FIELD RELIABILITY OF RICOR MICROCOOLERS

N. Pundak, Z. Porat, M. Barak, Y. Zur, G. Pasternak

Ricor, Cryogenic and Vacuum Systems, En Harod Ihud, Israel 18960

ABSTRACT

Over the recent 25 years Ricor has fielded in excess of 50,000 Stirling cryocoolers, among which approximately 30,000 units are of micro integral rotary driven type. The statistical population of the fielded units is counted in thousands/ hundreds per application category. In contrast to MTTF values as gathered and presented based on standard reliability demonstration tests, where the failure of the weakest component dictates the end of product life, in the case of field reliability, where design and workmanship failures are counted and considered, the values are usually reported in number of failures per million hours of operation. These values are important and relevant to the prediction of service capabilities and plan.

Keywords: Cryocoolers, reliability

INTRODUCTION

This paper refers to Ricor microcoolers models K508. This model belongs to the Ricor's Integral rotary IDCA type Stirling coolers, as shown in Figure 1.

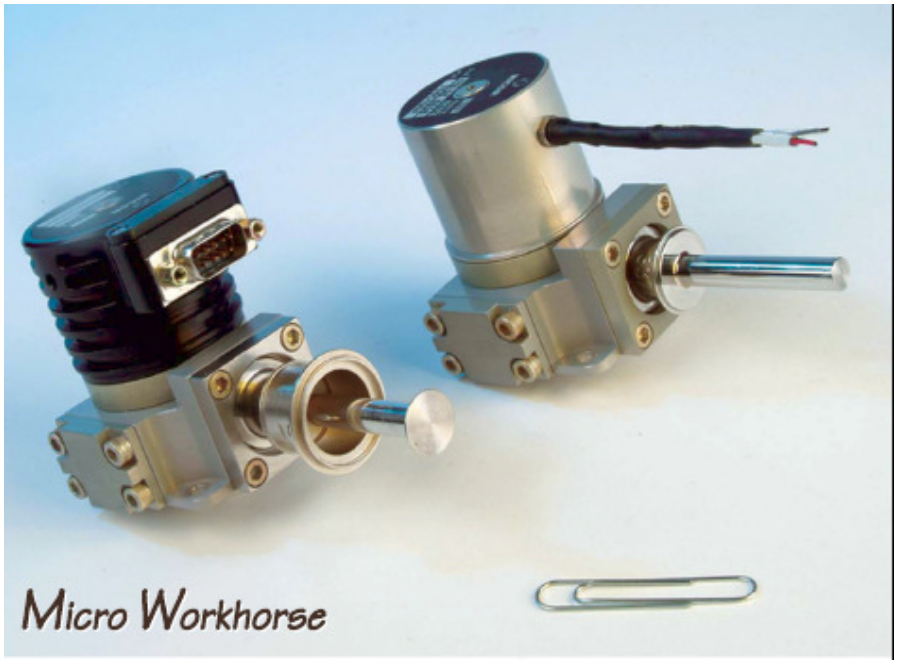

Figure 1. Model K508 micro cooler - general view

This model is under routine production since 1995 at a rate of several thousand units per year. The large number of fielded units and the duration in field use allow performing statistical analysis of the actual field reliability of this model. The analysis refers to several projects where large number of coolers was supplied for a specific application. Unfortunately, due to NDA commitments to customers the projects names, the systems where the coolers are onboard and the customers cannot be exposed. Table No.1 below defines the applications and the number of coolers as supplied to each of these projects.

Table 1. Applications and quantities of coolers

/	Cooler model	Application	No. of fielded coolers
1	**K508**	**Ground – hand held**	**4412**
2	**K508**	**Aerial – non military**	**404**
3	**K508**	**Ground – static observation**	**1377**
4	**K508**	**Ground – Armored vehicle**	**962**
5	**K508**	**Ground – man portable**	**1042**

The following careful assumptions were taken in this analysis:

a. This paper is based on data as collected by Ricor's quality assurance department records with regard to the delivery and return for repairs dates and quantities of coolers from the above mentioned applications / projects. The data collection period refers to the years **2003 – 2007**.
b. On the average, the coolers are assumed to be actually fielded 6 months from the leave of Ricor's facilities.
c. Returns due to failures in a period shorter than 6 month from delivery are not counted and considered as Infant mortality failures.
d. The average time from cooler failure in the field to arrival to Ricor dock is assumed to be 3 months.
e. 30% of the coolers are assumed to be kept unused as spare parts.
f. Due to the fact that the systems where these coolers are onboard do not contain elapsed time indicator, the average annual use of the coolers per the given applications were estimated as follows:
   - Hand held systems – 1500 hours/ year
   - Ground static (24/7) - 5000 hours/ year
   - Armored vehicle – 500 hours/ year
   - Aerial lending aid (non military) - 500 hours/year

These assumptions are based and supported by customers and military expert commanders estimations. As examples, the delivery and return rate of the Ground static observation project with reference to the year of supply is presented in table 2 (deliveries), and table 3 (returns) are presented below:

Table 2. Project of Ground static observation systems

Annual rate of deliveries

Delivery year	**2003**	**2004**	**2005**	**2006**	**2007**
Units delivered	**158**	**48**	**228**	**350**	**593**

Table 3. Project of Ground static observation systems

Return for repair annual rate

Return / Production	2003	2004	2005	2006	2007
2003	31	5	1	1	-
2004		24	27	5	3
2005			24	14	6
2006				5	4
2007					4

Based on the above mentioned data and assumptions the average operational hours of the coolers per each specific application were calculated and presented in Table 4.

Table 4. **Operational hours calculation**

/	Cooler model	Application	Fielded units	Number of relevant failures	Total hours of operation	Average hours of operation
1	**K508**	**Ground – hand held**	**4412**	**100**	**7744875**	**1950**
2	**K508**	**Aerial – non military**	**404**	**18**	**427706**	**1176**
3	**K508**	**Ground – static observation**	**1377**	**72**	**7655156**	**6177**
4	**K508**	**Ground – Armored vehicle**	**895**	**48**	**1090106**	**1353**
5	**K508**	**Ground – man portable**	**1042**	**56**	**4356616**	**4181**

THEORETICAL BACKGROUND

Laboratory life tests conducted at Ricor facilities on various types of Ricor's cryocoolers, have demonstrated Weibull life distribution with high values of shape parameter (β), in the range 4-8. The assumption is that the coolers' field life distribution would be also Weibull but with smaller β. Distinct evidences are not available, however the hypothesis is that the value of β at field is in the range 2-3. The argumentation is as follows.

1. The Weibull life distribution function $f_T(t)$, and its coefficient of variation, denoted by D, are provided in Equations (1) and (2), respectively .

$$f_T(t) = \frac{\beta}{\alpha}\left(\frac{t}{\alpha}\right)^{\beta-1} e^{-\left(t/\alpha\right)^{\beta}}, \quad t \geq 0, \alpha, \beta > 0 \tag{1}$$

$$D = \frac{\sigma}{MTTF} = \frac{\left\{\Gamma\left(2/\beta + 1\right) - \left(1/\beta + 1\right)^2\right\}^{1/2}}{\left(1/\beta + 1\right)} \tag{2}$$

where:

α	- Weibull distribution's scale parameter
β	-Weibull distribution's shape parameter
σ	-life standard deviation
$MTTF$	-life Mean Time To Failure

2. As shown in Equation 2, the Weibull coefficient of variation is solely a function of β. It becomes larger as β decreases. The belowt table depicts some values of D as a function of β.

β	1	2	3	4	5	6
D%	100	52	36	28	23	19

3. We expect that in real life situation the coolers would experience less controlled working conditions and handling than that in Ricor's facilities and laboratories. Thus, a larger coefficient of variation is anticipated, implying smaller value of β than that revealed in the laboratory life tests. Reasonable field values seem to be in the range 2-3. Under these considerations where the value for β is 2.0 , the number of failures per million hours of operation (1/ MTTF) is calculated and presented in table No. 5

Table 5. **Predicted failures rate per a given application**

/	Application	Failures per million hours of operation
1	Ground – hand held	81
2	Aerial – non military	182
3	Ground – static observation	30
4	Ground – Armored vehicle	186
5	Ground – man portable	60

CONCLUSIONS

The main purpose of this paper was to assist the IR systems service engineers in the prediction of systems failures due to coolers malfunctioning and to build their plans (spare coolers, preventive maintenance, etc) accordingly .
In order to improve the reliability of model K508 cryocoolers, a new derivative designated as K508N is now under qualification and accelerated life demonstration tests. This derivation meets the FFF criteria vs the ordinary model K508 coolers but assumed to improve reliability in a factor of 2. This extended life version is assumed to be commercially available in the 3rd quarter of 2009.

REFERENCES

[1] Breniere X, Manissadjian A, Vuillermet Michel, Terme JC, Tribolet P, Cauquil JM, Martin JY, "Reliability optimization for IR detectors with compact cryo-coolers", Proceedings of Infrared Technology and Applications XXXI, Orlando, Florida, (2005)

[2] Porat Z, Sne-Or A, Pundak N, Livni D, "Reliability assessment procedure of cryocoolers", Proceedings of Infrared Technology and Applications XXXIV, Orlando, Florida, (2008)

[3] Pundak N, Meromi A, Tzur Y, Bar-Haim Z, Riabzev S, Leonard G, Toft B, Long M, "Reliability growth of Ricor's micro IDCA products: status report", Proceedings of Infrared Technology and Applications XXXI, Orlando, Florida, (2005)

[4] Salazar WE, "Status Report on the Linear Drive Coolers for the Department of Defense Standard Advanced Dewar Assembly (SADA)", U. S. Army Communications and Electronics Command, Research, Development, and Engineering Center Night Vision and Electronic Sensors Directorate, Fort Belvoir, VA 22060-580, (2002)