

# Cobham Microcooler for High Temperature Applications

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## ABSTRACT

Cobham Mission Systems of Davenport, Iowa is developing a new microscale cryogenic cooler intended for use in high temperature applications (greater than 95 K). This new cooler uses a linear dual opposed compressor and split expander and aims to be the smallest and highest performing cooler in the this emerging micro class. This paper will highlight and compare the cooler’s performance against its expected performance.

## INTRODUCTION

Cobham began development of its LC1076 split dual opposed linear cryogenic cooler in January 2013. The objective for the LC1076 microcooler was to develop the smallest and highest performing cooler in the emerging microcooler class.

Development began with a target compressor size of 2.1” long with a 1” outer diameter housing. A 0.196” outer diameter coldfinger was selected as the coldfinger size. Trade studies were performed using Sage<sup>1</sup> in an attempt to optimize the operating parameters.

Performance targets for the cooler are shown in Table 1.

Prototypes of the cooler were built in early 2014 and are currently undergoing performance validation and optimization testing.

**Table 1.** Performance targets for the LC1076 cooler.

Target	-40 °C ambient	23 °C ambient	71 °C ambient
Heat Lift at 95 K (mW)	375	250	100
Heat Lift at 120 K (mW)	575	475	275
Heat Lift at 150 K (mW)	750	675	500
Maximum AC Input Power (W)	18	20	25
Drive Frequency (Hz)	85	85	85
Lifetime (hours)	>15,000 (>20,000 expected)		

## DEVELOPMENT AND PERFORMANCE ESTIMATES

The development process to date has followed the basic progression: conception, proof-of-concept, performance modeling, parameter optimization, prototype testing and optimization. The microcooler development is currently nearing the end of the prototype testing and optimization phase, and will soon enter qualification testing and then followed by full production. Reliability testing will also be performed.

The microcooler project was inspired by the emergence and maturation of high operating temperature (HOT) focal plane array (FPA) technology in the infrared marketplace (see Tsao<sup>2</sup> for instance). As the operating temperature of the FPA increases, the cooling needs decrease, meaning that a much smaller and lower capacity cooler can be used than if the FPA was at traditional cryogenic temperatures such as 77 K. The smaller coolers are able to operate at a low input power and low heat lift very efficiently with a very small package and weight.

Cobham completed development of its LC1070 1/5 W cryocooler in 2013, and a modified LC1070 was used as a proof-of-concept for the microcooler. An LC1070, cut in half and operating with a single piston contains approximately the swept volume expected in the microcooler. The half LC1070 was able to hold more than 610 mW at 120 K with 14.8 watts AC input power, which provided confidence that the design targets were feasible. Figure 1 shows the modified LC1070 that served as the proof of concept hardware for the LC1076 microcooler next to a rapid prototype of the LC1076 envelope.

Performance optimization of the LC1076 microcooler was completed using Sage. The performance parameters that were considered for optimization are shown as follows:

- Compressor piston diameter
- Compressor piston clearance
- Compressor spring rate
- Charge pressure
- Operating frequency
- Compressor moving mass
- Coil parameters (number of turns, gauge)



**Figure 1.** Comparison of the cut in half LC1070 proof of concept (left) as compared to a rapid prototype LC1076 (right).

- Regenerator length
- Regenerator diameter
- Regenerator matrix parameters (wire size, mesh number)
- Regenerator spring rate
- Regenerator moving mass
- Working volumes (compressor, bounce space, expander)

The resulting parameters gave a cooler that fit within the desired envelope and met the desired targets in simulation.

## PROTOTYPE PERFORMANCE

At the time of this writing, prototype units are currently undergoing performance and optimization testing. Figure 2 shows the prototype unit. Figure 3 shows the correlation of the simulated performance to prototype performance at 23 °C, while Figures 4 and 5 show the tested performance of the cooler at 23 °C and 50 °C for cold tip temperatures of 120 K and 140 K, respectively.

## ESTIMATED RELIABILITY

The Cobham LC1076 cryocooler is based on the same patented technologies as its bigger siblings, such as the LC1047 and LC1065. These coolers have demonstrated lifetimes in excess of 20,000 hours<sup>3</sup>. The microcooler operates under much lower loads, resulting in much lower stress. By utilizing the general logic originated by Miskimmons<sup>4</sup> and described by Kuo<sup>5</sup>, the reliability of the LC1076 is expected to exceed that of its siblings due to its lower operating stress.

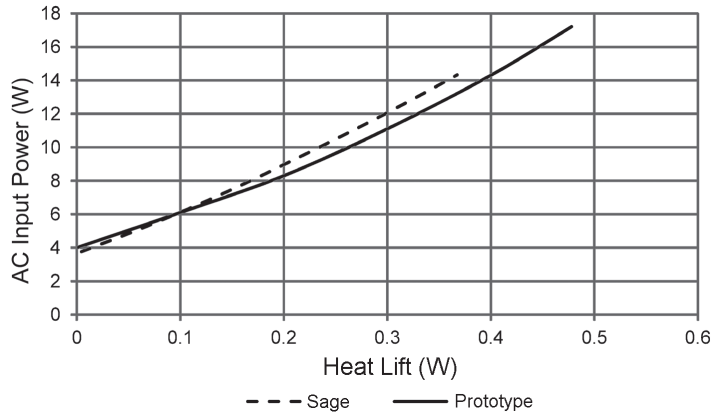
The LC1076 is slated to undergo reliability testing at the conclusion of optimization testing.

## CONCLUSION

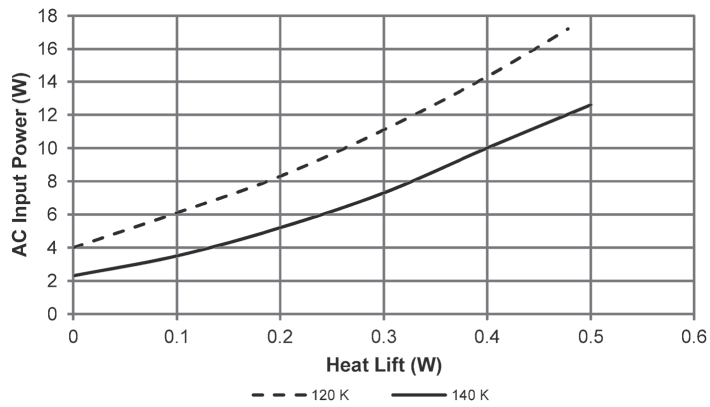
Cobham has developed a new microcooler using simulation and hardware optimization techniques. The cooler is in optimization testing at time of writing and is performing well and appears to meet its design objectives. The reliability of the new cooler is expected to be in excess of 20,000 hours, due to its similarity in design to other Cobham coolers and its reduced operational stress.



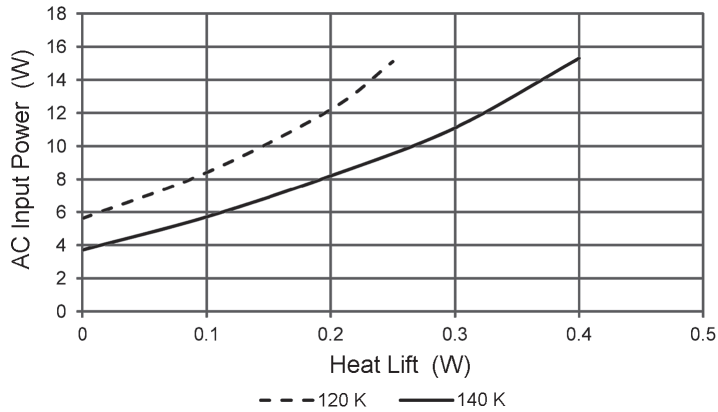
**Figure 2.** The prototype unit as tested. A US quarter dollar is shown for scale.



**Figure 3.** Correlation of Sage model to prototype at 120 K and 23 °C.



**Figure 4.** Prototype performance at 23 °C.



**Figure 5.** Prototype performance at 50 °C.

**REFERENCES**

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