Thermoelectric Cooler Reliability Report

RMT Ltd
53 Leninskij prosp
Moscow 119991 Russia
Phone +7-095-132-6817
Fax +7-095-132-5870
e-mail rmtcom@dol.ru
http://www.rmtltd.ru

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Contents

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 has performed complex qualification testing of TE modules for application is Space program.

Thermoelectric cooler type– 1MC06-060-10.

1.2 Contents of This Report

Section 2 contains brief description of Qualification Test Program. Section 3 – brief description of produced batch of TE modules. Sections 4 through 9 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.

53 Leninskij prosp Moscow 119991 Russia phone +7-095-132-6817 fax +7-095-132-5870 e-mail rmtcom@dol.ru http://www.rmtltd.ru

2 Test Program

2.1 Test Program Content

Content of the Test Program is the following:

Table 2.1-1 Qualification Inspection Sequence

No	Test	Test Conditions
1	Electrical Measurements	Per Table 2.1.2
2	Mounting of units to test base	With InSb solder (117 °C)
3	Performance Test in Nitrogen	Note 1
4	Vibration	MIL-STD-883E, Method 2007.2, Vibration, Variable Frequency
5	Mechanical Shock	MIL-STD-883E, Method 2002.3, Mechanical Shock
6	Electrical Measurements	Per Table 2.1.2
7	Life Test	MIL-STD-883E, Method 1006, Intermittent Life T_{amb}= 85°C Current: I_{max}=1.65 A Cycle Time: 5 minutes on and 5 minutes off. Number of cycles: 6000 cycles (1000 hrs)
8	Performance Test in Vacuum	Note 1
9	Final electrical Measurement	Per Table 2.1.2, AC Resistance change: < 5% of initial value
10	External Visual Inspection	Note 2

Notes:

1) Verify that the performance meets the following specification:
   a. T_{hot} = 30 °C
   b. T_{cold} = -42 ±2°C
   c. Current = I_{max}=1.65 A ±5%
   d. Voltage = U_{max}=7.5 V ±5%
2) The TEC shall be examined to verify that the materials, design and construction, physical dimensions, marking and workmanship are in accordance with the requirements specified herein. They shall be free from cracks, voids, sharp edges and other defects that would be adversely affect life or serviceability.

Table 2.1-2 Electrical Measurements at Room Temperature

No	Characteristics	Symbol	Test Conditions	Limits		Unit	Note
				Min	Max		
1	AC Resistance	R		3.40	3.75	Ω	
2	Insulation Resistance	R_i	V_{DC}= 500 ± 50V	10	-	MΩ	

Testing includes the following methods:

1) Vibration
2) Mechanical Shock
3) Life Test (High temperature Burn-In)
4) To this report additional method is included – Temperature Cycling

2.2 Sampling Plan

Sampling Plan for the program is the following:

Table 2.2-1 Sampling Plan

No	Test	LTPD, %	Acceptance Number	Sample Size, pcs
1	Vibration	10	0	22
2	Mechanical Shock	10	0	22
3	Life Test (Power Cycle Test)	2	0	116
4	Temperature Cycling	7	0	32

2.3 Test Plan

Total batch of produced TE modules was divided into lots according to Test Plan:

Table 2.3.1 Test Plan

No	Test	Lot 22 pcs	Lot 22 pcs	Lot 116 pcs	Lot 32 pcs
1	Electrical Measurements	100%	100%	100%	100%
2	Performance Test in Vacuum	2 pcs	2 pcs	6 pcs	2 pcs
3	Vibration	100%	-	-	-
4	Mechanical Shock	-	100%	-	-
5	Life Test (Power Cycle Test)	-	-	100%	-
6	Temperature Cycling	-	-	-	100%
7	External Visual Inspection	100%	100%	100%	100%
8	Performance Test in Vacuum	2 pcs	2 pcs	6 pcs	2 pcs
9	Final Electrical Measurement	100%	100%	100%	100%

3 Methods

3.1 General

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

3.2 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.

3.3 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.

4 Thermoelectric Coolers

Total batch of 250 TE modules was produced for purposes of current Qualification Test Program. Production Specification # 1157 dated 15.12.2003. The Specification is attached.

All TE modules were hot side metallized and pre-tinned by InSn solder (117 deg. C melting point)

Hot side – nicked (clear) ceramics, except 12 samples prepared for performance testing in vacuum. Cold side of these 12 TE modules was metallized for thermocouples mounting.

The first 192 samples were divided into four lots according to Sampling Plan (Item 2.2).

5 Variable Frequency Vibration Testing

5.1 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.

5.2 Test Method Used

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

All 22 samples have been taken from produced batch # 1157 (Appendix 1).

Every TE module has been soldered (solder InSn, 117 deg. C melting point) onto individual flat copper sub-holder.

The 22 parts were 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 four more times. The axis was then changed and the sweep was repeated another four times. The same process was repeated for three axis as well.

A measurement of the AC Resistance and Figure-of-Merit of each part was taken before and after each test. Performance pre-test and post-test are compared of selected samples from the lot.

Performance pre-test and post-test are compared of selected samples from the lot.

5.3 Test Equipment Details

The following test equipment was used to conduct this test.

Vibration Machine ВЭДС-200А (Russia), S/N 44-24675.

TEC Vacuum Performance Tester DX3085.

DX4065 Z-Meter (ACR, Z, Time Constant), S/N 10-0012.

Insulation Tester MEG, P/N 690326.

Microscope LOMO Stereo-MX-3, S/N TT0009.

5.4 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.

Ambient conditions: temperature 22 ^{o}C, humidity 57%, pressure 742 mmHg

5.5 Test Data

After testing visual inspection shows no any damaged sample.

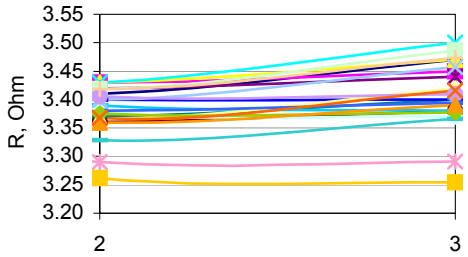
Insulation resistance measurement before and after testing shows R_i>300 MOhm, close to the upper level of Tester scale. Table with detailed listing of each tested samples did not included into the document.

Table 5.1-1 shows the data from the test of the TEC 1MC06-060-10 part. The before and after test Resistances in Ohms and Figure-of-Merit (Z) in 1000/K are shown, as well as the calculated change value.

Table 5.5-1. Resistance and Figure-of-Merit Data for TEC 1MC06-060-10 Vibration Test (dated 20/01/04)

Sample #	Before Ohm	After Ohm	ΔR %
A1	3.41	3.47	1.76%
A2	3.43	3.45	0.58%
A3	3.43	3.47	1.17%
A4	3.43	3.50	2.04%
A5	3.42	3.44	0.58%
A6	3.36	3.38	0.60%
A7	3.37	3.40	0.89%
A8	3.40	3.40	0.00%
A9	3.39	3.38	-0.29%
A10	3.38	3.37	-0.30%
A11	3.42	3.49	1.95%
A12	3.37	3.42	1.55%
A13	3.40	3.46	1.67%
A14	3.29	3.29	0.01%
A15	3.41	3.41	0.12%
A16	3.42	3.47	1.60%
A17	3.38	3.39	0.42%
A18	3.33	3.37	1.13%
A19	3.38	3.38	0.06%
A20	3.26	3.25	-0.22%
A21	3.36	3.39	0.92%
A22	3.37	3.42	1.44%
Average	**3.38**	**3.41**	**0.80%**
Min	**3.26**	**3.25**	**-0.30%**
Max	**3.43**	**3.50**	**2.04%**

Sample #	Before 1000/K	After 1000/K	ΔZ %
A1	2.70	2.73	1.11%
A2	2.72	2.72	0.00%
A3	2.73	2.74	0.37%
A4	2.74	2.69	-1.82%
A5	2.72	2.71	-0.37%
A6	2.75	2.73	-0.73%
A7	2.72	2.72	0.00%
A8	2.75	2.72	-1.09%
A9	2.74	2.74	0.00%
A10	2.69	2.64	-1.86%
A11	2.71	2.69	-0.77%
A12	2.72	2.73	0.40%
A13	2.73	2.72	-0.37%
A14	2.72	2.66	-2.17%
A15	2.72	2.67	-1.75%
A16	2.72	2.74	0.64%
A17	2.73	2.70	-1.11%
A18	2.71	2.71	0.04%
A19	2.70	2.72	0.69%
A20	2.74	2.71	-1.06%
A21	2.71	2.68	-0.86%
A22	2.70	2.67	-1.28%
Average	**2.72**	**2.71**	**-0.54%**
Min	**2.69**	**2.64**	**1.11%**
Max	**2.75**	**2.74**	**-2.17%**



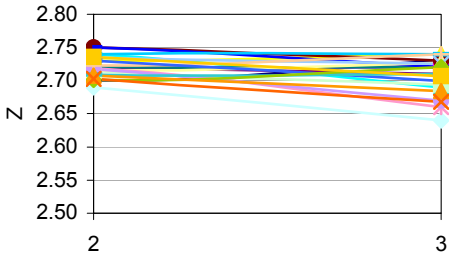


Table 5.5-2 Performance of TECs 1MC06-060-10 before and after Vibration Test

Sample #	Before test			After test		
	ΔT_{max} K	U_{max} V	I_{max} A	ΔT_{max} K	U_{max} V	I_{max} A
A11	70.5	7.3	1820	69.8	7.4	1820
A22	70.0	7.2	1800	69.5	7.3	1800

5.6 Test Results

5.6.1 A total of 22 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 maximal change in resistance 2.04%, minimal change -0.37 %. The average change value is of 0.80%.

5.6.2 Figure–of-Merit (Z) was controlled too. All parts showed slight change of TEC performance with maximal change in Z is -2.17%, minimal change 1.11%. The average change value is of -0.54%.

Performance testing in vacuum also before and after test of selected samples showed good correlation with Z measurements of all samples of the lot – correspondent only slight reduction of ΔT_{max}

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.

All 22 samples have been taken from produced batch # 1157 (Appendix 1).

Every TE module has been soldered (solder InSn, 117 deg. C melting point) onto individual flat copper sub-holder.

The 22 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 AC Resistance and Figure-of-Merit of each part was taken before and after each test. Performance pre-test and post-test are compared of selected samples from the lot.

Performance pre-test and post-test are compared of selected samples from the lot.

6.3 Test Equipment Details

The following test equipment was used to conduct this test.

Single Impact Machine STT, S/N P24/78-13617.

TEC Vacuum Performance Tester DX3085.

DX4065 Z-Meter (ACR, Z, Time Constant), S/N 10-0012.

Insulation Tester MEG, P/N 690326.

Microscope LOMO Stereo-MX-3, S/N TT0009.

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.

Ambient conditions: temperature 22 ^{o}C, humidity 56%, pressure 740 mmHg

6.5 Test Data

After testing visual inspection shows no any damaged sample.

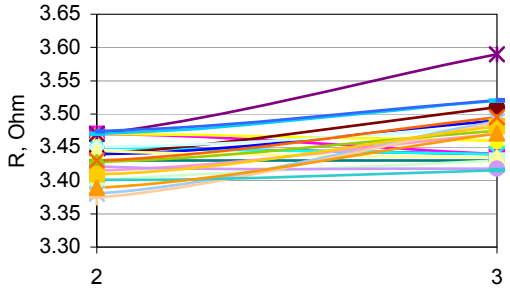
Insulation resistance measurement before and after testing shows R_i>300 MOhm, close to the upper level of Tester scale. Table with detailed listing of each tested samples did not included into the document.

Table 6.5-1 shows the data from the test of the TEC 1MC06-060-10 part. The before and after test AC Resistances in Ohms and Figure-of-Merit (Z) in 1000/K are shown, as well as the calculated change value.

Table 6.5-1. Resistance and Figure-of-Merit Data for TEC 1MC06-060-10 Mechanical Shock Test (dated 27/01/04)

Sample #	R Before	R After	ΔR
B1	3.45	3.44	-0.29%
B2	3.47	3.44	-0.86%
B3	3.47	3.46	-0.29%
B4	3.45	3.44	-0.29%
B5	3.47	3.59	3.46%
B6	3.44	3.51	2.03%
B7	3.43	3.43	0.00%
B8	3.44	3.49	1.45%
B9	3.47	3.52	1.44%
B10	3.45	3.48	0.87%
B11	**3.40**	**3.43**	**0.88%**
B12	3.44	3.43	-0.29%
B13	3.38	3.49	3.23%
B14	3.41	3.47	1.64%
B15	3.42	3.42	-0.10%
B16	3.37	3.49	3.33%
B17	3.47	3.52	1.33%
B18	3.40	3.42	0.42%
B19	3.43	3.48	1.38%
B20	3.41	3.48	2.11%
B21	3.39	3.47	2.42%
B22	**3.43**	**3.50**	**1.90%**
Average	**3.43**	**3.47**	**1.17%**
Min	**3.37**	**3.42**	**-0.86%**
Max	**3.47**	**3.59**	**3.46%**

Sample #	Z Before	Z After	ΔZ
B1	2.74	2.73	-0.36%
B2	2.75	2.74	-0.36%
B3	2.74	2.74	0.00%
B4	2.75	2.75	0.00%
B5	2.74	2.66	-2.92%
B6	2.75	2.68	-2.55%
B7	2.74	2.73	-0.36%
B8	2.75	2.73	-0.73%
B9	2.74	2.74	0.00%
B10	2.75	2.76	0.36%
B11	**2.74**	**2.74**	**0.00%**
B12	2.70	2.63	-2.78%
B13	2.69	2.64	-1.72%
B14	2.70	2.69	-0.54%
B15	2.74	2.69	-1.82%
B16	2.75	2.74	-0.45%
B17	2.69	2.63	-2.05%
B18	2.69	2.61	-3.17%
B19	2.69	2.67	-0.88%
B20	2.67	2.61	-1.98%
B21	2.69	2.65	-1.52%
B22	**2.74**	**2.75**	**0.30%**
Average	**2.72**	**2.70**	**-1.07%**
Min	**2.67**	**2.61**	**0.36%**
Max	**2.75**	**2.76**	**-3.17%**



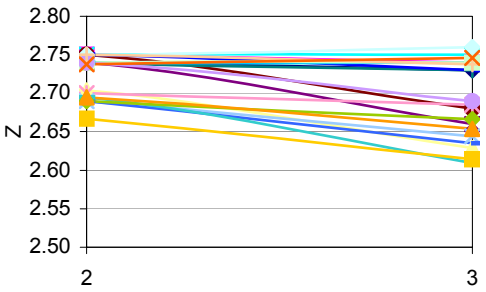


Table 6.5-1. Performance of TECs 1MC06-060-10 before and after Mechanical Shock Test

Sample #	Before test			After test		
	ΔT_{max} K	U_{max} V	I_{max} A	ΔT_{max} K	U_{max} V	I_{max} A
B11	71.0	7.5	1850	70.0	7.6	1850
B22	70.5	7.3	1800	70.5	7.4	1800

6.6 Test Results

6.6.1 A total of 22 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 maximal change in resistance 3.46%, minimal change -0.86 %. The average change value is of 1.17%.

6.6.2 Figure–of-Merit (Z) was controlled too. All parts showed slight change of TEC performance with maximal change in Z is -3.17%, minimal change 0.36%. The average change value is of -1.07%.

6.6.3 Performance testing in vacuum also before and after test of selected samples showed good correlation with Z measurements of all samples of the lot – correspondent only slight reduction of ΔT_{max}

7 Temperature Cycling

7.1 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.

7.2 Test Method Used

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

All 32 samples have been taken from produced batch # 1157 (Appendix 1).

The ovens were then heated to 125^{o}C and the cold chamber was brought down to -55^{o}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. Fast transfer between cold and hot chambers (less then 5 sec) was provided.

This cycling was repeated until any sample of the tested lot reaches 5% change in AC Resistance.

A measurement of the AC Resistance and Figure-of-Merit of each part was taken before and after each test. Performance pre-test and post-test are compared of selected samples from the lot.

Performance pre-test and post-test are compared of selected samples from the lot..

7.3 Test Equipment Details

The following test equipment was used to conduct this test.

TABAI Thermal Shock Chamber TSE-10, S/N450118

TEC Vacuum Performance Tester DX3085.

DX4065 Z-Meter (ACR, Z, Time Constant), S/N 10-0012.

Insulation Tester MEG, P/N 690326.

Microscope LOMO Stereo-MX-3, S/N TT0009.

7.4 Test Parameters

The hot chamber temperature was set to 125^{o}C. while the cold chamber was set to -55^{o}C. The parts were held at each temperature for a minimum of 10 minutes for each exposure.

This cycling was repeated until any sample of the tested lot reaches 5% change in AC Resistance.

7.5 Test Data

After testing visual inspection shows no any damaged sample.

Insulation resistance measurement before and after testing shows R_i>300 MOhm, close to the upper level of Tester scale. Table with detailed listing of each tested samples did not included into the document.

Tables 7.5-1 and 7.5-2 shows the data from the test of the TEC 1MC06-060-10 part. The before and after test AC Resistances in Ohms and Figure-of-Merit (Z) in 1000/K are shown, as well as the calculated change value.

Table 7.5-1. Resistance Data for TEC 1MC06-060-10 Temperature Cycling Test (finished 25.01.04)

Sample #	Cycles/R, Ohm								ΔR
	0	130	270	410	500	630	760	900	
C1	3.45	3.45	3.54	3.54	3.48	3.53	3.59	3.57	3.48%
C2	3.48	3.46	3.46	3.48	3.45	3.54	3.51	3.52	1.15%
C3	3.50	3.49	3.56	3.52	3.49	3.51	3.55	3.55	1.43%
C4	3.50	3.47	3.49	3.49	3.46	3.52	3.48	3.51	0.29%
C5	3.49	3.47	3.54	3.56	3.51	3.56	3.55	3.57	2.29%
C6	3.44	3.41	3.48	3.48	3.42	3.50	3.43	3.47	0.87%
C7	3.35	3.36	3.42	3.40	3.39	3.43	3.42	3.45	2.99%
C8	3.36	3.37	3.43	3.44	3.42	3.45	3.44	3.51	4.46%
C9	3.47	3.45	3.51	3.50	3.55	3.54	3.57	3.53	1.73%
C10	3.49	3.47	3.47	3.49	3.51	3.54	3.48	3.53	1.15%
C11	**3.43**	**3.41**	**3.44**	**3.42**	**3.45**	**3.45**	**3.44**	**3.45**	**0.58%**
C12	3.52	3.48	3.51	3.49	3.52	3.49	3.51	3.51	-0.28%
C13	3.44	3.45	3.51	3.47	3.49	3.46	3.50	3.51	2.03%
C14	3.44	3.44	3.46	3.45	3.48	3.52	3.46	3.47	0.87%
C15	3.41	3.41	3.43	3.46	3.51	3.51	3.46	3.46	1.47%
C16	3.45	3.45	3.48	3.47	3.48	3.47	3.45	3.51	1.74%
C17	3.47	3.44	3.45	3.47	3.48	3.51	3.46	3.48	0.29%
C18	3.45	3.43	3.43	3.42	3.42	3.45	3.43	3.46	0.29%
C19	3.47	3.44	3.46	3.45	3.44	3.44	3.45	3.46	-0.29%
C20	3.41	3.42	3.41	3.41	3.41	3.46	3.50	3.44	0.88%
C21	3.38	3.39	3.47	3.39	3.40	3.42	3.43	3.43	1.48%
C22	**3.36**	**3.35**	**3.38**	**3.37**	**3.36**	**3.38**	**3.40**	**3.38**	**0.60%**
C23	3.36	3.40	3.44	3.45	3.46	3.49	3.38	3.52	4.76%
C24	3.36	3.37	3.39	3.38	3.39	3.40	3.40	3.41	1.49%
C25	3.37	3.37	3.37	3.38	3.39	3.39	3.39	3.40	0.89%
C26	3.36	3.35	3.37	3.38	3.40	3.38	3.39	3.41	1.49%
C27	3.45	3.45	3.44	3.46	3.48	3.51	3.48	3.48	0.87%
C28	3.44	3.43	3.43	3.44	3.45	3.48	3.46	3.46	0.58%
C29	3.43	3.43	3.43	3.47	3.44	3.48	3.46	3.47	1.17%
C30	3.35	3.37	3.39	3.39	3.44	3.41	3.46	3.41	1.79%
C31	3.43	3.42	3.45	3.46	3.49	3.51	3.47	3.50	2.04%
C32	3.39	3.41	3.39	3.42	3.45	3.47	3.42	3.43	1.18%
Average	3.43	3.42	3.45	3.45	3.45	3.48	3.46	3.48	**1.43%**
Min	3.35	3.35	3.37	3.37	3.36	3.38	3.38	3.38	**-0.29%**
Max	3.47	3.45	3.51	3.47	3.51	3.52	3.50	3.52	**4.76%**

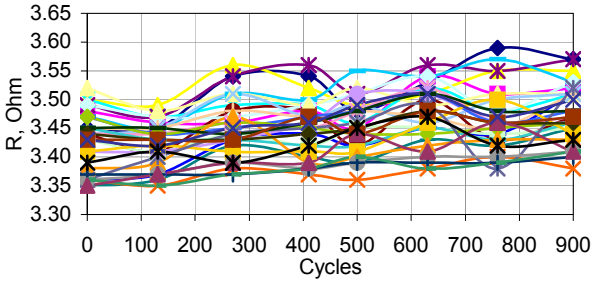


Table 7.5-2. Figure-of-Merit TEC 1MC06-060-10 Temperature Cycling Test (finished 25.01.04)

Sample #	Cycles/Z, 1000/K								ΔZ
	0	130	270	410	500	630	760	900	
C1	2.76	2.74	2.75	2.73	2.73	2.73	2.73	2.73	-1.09%
C2	2.79	2.79	2.78	2.79	2.77	2.80	2.77	2.78	-0.36%
C3	2.73	2.73	2.73	2.73	2.68	2.72	2.72	2.73	0.00%
C4	2.72	2.71	2.71	2.71	2.69	2.71	2.70	2.70	-0.74%
C5	2.73	2.72	2.71	2.71	2.68	2.70	2.70	2.70	-1.10%
C6	2.70	2.70	2.71	2.70	2.69	2.70	2.69	2.69	-0.37%
C7	2.71	2.69	2.70	2.69	2.64	2.69	2.68	2.68	-1.11%
C8	2.74	2.72	2.72	2.71	2.71	2.70	2.70	2.71	-1.09%
C9	2.75	2.74	2.71	2.73	2.74	2.73	2.72	2.72	-1.09%
C10	2.74	2.74	2.74	2.73	2.73	2.73	2.72	2.71	-1.09%
C11	**2.72**	**2.72**	**2.72**	**2.71**	**2.72**	**2.71**	**2.70**	**2.71**	**-0.37%**
C12	2.77	2.76	2.76	2.75	2.76	2.75	2.75	2.75	-0.72%
C13	2.73	2.72	2.76	2.72	2.72	2.72	2.72	2.71	-0.73%
C14	2.76	2.75	2.78	2.74	2.74	2.73	2.73	2.71	-1.81%
C15	2.71	2.70	2.73	2.70	2.71	2.71	2.71	2.72	0.37%
C16	2.75	2.74	2.78	2.74	2.73	2.73	2.73	2.73	-0.73%
C17	2.74	2.74	2.77	2.74	2.73	2.74	2.73	2.73	-0.36%
C18	2.66	2.66	2.64	2.65	2.64	2.65	2.64	2.64	-0.75%
C19	2.75	2.75	2.73	2.73	2.72	2.73	2.72	2.72	-1.09%
C20	2.73	2.73	2.72	2.72	2.71	2.72	2.67	2.71	-0.73%
C21	2.70	2.69	2.69	2.68	2.68	2.68	2.71	2.67	-1.11%
C22	**2.74**	**2.74**	**2.74**	**2.73**	**2.73**	**2.73**	**2.68**	**2.72**	**-0.73%**
C23	2.73	2.71	2.69	2.69	2.68	2.68	2.73	2.67	-2.20%
C24	2.74	2.74	2.73	2.72	2.72	2.71	2.72	2.71	-1.09%
C25	2.77	2.76	2.75	2.75	2.75	2.75	2.74	2.74	-1.08%
C26	2.74	2.73	2.73	2.72	2.72	2.71	2.71	2.70	-1.46%
C27	2.74	2.74	2.73	2.73	2.73	2.73	2.72	2.72	-0.73%
C28	2.71	2.70	2.70	2.69	2.70	2.70	2.69	2.69	-0.74%
C29	2.76	2.75	2.75	2.74	2.75	2.75	2.74	2.74	-0.72%
C30	2.77	2.76	2.75	2.75	2.75	2.74	2.75	2.74	-1.08%
C31	2.68	2.67	2.66	2.65	2.66	2.65	2.64	2.65	-1.12%
C32	2.77	2.77	2.70	2.75	2.76	2.76	2.69	2.69	-2.89%
Average	2.74	2.73	2.73	2.72	2.71	2.72	2.71	2.71	**-0.94%**
Min	2.66	2.66	2.64	2.65	2.64	2.65	2.64	2.64	**-2.89%**
Max	2.77	2.77	2.78	2.75	2.76	2.76	2.75	2.74	**0.37%**

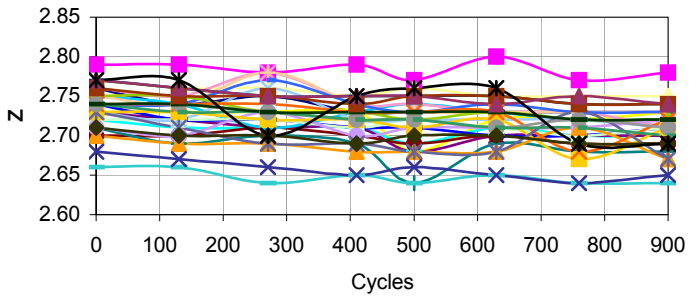


Table 7.5-3. Performance of TECs 1MC06-060-10 before and after Temperature Cycling Test

Sample #	Before test			After test		
	ΔT_{max} K	U_{max} V	I_{max} mA	ΔT_{max} K	U_{max} V	I_{max} mA
C11	70.2	7.3	1800	70.0	7.4	1800
C22	70.5	7.3	1850	70.3	7.4	1850

7.6 Test Results

7.6.1 A total of 32 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 maximal change in resistance 4.76%, minimal change -0.29 %. The average change value is of 1.43%.

7.6.2 Figure –of-Merit (Z) was controlled too. All parts showed slight change of TEC performance with maximal change in Z is -2.89%, minimal change 0.37%. The average change value is of -0.94%.

7.6.3 Performance testing in vacuum also before and after test of selected samples showed good correlation with Z measurements of all samples of the lot – correspondent only slight reduction of ΔT_{max}

7.6.4 The tested samples withstood 9 times longer testing than required by Telcordia GR-468 CORE.

8 Power Cycle Testing

8.1 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.

8.2 Test Method Used

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

It is required to confirm reliability of selected TE modules of 50 FIT. That is why sample size increased to 116 samples (LTPD 2%) is applied.

All 116 samples have been taken from produced batch # 1157 (Appendix 1).

Every TE module has been soldered (solder InSn, 117 deg. C melting point) onto individual flat copper sub-holder.

Prior to the test, the AC Resistance and Insulation Resistance of each TE module were recorded. Measurement of Performance in vacuum of 6 selected samples has been made prior the test.

Every TE module mounted onto sub-holder has been mounted onto common heat sink using thermally conductive grease as an interface material. The wires from the test TE modules were run to a power supply controlled by a programmable controller. The heat sink with mounted TE modules was placed into oven.

The oven temperature was then set to keep the parts at 85^{o}C. The programmable controller cycled the thermoelectric modules between the “on” and “off” conditions for 1000 hours.

8.3 Test Equipment Details

The following test equipment was used to conduct this test.

HERAEUS Power Controller KRGU.UI-45-7785

HERAEUS Oven HEP 2, S/N 8903510

DX2050 Programmable Time Controller

TEC Vacuum Performance Tester DX3085.

DX4065 Z-Meter (ACR, Z, Time Constant), S/N 10-0012.

Insulation Tester MEG, P/N 690326.

Microscope LOMO Stereo-MX-3, S/N TT0009.

8.4 Test Parameters

The TE modules were run at maximum current (I_{max}) according to specification on the TE modules, which was specified as 1.65 Amps at a duty cycle of 5 min on and 5 min off.

The ambient temperature was set at 85^{o}C, and the parts were tested for 1000 hrs (6000 cycles) to meet the requirements of the intermittent life test.

8.5 Test Data

After testing visual inspection shows no any damaged sample.

Insulation resistance measurement before and after testing shows R_i>300 MOhm, close to the upper level of Tester scale. Table with detailed listing of each tested samples did not included into the document.

Tables 8.5-1 and 8.5-2 shows the data from the test of the TEC 1MC06-060-10 part. The before and after test AC Resistances in Ohms and Figure-of-Merit (Z) in 1000/K are shown, as well as the calculated change value.

Table 8.5-1. Resistance (Ohm) Data for TEC 1MC06-060-10 Power Cycling (finished 24.01.04)

Samples #	Before	After	ΔR	Samples #	Before	After	ΔR	Samples #	Before	After	ΔR
D1	**3.43**	**3.49**	**1.54%**	D45	3.40	3.50	2.83%	D89	3.40	3.48	2.46%
D2	3.37	3.47	2.88%	D46	3.42	3.49	1.93%	D90	3.37	3.50	3.75%
D3	3.42	3.46	1.17%	D47	3.42	3.52	2.90%	D91	3.38	3.49	3.38%
D4	3.39	3.44	1.47%	D48	3.38	3.47	2.61%	D92	3.38	3.45	2.12%
D5	3.38	3.42	1.15%	D49	3.42	3.52	2.78%	D93	3.41	3.48	2.08%
D6	3.39	3.51	3.57%	D50	3.37	3.41	1.20%	D94	3.43	3.48	1.46%
D7	3.38	3.51	3.76%	D51	3.44	3.52	2.47%	D95	3.39	3.51	3.53%
D8	3.38	3.45	2.10%	D52	3.40	3.49	2.75%	D96	3.40	3.50	3.02%
D9	3.38	3.43	1.48%	D53	3.40	3.50	2.85%	D97	3.40	3.47	2.20%
D10	3.42	3.48	1.75%	D54	3.38	3.51	3.70%	D98	3.45	3.56	3.22%
D11	3.40	3.43	0.76%	D55	3.44	3.50	1.65%	D99	3.40	3.51	3.03%
D12	3.42	3.48	1.77%	D56	3.40	3.45	1.60%	D100	3.42	3.48	1.63%
D13	3.40	3.50	2.98%	D57	3.39	3.48	2.72%	D101	3.41	3.47	1.65%
D14	3.40	3.52	3.50%	D58	3.39	3.44	1.57%	D102	3.42	3.54	3.61%
D15	3.39	3.44	1.49%	D59	3.38	3.45	2.11%	D103	3.38	3.48	2.97%
D16	3.38	3.45	1.93%	D60	3.40	3.53	3.66%	D104	3.39	3.49	2.84%
D17	3.42	3.49	2.07%	D61	3.42	3.47	1.56%	D105	3.41	3.52	3.13%
D18	3.40	3.46	1.81%	D62	3.43	3.49	1.69%	D106	3.44	3.56	3.41%
D19	3.42	3.50	2.33%	D63	3.40	3.48	2.10%	D107	3.42	3.48	1.68%
D20	3.42	3.50	2.30%	D64	3.37	3.48	3.24%	D108	3.39	3.47	2.15%
D21	3.40	3.49	2.73%	D65	3.39	3.51	3.40%	D109	3.36	3.47	3.05%
D22	**3.41**	**3.45**	**1.23%**	**D66**	**3.39**	**3.43**	**1.41%**	**D110**	**3.42**	**3.47**	**1.54%**
D23	3.40	3.49	2.87%	D67	3.44	3.57	3.65%	D111	3.40	3.48	2.24%
D24	3.42	3.52	3.01%	D68	3.40	3.46	1.95%	D112	3.43	3.49	1.54%
D25	3.41	3.54	3.95%	D69	3.42	3.48	2.04%	D113	3.42	3.47	1.58%
D26	3.42	3.52	2.91%	D70	3.38	3.44	1.71%	D114	3.40	3.51	3.29%
D27	3.40	3.46	1.60%	D71	3.41	3.51	2.98%	D115	3.41	3.50	2.61%
D28	3.40	3.47	2.19%	D72	3.40	3.49	2.63%	D116	3.39	3.50	3.37%
D29	3.37	3.47	2.87%	D73	3.43	3.54	3.38%	**Average**	**3.40**	**3.48**	**2.35%**
D30	3.42	3.46	1.31%	D74	3.38	3.46	2.42%	**Min**	**3.37**	**3.42**	**0.76%**
D31	3.44	3.50	1.94%	D75	3.39	3.44	1.41%	**Max**	**3.44**	**3.54**	**3.95%**
D32	3.42	3.53	3.28%	D76	3.37	3.49	3.57%				
D33	3.38	3.45	1.89%	D77	3.41	3.46	1.69%				
D34	3.43	3.54	3.32%	D78	3.43	3.50	2.17%				
D35	3.40	3.46	1.60%	D79	3.39	3.47	2.31%				
D36	3.42	3.51	2.70%	D80	3.40	3.46	1.70%				
D37	3.39	3.50	3.14%	D81	3.41	3.52	3.43%				
D38	3.41	3.51	2.71%	D82	3.39	3.44	1.73%				
D39	3.42	3.51	2.63%	D83	3.39	3.49	3.16%				
D40	3.41	3.54	3.53%	D84	3.42	3.51	2.65%				
D41	3.37	3.44	2.05%	D85	3.40	3.45	1.58%				
D42	3.40	3.46	1.81%	D86	3.39	3.44	1.59%				
D43	3.40	3.52	3.50%	D87	3.43	3.52	2.75%				
D44	**3.44**	**3.53**	**2.66%**	**D88**	**3.42**	**3.54**	**3.42%**				

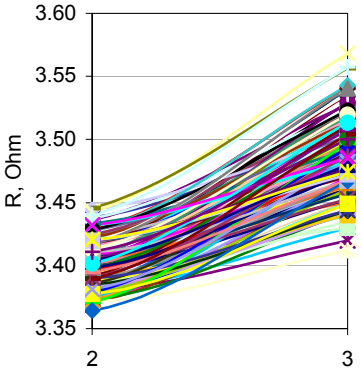


Table 8.5-2. Figure-of-Merit (1000/K) for TEC 1MC06-060-10 Power Cycling (finished 24.01.04)

Samples #	Before	After	ΔR	Samples #	Before	After	ΔR	Samples #	Before	After	ΔR
D1	**2.75**	**2.64**	**-4.00%**	D45	2.73	2.67	-2.09%	D89	2.72	2.66	-2.28%
D2	2.70	2.66	-1.48%	D46	2.75	2.66	-3.20%	D90	2.68	2.64	-1.35%
D3	2.73	2.72	-0.37%	D47	2.73	2.70	-1.10%	D91	2.71	2.65	-2.21%
D4	2.69	2.66	-1.12%	D48	2.73	2.64	-3.26%	D92	2.69	2.64	-1.79%
D5	2.73	2.69	-1.47%	D49	2.72	2.67	-1.77%	D93	2.73	2.66	-2.60%
D6	2.69	2.62	-2.53%	D50	2.72	2.66	-2.13%	D94	2.75	2.66	-3.10%
D7	2.71	2.70	-0.48%	D51	2.69	2.60	-3.27%	D95	2.74	2.65	-3.14%
D8	2.70	2.60	-3.70%	D52	2.71	2.69	-0.81%	D96	2.73	2.65	-2.79%
D9	2.73	2.72	-0.44%	D53	2.73	2.65	-3.00%	D97	2.70	2.62	-2.82%
D10	2.73	2.72	-0.37%	D54	2.72	2.63	-3.38%	D98	2.72	2.69	-1.03%
D11	2.72	2.68	-1.47%	D55	2.68	2.58	-3.70%	D99	2.73	2.63	-3.66%
D12	2.72	2.66	-2.13%	D56	2.72	2.64	-2.76%	D100	2.73	2.66	-2.42%
D13	2.76	2.71	-1.63%	D57	2.74	2.70	-1.35%	D101	2.73	2.65	-2.89%
D14	2.73	2.61	-4.40%	D58	2.70	2.60	-3.74%	D102	2.69	2.64	-1.93%
D15	2.70	2.66	-1.65%	D59	2.71	2.61	-3.55%	D103	2.73	2.71	-0.84%
D16	2.70	2.65	-1.85%	D60	2.73	2.63	-3.56%	D104	2.70	2.65	-1.96%
D17	2.73	2.67	-2.34%	D61	2.73	2.63	-3.70%	D105	2.71	2.64	-2.73%
D18	2.74	2.71	-0.95%	D62	2.69	2.66	-0.93%	D106	2.68	2.64	-1.42%
D19	2.70	2.68	-0.78%	D63	2.71	2.68	-1.18%	D107	2.74	2.65	-3.28%
D20	2.71	2.68	-1.18%	D64	2.68	2.64	-1.46%	D108	2.70	2.61	-3.44%
D21	2.73	2.71	-0.81%	D65	2.71	2.61	-3.55%	D109	2.71	2.63	-2.95%
D22	**2.68**	**2.58**	**-3.87%**	**D66**	**2.73**	**2.63**	**-3.66%**	**D110**	**2.75**	**2.71**	**-1.38%**
D23	2.70	2.69	-0.41%	D67	2.73	2.68	-1.83%	D111	2.70	2.65	-1.74%
D24	2.73	2.68	-1.87%	D68	2.73	2.63	-3.66%	D112	2.69	2.62	-2.71%
D25	2.73	2.65	-2.79%	D69	2.71	2.61	-3.73%	D113	2.68	2.59	-3.43%
D26	2.70	2.67	-1.22%	D70	2.69	2.64	-1.79%	D114	2.70	2.66	-1.37%
D27	2.69	2.66	-1.19%	D71	2.69	2.64	-1.68%	D115	2.73	2.72	-0.33%
D28	2.72	2.69	-1.18%	D72	2.73	2.68	-1.90%	D116	2.73	2.69	-1.47%
D29	2.75	2.64	-3.83%	D73	2.69	2.66	-1.23%	**Average**	**2.72**	**2.67**	**-1.85%**
D30	2.73	2.65	-3.07%	D74	2.67	2.60	-2.77%	**Min**	**2.68**	**2.58**	**-0.37%**
D31	2.69	2.59	-3.68%	D75	2.72	2.66	-2.13%	**Max**	**2.76**	**2.72**	**-4.40%**
D32	2.72	2.70	-0.74%	D76	2.68	2.67	-0.34%				
D33	2.69	2.61	-2.94%	D77	2.73	2.69	-1.54%				
D34	2.73	2.71	-0.73%	D78	2.70	2.66	-1.44%				
D35	2.72	2.62	-3.53%	D79	2.74	2.71	-0.95%				
D36	2.70	2.66	-1.44%	D80	2.74	2.71	-1.20%				
D37	2.73	2.64	-3.40%	D81	2.69	2.66	-1.26%				
D38	2.70	2.68	-0.85%	D82	2.73	2.67	-2.34%				
D39	2.70	2.66	-1.37%	D83	2.76	2.65	-3.85%				
D40	2.71	2.64	-2.62%	D84	2.70	2.68	-0.78%				
D41	2.72	2.65	-2.50%	D85	2.68	2.59	-3.39%				
D42	2.71	2.69	-0.66%	D86	2.74	2.72	-0.55%				
D43	2.73	2.68	-1.69%	D87	2.69	2.60	-3.38%				
D44	**2.71**	**2.69**	**-0.88%**	**D88**	**2.72**	**2.70**	**-0.63%**				

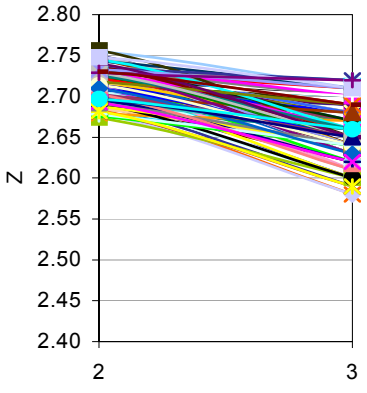
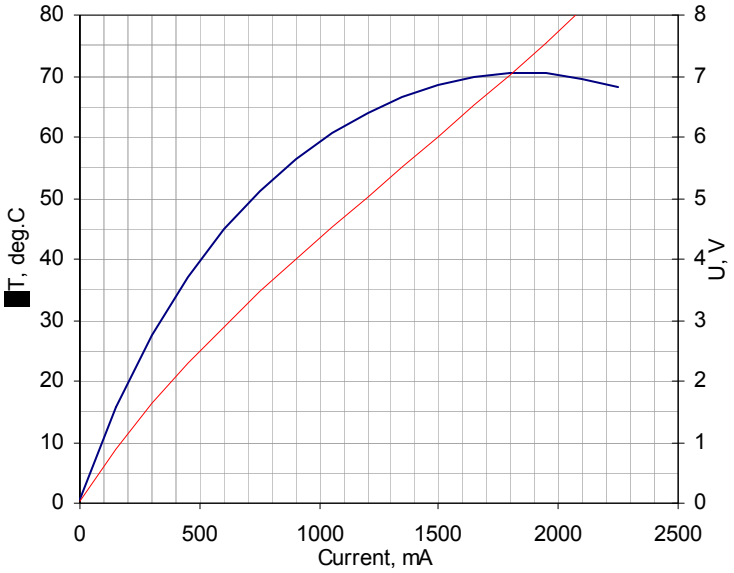


Table 8.5-3. Performance of TECs 1MC06-060-10 before and after Power Cycling

Sample #	Before test			After test		
	ΔT_{max} K	U_{max} V	I_{max} mA	ΔT_{max} K	U_{max} V	I_{max} mA
D1	71.0	7.4	1850	69.5	7.4	1850
D22	70.5	7.3	1850	69.0	7.4	1850
D44	71.0	7.3	1830	70.0	7.5	1830
D66	71.0	7.2	1800	70.0	7.3	1810
D88	71.0	7.2	1800	70.5	7.5	1830
D110	71.5	7.2	1820	70.0	7.3	1820

Fig. 8.5-1. Example of Performance Test in vacuum (sample # D22, before)



8.6 Test Results

8.6.1 A total of 116 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 maximal change in resistance 3.95%, minimal change -0.76%. The average change value is of 2.35%.

8.6.2 Figure–of-Merit (Z) was controlled too. All parts showed slight change of TEC performance with maximal change in Z is -4.40%, minimal change - 0.37%. The average change value is of -1.85%.

8.6.3 Performance testing in vacuum also before and after test of selected samples showed good correlation with Z measurements of all samples of the lot – correspondent only slight reduction of ΔT_{max}

9 Thermoelectric Cooler Qualification Summary Sheet

TEC MODEL	**1MC06-060-10**
Cold Side Dimensions	10 x 12 mm^2
Hot Side Dimensions	12 x 12 mm^2
Height	2,1 mm
ΔT_{max}	72 deg.
Q_{max}	6.6 W
I_{max}	1.65 A
U_{max}	7.5 V
No of Couples	60
Element Cross-Section	0.6x 0.6 mm^2
Element Height	1.0 mm
End Plates Ceramics	Al_2O_3 (100%)
Assembly Solder	PbSn (187 deg. C)
Barrier	Ni
Connection	Horizontal wires
QUALIFICATION TESTS	
Power Cycling Specification No A10-DJO-TS-0005, Table 8-1 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
Mechanical Shock Specification No A10-DJO-TS-0005, Table 8-1 MIL STD 883 Method 2002. Condition B Telcordia GR-468 CORE R4-89	Complete
Vibration Test Specification No A10-DJO-TS-0005, Table 8-1 MIL STD 883 Method 2007. Condition A 2 Telcordia GR-468 CORE. R4-90	Complete

Quality Manager _____ Y.V. Zakhartsev

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