Thermoelectric Cooler
Reliability Report

Thermion

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1. Introduction

This section contains a description of the testing background and a brief overview of this Report.

1.1 Background

With the goal of providing advanced information about our thermoelectric coolers (TECs), Thermion has performed reliability tests of the module 1MC(L)04-6.4x2.4-08-0000. The tests were executed according to the specifications accepted in military and telecommunications industries.

The TEC 1MC(L)04-6.4x2.4-08-0000 has twenty two TE pellets each 0.8 mm long and 0.4x0.4 mm in cross-section. Overall dimensions are as follows: length - 6.4 mm, width - 2.4 mm, height – 1.5 mm. Nominal themoelectic parameters: maximum current – 1A, maximum voltage – 1.5 V, maximum temperature difference 72+/-2°C, maximum cooling power 0.87 W. The TEC is supplied with alumina substrates without metallization at outer surfaces.

1.2 Contents of the Report

Section 2 to 9 contain detailed information concerning different types of testing conducted on the specified module. For each test, its purpose, test method, used equipment, test conditions, results and conclusion are represented.

2. Methods

2.1 General

Methods used for the testing herein are based on military standards and Telcordia requirements for microelectronic devices.

2.2 Military standards

Military standards (MIL-STD) were originally developed for defense and aerospace related products, but lately they are adopted for tests and specification of a wide range of thermoelectric devices from those used for telecommunications to those destined for medical application.

2.3 Telcordia requirements

Telcordia requirements define the methods, conditions and equipments for reliability tests of optoelectronic devices for telecommunication market. Telcordia's GR-408 CORE is their generic reliability requirement.

3. Mechanical Shock Testing

3.1 Purpose of the Test

The test is intended to determine the suitability of the TEC for use in equipment which may be subjected to severe shocks as a result of a suddenly applied forces or abrupt changes in motion.

3.2 Test method used

Test method used: MIL-STD-883E, Method 2002, Condition B, Mechanical Shock, 1500 G, 0.5 ms, 5 times/axis.

3.3 Procedure

Total 12 modules were manufactured with metallized bottom substrates for this test and were put to the pre-test ACR and Z measurement. Then the modules were soldered to the metallized and patterned alumina plate, which was glued with epoxy adhesive to the duralumin test platform. These items then were subjected to the shock at 1500 G level with 0.5 ms duration half-sine wave pulse. Each item was shocked total 5 times in the first axis. The axis was then changed and the shock was repeated another 5 times. This procedure was repeated for each of the remaining four axes as well. A measurement of resistance of each part was made before and after each test.

3.4 Test equipment

Percussion Test Stand ИСУ-1 (Institute of Thermoelectricity, Chernivtsy, Ukraine)

Thermion ACR-Z- meter.

3.5 Test Parameters

The test was conducted at a room temperature with parts in non-operating mode. A total of 5 shocks were conducted in each of 6 axes.

3.6 Test Data

Table 3.1 Resistance data (Ohm) and Z-factor for Mechanical Shock Test

Module #	ACR (Ohm)			Z-factor ($10^{-3}K^{-1}$)		
	Initial	Final	Change (%)	Initial	Final	Change (%)
A1	1.123	1.131	0.71	2.379	2.344	- 1.47
A2	1.125	1.140	1.33	2.368	2.367	-0.04
A3	1.146	1.152	0.52	2.352	2.340	- 0.51
A4	1.144	1.150	0.52	2.390	2.350	- 1.67
A5	1.130	1.128	- 0.18	2.206	2.242	1.63
A6	1.172	1.183	0.94	2.382	2.333	- 2.06
A7	1.112	1.125	1.17	2.354	2.305	- 2.08
A8	1.147	1.170	2.01	2.348	2.301	- 2
A9	1.135	1.157	1.94	2.330	2.289	-1 .76
A10	1.160	1.172	1.03	2.369	2.319	- 2.11
A11	1.143	1.165	1.92	2.368	2.310	- 2.44
A12	1.157	1.176	1.64	2.357	2.301	- 2.38

Table 3.1 shows the data from the test of the TECs 1MC(L)04-6.4x2.4-08-0000. The before and after tests resistances and Z-factors are shown, as well as the calculated relative change value.

3.7 Test Results

All the items were inspected under magnification after tests. No cracks or damages were observed. The test results indicate that all the items meet the MIL-STD-883E suggested passing criterion of less than 5% electrical resistance change.

4. Variable Frequency Vibration Testing

4.1 Purpose of the Test

This test was performed for determining the effect of vibration in the specified frequency range on the parts.

4.2 Test Method Used

Test basic method used: MIL-STD-883E, Method 2007.3, VIBRATION, VARIABLE FREQUENCY.

4.3 Conditions

20 g from 20 to 2000 Hz

4 minutes per cycle

4 cycles per axis

4.4 Procedure

12 modules were put to the pre-test ACR and Z measurement. Then the modules were mounted on one side of cubic duralumin pedestal, which was fastened to the vibration table by its opposite side. The parts were then subjected to the vibrations at a 20 G level from 20 to 2000 Hz. Four cycles were performed each including frequency change up and down with cycle duration 4 minutes each. Then the position of the cub was changed by turning it on 90° and the procedure was repeated for the second axis. The same method was used to make vibration testing along third axis.

4.5 Test Equipment Details

Vibration System TIRAvib, Model TV 56363/LS-340, Germany (OOO TELEKART, Odessa, Ukraine)

Thermion Computerized ACR-Z-meter

4.6 Metering Accuracy

Maximum metering errors are evaluated to be as follows:

- Temperature: +/- 0.5 ºC
- ACR value: +/- 1.2%
- Z-factor: +/- 2.2%

4.7 Test Results

Table 4-1. Results of ACR and Z Measurement for the TECs 1MC(L)04-6.4x2.4-08-0000 Prior and After Exposure to Vibration Testing

Module #	ACR (Ohm)			Z-factor ($10^{-3}K^{-1}$)		
	Before	After	Change (%)	Before	After	Change (%)
B1	1.126	1.126	0	2.384	2.375	-0.38
B2	1.179	1.178	-0.08	2.315	2.311	-0.17
B3	1.144	1.141	-0.26	2.409	2.401	-0.33
B4	1.103	1.101	-0.18	2.368	2.37	0.08
B5	1.16	1.156	-0.35	2.305	2.352	2.03
B6	1.15	1.154	0.35	2.37	2.356	-0.59
B7	1.095	1.096	0.09	2.357	2.356	0.04
B8	1.142	1.144	0.18	2.375	2.377	0.08
B9	1.164	1.164	0	2.338	2.342	0.17
B10	1.132	1.132	0	2.362	2.363	0.04
B11	1.152	1.152	0	2.369	2.372	0.13
B12	1.128	1.130	0.18	2.398	2.403	0.21

4.8 Conclusion

- All items tested meet the suggested passing criterion of 5% or less change in resistance and Z factor.
- For all items the changes are oscillating near zero and lay inside of the range of maximum random error what means that vibrations within given test conditions do not affect TECs performanse.

5. Shear Force Testing

5.1 Purpose of the Test

The test is intended to quantify the actual highest level of shear force that the 1MC(L)04-6.4x2.4-08-0000 TEC can withstand.

5.2 Module strength requirements

Total cross-section area of 22 TE pellets 0.4x0.4 mm is of 3.52 mm^2 or 54.6 X 10^{-4} sq.in. Accordingly to the MIL-STD-883E, Method 2019.7, Die Shear Strength, Chart # 2019-4, the TECs have to withstand minimum 1X force value of 2.15 kg or 1.25X force value of 2.7 kg, or 2X force value of 4.3 kg.

5.3 Test Method Used

Test basing method used: MIL-STD-883E, Method 2019.7, Die Shear Strength.

Total 12 TECs were initially prepared by gluing bottom substrate of each one to the metal pedestal using epoxy resin. With a pedestal held in place, the top substrate of a TEC was loaded by a force parallel to the substrate surface. While the shear force was measured, it was scaled up gradually until a TEC destroyed. Each of 12 modules was subjected to this procedure.

As the TEC has a rectangular form with considerably different edge dimensions, the tests were carried out in two directions – 6 modules with the shear force perpendicular to the longer (6.4 mm) edge and the rest 6 modules with the shear force perpendicular to the shorter (2.4 mm) edge.

5.4 Test Equipment Details

The test equipment consisted of a fixing clamp for the pedestal with a TEC and a load-applying instrument with a sliding contact tool movable in a plane parallel to a TEC surface. The device included also a micrometrical mechanism for adjusting a contact tool to a TEC top substrate and a binocular microscope with 10X resolution for visual control of the TEC and contact tool interface during testing. The reference dynamometer (master proving ring ДОСМ-3 with position indicator of watch type, model ИЧ 10 МН) was used to apply and to monitor the shear force gradually from zero to specified value.

5.5 Test Parameters

The test was conducted at a room temperature with parts in non-operating mode.

5.6 Test Data

Table 5.1 Breaking Point Data (Kg of Force) for the modules 1MC(L)04-6.4x2.4-08-0000

Shear Force Direction			
Perpendicular to 6.4 mm edge		Perpendicular to 2.4 mm edge	
C1	3.025	C7	4,050
C2	3.330	C8	4.610
C3	3.545	C9	4.060
C4	3.120	C10	3.950
C5	4.080	C11	4.170
C6	3.530	C12	4.210
Average	3.438		4.175

Table 5.1 shows shear force needed to induce failure to the TEC 1MC(L)04-6.4x2.4-08-0000.

5.7 Test Results

The test results indicate that for all parts their shear force capabilities exceed considerably 1.25X minimum with a lowest value of 3.02 kg and a highest of 4.6 kg. In the direction perpendicular to the TEC short edge the average shear force is near 2X level but in the orthogonal direction it is 20% lower.

6. High Temperature Storage

6.1 Purpose of the Test:

The purpose of this test is to determine the resistance and Z-parameter of the parts to prolonged exposure at high temperature.

Note: Though storage temperature is specified as 85ºC, more severe temperature conditions (100 ºC) were applied, this because the tests were started by Thermion prior to the specification.

6.2 Test Method

The basic test method used was Telcordia GR-468 CORE, R4-92

The 10 modules were put to the pre-test ACR and Z measurement. Then the modules were inserted in a glass tube and vacuumed to the residual pressure of $1.5X10^{-2}$ mm Hg (2 Pa). The tube was sealed using gas burner and placed into the storage oven whose temperature was maintained at 100ºC. The modules were removed and their ACR and Z parameters were measured after 240, 500, 1000 and finally after 2000 hours of storage. Every time the modules were resealed into glass tubes after measurements for further storage.

6.3 Measured Parameters:

AC Resistance
Z parameter (by Harman method in still air)
Temperature
Vacuum level

6.4 Metering Accuracy

Metering errors are evaluated to be as follows:

- Temperature: +/- 0.5 ºC
- ACR value: +/- 1.2%
- Z-factor: +/- 2.2%

6.5 Apparatus and Measuring Instruments:

Controlled temperature oven
Computerized ACR-Z-meter
Thermometer 0-150ºC
Vacuum-meter

6.6 Test Conditions

The testing was conducted in a temperature-controlled oven set at 100ºC with the parts in vacuumed ampoules in a non-operational mode. The test duration for this report is restricted to 2000 hours though the test is still in progress.

6.7 Test Results

Dynamics of the TECs performance when stored at 100 ºC is shown at the Figures 6-1, 6-2. The final deviation of the measured parameters after 2000 hours storage is given in the Table 6-1.

6.8 Conclusion

As can be seen from Table 6-1, the ACR value is growing gradually while Z factor time dependence is more complex. The average change in resistance for the group of 10 modules is of 2.7% with minimum of 0.9% for item # 9 and maximum 4.8% (item # 4). This meets a Telcordia’s suggested criterion of maximum change of less than 5%. Even less degradation is observed in Z-factor, whose maximum is of 1.9% only, this being inside the region of experimental error.

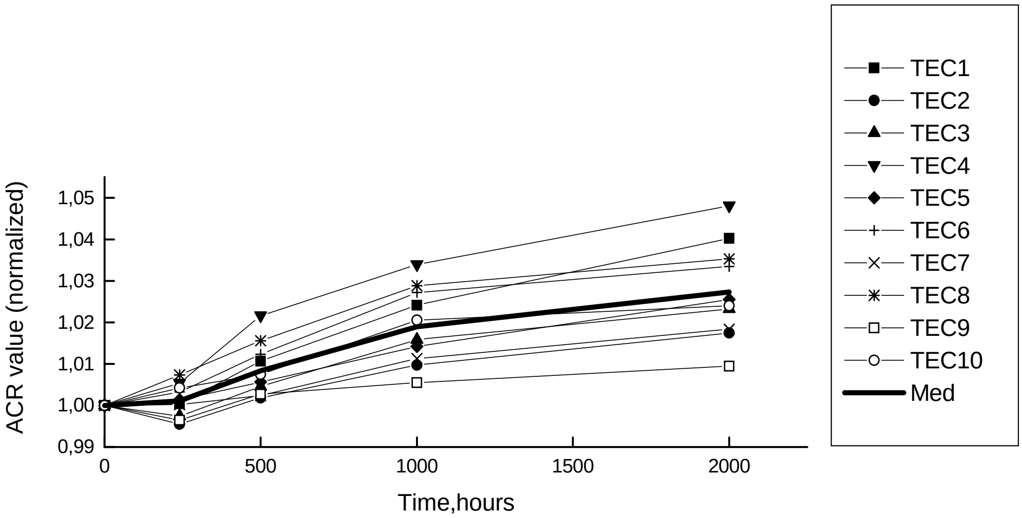

Figure 6-1. Time dependence of the ACR value (normalized on the initial data)

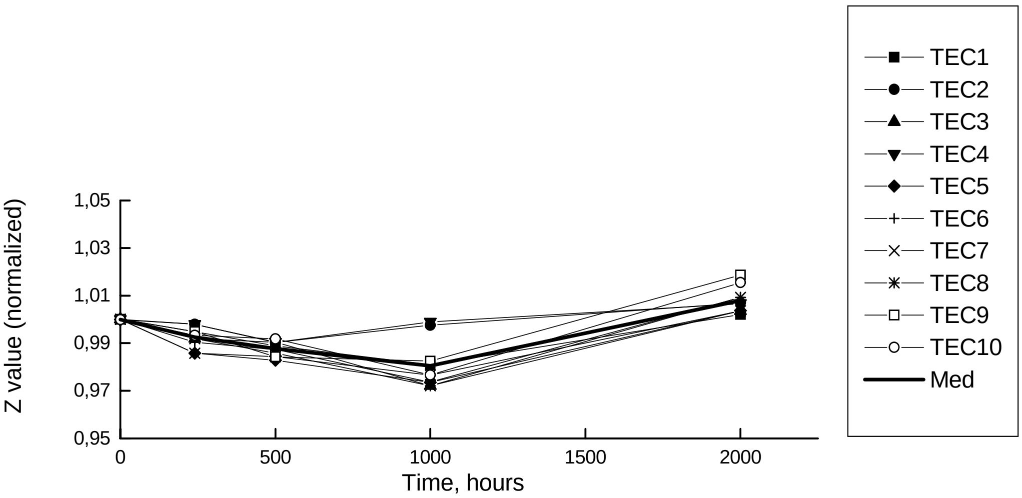

Figure 6-2. Time dependence of the Z value (normalized on the initial data)

Table 6-1. Results of ACR and Z measurements for the TECs 1MC(L)04-6.4x2.4-08-0000 after 2000 hours storage at 100ºC (measured at 19 ºC)

Module #	ACR (Ohm)			Z-factor ($10^{-3}K^{-1}$)		
	Before	After	Change (%)	Before	After	Change (%)
D1	1.002	1.042	4.0	2.26	2.27	0.2
D2	1.000	1.017	1.7	2.24	2.25	0.7
D3	1.014	1.038	2.3	2.26	2.27	0.4
D4	1.000	1.048	4.8	2.25	2.27	0.7
D5	1.008	1.034	2.6	2.25	2.26	0.4
D6	1.016	1.050	3.3	2.27	2.29	0.9
D7	1.031	1.050	1.8	2.26	2.27	0.4
D8	1.004	1.039	3.5	2.27	2.29	0.9
D9	1.008	1.017	0.9	2.24	2.28	1.9
D10	1.016	1.040	2.4	2.25	2.29	1.5
Average	1.010	1.038	2.7	2.26	2.27	0.8

7. Temperature Cycling

7.1 Purpose of the Test:

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

7.2 Test Method

The basic test method used was GR-468, Section 5.20 and MIL-STD-883E, Method 1010.7.

7.3 Conditions

The following conditions are accepted in this experiment:

From -45 (-2) to +85 (+3) ºC

100 cycles pass/fail

500 cycles for information purposes

Timing:

- Total transfer time from cold to hot/from hot to cold – 2/1.5 min
- Dwell time – 10 min

The items are to be in non-operation mode

Sample size – 12 pcs

Number of failures – zero

NOTES:

1. Though the lower temperature level was specified as -40ºC, more sever temperature condition (-45ºC) was accepted being accessible in our tests.
2. Accepted temperature ramp is 65ºC/min. This is more than 3 times faster than specified ramp.
3. To accelerate tests, the dwell time is reduced from 40 min specified to 10 min what is allowed by MIL-STD-883E, Method 1010.7 on condition that the parts achieve extreme temperatures -45 and 85ºC during exposure at constant temperature. This is just the case because time constant of micro TECs is many times less than dwell time.

7.4 Apparatus

Vacuum chamber ВУП-4 (Russia) with thermostatted plate inside

Ultra Thermostat УТ-15 (Russia)

Thermion TE Cooler 1MC10-070-15-0200, top and bottom substrates 22x22 mm

Stabilized power source Б5-49 (Russia)

Stabilized power source Б5-46 (Russia)

Mode selector switch ID 961 (electronic controller for refrigerating chambers with fan)

Copper-Konstantan thermocouple

Micro Voltmeter В7-21А (Russia)

Thermion's Computerized ACR-Z-meter

7.5 Procedure

12 modules were put to the pre-test ACR and Z measurement. Then the modules were glued by their bottoms to 20x20 mm base alumina plate which was mounted at the top of the supporting 1MC10-070-15-0000 TEC using thermal grease. The TEC was then mounted at the thermostatted plate inside of the vacuum chamber ВУП-4 using thermal grease and the chamber was evacuated to the residual pressure of 10-2 mm Hg (1.333 Pa). The temperature of the plate was maintained at 11ºC using Ultra Thermostat УТ-15. The supporting TEC was used to provide necessary temperature cycling from -45 (-2) to 85 (+3) ºC. For this purpose the TEC was supplied with a feeding electric current which was alternatively switched from 1.6 A in a cooling mode to reversed 0.63 A in a heating mode with 10 minutes of exposure at each temperature.

Switching was made automatically every 10 minutes using mode selector switch ID 961 and two DC power sources, one stabilized at 1.6 A and other at 0.63 A.. The temperature of the alumina base plate was controlled using copper-konstantan thermocouple and Micro Voltmeter В7-21А

7.6 Measured Parameters:

Modules AC Resistance

Modules Z parameter (by Harman method in still air)

Base plate temperature

7.7 Metering Accuracy

Metering errors are calculated to be as follows:

- Temperature: +/- 0.5 ºC
- ACR value: +/- 1.2%
- Z-factor: +/- 2.2%

7.8 Test Results

Table 7-1. Results of ACR Measurement for the TECs 1MC(L)04-6.4x2.4-08-0000 Prior and After Exposure to Thermal Cycling Tests

Module #	Initial Value	After 100 cycles		After 500 cycles	
		Value	Change %	Value	Change %
E1	1.207	1.203	-0.33	1.208	0.08
E2	1.199	1.198	-0.08	1.198	-0.08
E3	1.241	1.239	-0.16	1.241	0
E4	1.162	1.152	-0.86	1.154	-0.69
E5	1.172	1.172	0	1.172	0
E6	1.183	1.182	-0.08	1.182	-0.08
E7	1.212	1.213	0.08	1.213	0.08
E8	1.144	1.148	0.35	1.141	-0.25
E9	1.190	1.191	0.08	1.186	-0.35
E10	1.170	1.173	0.26	1.170	0
E11	1.158	1.163	0.43	1.158	0
E12	1.198	1.203	0.42	1.198	0

Table 7-2. Results of Z Measurement for the TECs 1MC(L)04-6.4x2.4-08-0000 Prior and After Exposure to Thermal Cycling Tests

Module #	Initial Value	After 100 cycles		After 500 cycles	
		Value	Change %	Value	Change %
E1	2.337	2.351	0.6	2.308	-1.24
E2	2.276	2.268	-0.35	2.295	0.83
E3	2.321	2.316	-0.22	2.340	0.82
E4	2.305	2.346	1.76	2.366	2.65
E5	2.328	2.321	-0.3	2.347	0.82
E6	2.316	2.310	-0.26	2.342	0.95
E7	2.307	2.291	-0.69	2.332	1.08
E8	2.317	2.293	-0.35	2.339	0.95
E9	2.313	2.296	-0.73	2.347	1.5
E10	2.338	2.320	-0.77	2.350	0.5
E11	2.336	2.314	-0.94	2.359	0.98
E12	2.318	2.299	-0.82	2.346	1.21

7.9 Conclusion

All items tested meet the suggested passing criterion of 5% or less change in resistance and Z factor.

Obtained changes in resistance and Z factor lay in the range of random error of measurements.

For all items the changes in ACR value oscillate near zero what means that 100 and 500 temperature cycles from -45 to +85°C do not affect TECs efficiency.

8. Thermal Shock Testing

8.1 Purpose of the Test:

The purpose of this test is to determine the resistance of the TECs to sudden exposure to extreme changes in temperature and the effect of alternate exposures to these extremes.

8.2 Test Method

The basic test method used was MIL-STD-883-E, Method 1011.9, Condition A.

The 10 modules were put to the pre-test ACR measurement. Then the modules were fixed by ends of their wires on the edge of a thin plastic tube so that the TECs were suspended below the tube. Two large glasses were used for testing, one with boiling de-mineralized water at 100ºC and another with water ice in de-mineralized water at 0ºC. The modules were alternatively dipped in cold water at 0ºC for 5 minutes and then in hot water at 100ºC for 5 minutes. This cycle was repeated 20 times.

8.3 Measured Parameters:

AC Resistance

Temperature

8.4 Metering Accuracy

Metering errors are evaluated to be as follows:

- Temperature: +/- 0.5 ºC
- ACR value: +/- 1.2%

8.5 Apparatus and Measuring Instruments:

Hot plate

Ice maker

Glasses with de-mineralized water

Computerized ACR-Z-meter

Thermometer 0-150ºC

8.6 Test Conditions

The water temperatures were set at 0ºC and 100ºC. The modules were held at each temperature for five minutes to provide full temperature uniformity. The modules were exposed to hot and cold cycles total 20 times.

8.7 Test Results

Table 8-1. Results of ACR measurements for the TECs 1MC(L)04-6.4x2.4-08-0000 Before and After 20 Cycles of Thermal Shock Testing (Measured at 25ºC)

Module #	ACR (Ohm)		
	Before	After	Change (%)
G1	1.051	1.068	1.6
G2	1.040	1.068	2.7
G3	1.054	1.085	2.9
G4	1.066	1.070	0.4
G5	1.046	1.068	2.1
G6	1.054	1.074	1.9
G7	1.070	1.091	2.0
G8	1.043	1.062	1.8
G9	1.060	1.073	1.4
G10	1.076	1.105	2.7
Average	1.056	1.076	1.9

8.8 Test results

The maximum change in resistance for the group of 10 modules is of 2.9% (module # 3), what meets a suggested criterion of maximum change of less than 5%.

9. Power Cycling

9.1 Purpose of the Test:

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

9.2 Test Method

The basic test method used was GR-468, Section 4.5.2 and MIL-STD-883E, Method 1006.

9.3 Conditions

Modules are to be cycled 1.5 minutes on and 4.5 minutes off for 5000 cycles at 70ºC.

Electrical current during operation is to be of 1 A.

Sample size – 11pcs

Number of failures - zero

9.4 Apparatus

Hot Chamber ШС-3 with automatically controlled temperature

Stabilized Power Source Б5-47 (Russia)

Mode selector switch ID 961with cut-in relay РПУ-1

Mercury Thermometer 0-100ºC

Computerized ACR-Z-meter

9.5 Procedure

11 modules were manufactured with metallized bottom substrates for these tests and were put to the pre-test ACR and Z measurement. Then the modules were soldered to the copper plate and connected electrically in series. Copper plate was mounted at a massive duralumin plate which was placed into the Hot Chamber heated to 70ºC. The automatic switch was used for connection the modules to the Power Source whose output was stabilized at 1A. The switch provided automatically 1.5 min. on and 4.5 min. off cycle. The temperature of the duralumin block was monitored by mercury thermometer. Atmosphere in the Hot Chamber is still air.

9.6 Measured Parameters:

Modules AC Resistance

Modules Z parameter (by Harman method in still air)

Duralumin Block temperature

Time

9.7 Metering Accuracy

Metering errors are estimated to be as follows:

- Temperature: +/- 0.5 ºC
- ACR value: +/- 1.2%
- Z-factor: +/- 2.2%

9.8 Test Results

Table 9-1. Results of ACR and Z Measurement for the TECs 1MC(L)04-6.4x2.4-08-0000 Prior and After Exposure of Power Cycling (measured at 25ºC)

Module #	ACR (Ohm)			Z-factor ($10^{-3}K^{-1}$)		
	Before	After	Change (%)	Before	After	Change (%)
G1	1.200	1.210	0.83	2.249	2.266	0.76
G2	1.164	1.200	3.09	2.281	2.282	0.04
G3	1.183	1.200	1.44	2.276	2.270	-0.26
G4	1.148	1.164	1.39	2.286	2.276	-0.44
G5	1.167	1.189	1.89	2.269	2.246	-1.01
G6	1.133	1.151	1.59	2.253	2.246	-0.31
G7	1.230	1.252	1.79	2.183	2.151	-1.47
G8	1.127	1.133	0.53	2.289	2.285	-0.17
G9	1.150	1.179	2.52	2.261	2.254	-0.31
G10	1.155	1.167	1.04	2.272	2.259	-0.57
G11	1.133	1.151	1.59	2.270	2.266	-0.18
Average	1.163	1.181	1.61	2.263	2.255	-0.36

Note: As for Z factor changes are oscillating with alternating signs, mean-square change was calculated as being of 0.65%.

9.9 Conclusion

All items tested meet the suggested passing criterion of 5% or less change in resistance and Z factor. Averaged change of 1.6 % in ACR value is obtained with minimum of 0.8% for item # 1 and maximum of 3.1% for the item # 2. Even less change is observed in Z-factor, this being inside the region of experimental error for all items tested.