed was MIL-SDT-883E. Method 1010.7. Condition B.

A total of 10 parts were prepared by first recording the pre-test resistance of each TE module.

The ovens were then heated to 125°C. and the cold chamber was brought down to -55°C. The TE modules were then placed in the oven for a period of 10 minutes, and then place in the cold chamber. also for a period of 10 minutes. This cycle was repeated 100 times.

After the cycles were completed the post-test resistance of each TE module was taken for later comparison to the pre-test measurement.

4.3 Test Equipment Details

The following test equipment was used to conduct this test.

DX3065 Z-Meter (ACR, Z, time constant), S/N 20-0012

TABAI Thermal Shock Chamber TSE-10, S/N450118

4.4 Test Parameters

The hot chamber temperature was set to 125°C. while the cold chamber was set to -55°C. The parts were held at each temperature for a minimum of 10 minutes for each exposure. The parts were then exposed to each hot and cold cycle a total of 100 times.

4.5 Test Data

Table 4.1-1. Resistance Data for TEC 1ML06-023-09 Temperature Cycling Test (dated 18/03/03)

Module #	Before	After	Change
B1	1.289	1.302	1.01%
B2	1.292	1.311	1.47%
B3	1.247	1.263	1.28%
B4	1.259	1.272	1.03%
B5	1.281	1.335	4.22%
B6	1.251	1.260	0.72%
B7	1.306	1.340	2.60%
B8	1.247	1.250	0.24%
B9	1.271	1.280	0.71%
B10	1.262	1.270	0.63%
Average	1.271	1.288	1.39%

Table 4.1-1 shows the data from the test of the TEC 1ML06-023-09 part. The before and after resistances in Ohms are shown. as well as the calculated change value.

4.6 4.1.6. Test Results

A total of 10 parts were selected for the purpose of this report. All parts tested met the suggested passing criterion of 5% or less change in resistance. The average change value of 1.39% was obtained for the TEC 1ML06-023-09.

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Thermal Shock Testing

4.7 Purpose of Test

The purpose of this test was to determine the resistance of the parts to sudden exposure to cycling and extreme changes in temperature.

4.8 Test Method Used

The basic test method employed was MIL-SDT-883E. Method 1010.9. Thermal Shock. Condition A.

The first 10 parts were initially prepared by recording the pre-test resistance of each TE module.

The modules were then mounted on a thin wire rack so that the TE modules were suspended below the rack. Hot plate was used for heating to keep the water in a large glass jar filled with de-mineralized water stirred and at a temperature of 100^{o}C. The other glass jar was filled with ice and de-mineralized water and stirred to keep the water at 0^{o}C. The rack was alternately dipped in cold water at 0^{o}C for 5 minutes and then hot water at 100^{o}C for 5 minutes. This cycle was repeated 20 times.

After the exposure the parts were dried by first blowing the water out with lightly pressurized air and then dried out in a warm oven. The post-test resistance of each TE module was then taken for later comparison to the pre-test measurement.

4.9 Test Equipment Details

The following test equipment was used to conduct this test.

DX3065 Z-Meter (ACR, Z, time constant). S/N 20-0012

ERSA Hot plate HP100.

4.10 Test Parameters

The water temperature was set at 0^{o}C and 100^{o}C. The parts were held in the water at each temperature for 5 minutes to assure a good heat soak for uniform temperatures throughout the part. The parts were exposed to each hot and cold cycle a total of 20 times.

4.11 Test Data

Table 5.1-1. Resistance Data for TEC 1ML06-023-09 Thermal Shock Test (dated 06/02/03)

Module #	Before	After	Change
B11	1.245	1.266	1.69%
B12	1.249	1.274	2.02%
B13	1.274	1.298	1.92%
B14	1.233	1.254	1.73%
B15	1.287	1.298	0.85%
B16	1.254	1.276	1.77%
B17	1.264	1.273	0.69%
B18	1.255	1.261	0.48%
B19	1.246	1.255	0.73%
B20	1.273	1.290	1.37%
Average	1.258	1.275	1.32%

Table 5.1-1 shows the data from the test of the TEC 1ML06-023-09 part. The before and after resistances in Ohms are shown. as well as the calculated change value.

4.12 Test Results

The average change in resistance for the group of 10 modules reported is 1.32%, which meets a suggested criterion of average change of less than 5%. Also note that the thermal shock is the most challenging type of thermal stress test.

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5 High Temperature Storage

5.1 Purpose of Test

The purpose of this test was to determine the effect of prolonged exposure at a high temperature to the TE modules.

5.2 Test Method Used

The test involved placing the parts in a regulated temperature environment to measure the effect of that storage temperature on the parts.

The first 10 parts were initially prepared by measuring their pre-test resistances. The storage oven was heated to temperatures of 100 ^{0}C. The thermoelectric modules were placed in the oven for a period of 1000 hours. After the time period elapsed the parts were removed and the post-test resistance measured for comparison with the pre-test values.

5.3 Test Equipment Details

The following test equipment was used to conduct this test.

DX3065 Z-Meter (ACR. Z. time constant), S/N 20-0012

TABAI Hot and Cold Chamber MC-71, S/N 523199

5.4 Test Parameters

The test was conducted in a temperature-controlled oven set at 100 ^{0}C with the parts in a non-operational mode. The period of exposure was 1000 hours.

5.5 Test Data

Table 9.1-1. Resistance Data for TEC 1ML06-023-09 High Temperature Storage Test (dated 12/03/03)

Module #	Before	After	Change
D1	1.294	1.346	4.02%
D2	1.249	1.292	3.46%
D3	1.232	1.270	3.07%
D4	1.251	1.305	4.32%
D5	1.261	1.307	3.62%
D6	1.269	1.315	3.70%
D7	1.248	1.265	1.35%
D8	1.267	1.304	2.94%
D9	1.305	1.348	3.31%
D10	1.256	1.276	1.59%
Average	1.263	1.303	3.14%

Table 9.1-1 shows the data from the test of the TEC 1ML06-023-09 part. The before and after resistances in Ohms are shown, as well as the calculated change value.

5.6 Test Results

As can be seen from Table 9.1-1, all the reported results indicate the parts meet Telcordia's suggested passing criterion of 5% for such tests with average change in resistance of 3.14%.

6 Mechanical Shock Testing

6.1 Purpose of Test

The purpose of this test was to determine the suitability of the thermoelectric modules for use in equipment which may be subject to moderately severe shocks as a result of suddenly applied forces or abrupt changes in motion.

6.2 Test Method Used

The basic test method employed was MIL-SDT-883E. Method 2002.3. Mechanical Shock.

The first 10 parts were initially prepared by mounting them successively on the test platform. The test platform was impacted by a swing arm to apply the mechanical shock. These parts were then subjected to shock at 1500 G level using a 0.5 msec duration half-sine wave pulse. Each device was shocked a total of 5 times in the first axis. The axis was then changed and the shock was repeated another 5 times. The same process was repeated for each of the remaining four axes as well. A measurement of the resistance of each part was taken before and after each test.

6.3 Test Equipment Details

The following test equipment was used to conduct this test.

DX3065 Z-Meter (ACR. Z. time constant). S/N 20-0012

Single Impact Machine УПУ-10 (USSR).

6.4 Test Parameters

The test was conducted at room temperature with the parts in a non-operational mode. A total of five shocks were conducted in each of six axes.

6.5 Test Data

Table 6.1-1. Resistance Data for TEC 1ML06-023-09 Mechanical Shock Test (dated 04/02/03)

Module #	Before	After	Change
C1	1.297	1.308	0.85%
C2	1.291	1.300	0.74%
C3	1.247	1.249	0.12%
C4	1.269	1.278	0.72%
C5	1.257	1.265	0.64%
C6	1.253	1.255	0.16%
C7	1.249	1.262	1.00%
C8	1.306	1.312	0.46%
C9	1.289	1.313	1.86%
C10	1.262	1.276	1.07%
Average	1.272	1.282	0.76%

Table 6.1-1 shows the data from the test of the TEC 1ML06-023-09 part. The before and after resistances in Ohms are shown, as well as the calculated change value.

6.6 Test Results

The results for the 10 parts reported indicate that all met the suggested passing criterion of 5% or less change in resistance. The average change value of 0.76% was obtained for the TEC 1ML06-023-09.
6.1.3. Test Equipment Details

Variable Frequency Vibration Testing

6.7 Purpose of Test

The variable frequency vibration test was performed for the purpose of determining the effect of vibration frequency in the specified frequency range on component parts.

6.8 Test Method Used

The basic test method employed was MIL-SDT-883E. Method 2007.2. Vibration. Variable Frequency.

The first 10 parts were initially prepared by mounting them on several small test fixtures that bolted to the vibration table on three different faces. These parts were then subjected to vibration at a 20 G level from 20 to 2.000 Hz. The frequency sweep up and down was performed in four minutes and repeated three more times. The axis was then changed and the sweep was repeated another four times. The same process was repeated for the last axis as well. A measurement of the resistance of each part was taken before and after each test. During the after test measurement the part had a force applied to it by firmly pushing on the top of the part with a medium hardness rubber material to see if the resistance changed when this force was applied. This was done to assure no stress cracking had occurred during the test.

6.9 Test Equipment Details

The following test equipment was used to conduct this test.

DX3065 Z-Meter (ACR. Z. time constant). S/N 20-0012

Vibration Machine УИЭ5-5/10000 (USSR).

6.10 Test Parameters

The test was conducted at room temperature with the parts in a non-operational mode. A four-minute sweep up and down was conducted at 20 G's over a frequency range of 20 to 2.000 Hz in four minutes. Four such sweeps were done on each of three axes.

6.11 Test Data

Table 7.1-1. Resistance Data for TEC 1ML06-023-09 Vibration Test (dated 06/02/03)

Module #	Before	After	Change
C11	1.266	1.270	0.32%
C12	1.261	1.277	1.24%
C13	1.319	1.328	0.66%
C14	1.302	1.328	1.96%
C15	1.275	1.281	0.44%
C16	1.282	1.295	0.93%
C17	1.310	1.324	1.05%
C18	1.304	1.316	0.93%
C19	1.259	1.263	0.36%
C20	1.282	1.293	0.89%
Average	1.286	1.297	0.88%

Table 7.1-1 shows the data from the test of the TEC 1ML06-023-09 part. The before and after resistances in Ohms are shown, as well as the calculated change value.

6.12 Test Results

As can be seen from Table 7.1-1 all the reported results indicate the parts meet Telcordia's suggested passing criterion of 5% for such tests with average change in resistance of 0.88%

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7 Solderability

7.1 Purpose of Test

The purpose of this test was to determine the solderability of the module terminal leads. This evaluation is made on the basis of the ability of the leads to be wetted by a coating of solder and to produce a suitable fillet when dip soldered.

7.2 Test Method Used

The basic test method employed was MIL-SDT-883E. Method 2003.7.

The test involved placing the leads in flux maintained at room temperature for 5-10 seconds. The parts were drained for 5-20 seconds prior to dipping in the solder pot. All parts were pot dipped accordingly to 4.4 of MIL-SDT-883E.

7.3 Test Equipment Details

ERSA Soldering Station Rework 80.

7.4 Test Data

Table 10.1-1. Pass/Fail Data for TEC 1ML06-023-09 Solderability Test

Module #	Result
F1	Pass
F2	Pass
F3	Pass
F4	Pass
F5	Pass
F6	Pass
F7	Pass
F8	Pass
F9	Pass
F10	Pass

Table 10.1-1 shows the Pass/Fail data from the test of the TEC 1ML06-023-09 parts where the pass criteria indicates at least 95% continuous coating of new solder.

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8 Thermoelectric Cooler Qualification Summary Sheet

TEC MODEL	**1ML06-023-09**
Cold Side Dimensions	6 x 8 mm^2
Hot Side Dimensions	6 x 8 mm^2
Height	1,6 mm
ΔT_{max}	72 deg.
Q_{max}	3,3 W
I_{max}	1.8 A
U_{max}	2,9 V
No of Couples	23
Element Cross-Section	0.6x 0.6 mm^2
Element Height	0.95 mm
End Plates Ceramics	AlN
Assembly Solder	PbSn
Barrier	Ni
Connection	Horizontal wires
QUALIFICATION TESTS	
Power Cycling MIL Sdt 883 Method 1006 Telcordia GR-468 CORE. R4-94	Complete
Temperature Cycling MIL Std 883. method 1010 Condition B Teclcordia GR-468 CORE. R-93	Complete
Thermal Shock MIL Std 883 Method 1011 Condition A	Complete
High Temperature Storage 1000 hrs @ 100 C Telcordia GR-468 CORE. R-4-92	Complete
Mechanical Shock MIL STD 883 Method 2002. Condition B w/1 g mass Telcordia GR-468 CORE R4-89	Complete
Vibration Test MIL STD 883 Method 2007. Condition A 2/1 g mass Telcordia GR-468 CORE. R4-90	Complete
Soldarebility MIL Std 883 Method 2003	Complete

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