# HEC Pulse Tube Cooler Performance Enhancement

**T. Nguyen, G. Toma, J. Raab**

Northrop Grumman Aerospace Systems
Redondo Beach, CA, 90278

## ABSTRACT

The High Efficiency Cooler (HEC) space flight cooler performance has been extended both at lower temperatures (<40K) and at higher temperatures (>140K) with higher cooling powers. The 21 flight coolers delivered to date were configured for each of their payloads with customized linear and coaxial one and two temperature cold heads. The one temperature cold head requirements ranged down to 40K and in the case of the 2 stage coolers, upper temperature requirements ranged as high as 140K. Recently the need for higher cooling power coolers below 40K and above 140K has motivated us to develop pulse tube cold heads to address these requirements. In both cases only the cold heads are changed and are variants of existing designs that can be integrated with the existing flight proven compressor and flight drive electronics. As a consequence these higher capacity coolers have similar low masses (<5.5kg) to the existing flight coolers.

## INTRODUCTION

Northrop Grumman's HEC coaxial coolers have been characterized over a wide range of operating conditions. The single stage cooler was tested at cooling temperatures between 40K and 150K. High cooling capacity has been measured at temperatures of 150K and above. The two-stage coaxial HEC cooler has a simultaneous cooling capacity at 35 K and 100 K, with the advantage of the low mass of the HEC compressor.

## CRYOCOOLER

The High Efficiency Cryocooler (HEC)[1] can be configured with either a linear or a coaxial cold head with a low mass flight qualified compressor as shown in Figure 1. This integral pulse tube cooler configuration consists of a vibrationally balanced compressor driving a pulse tube cold head. The coaxial and linear HEC cooler have the same mechanical and thermal interfaces. The two stage coaxial cooler uses the same compressor with a parallel two stage cold head configuration. The parallel configuration allows flexibility in designing the distribution of energy between the stages. The efficiency of the low temperature stage is improved due to the heat strapping between the stages.

*Cryocoolers 17,* edited by S.D. Miller and R.G. Ross, Jr.

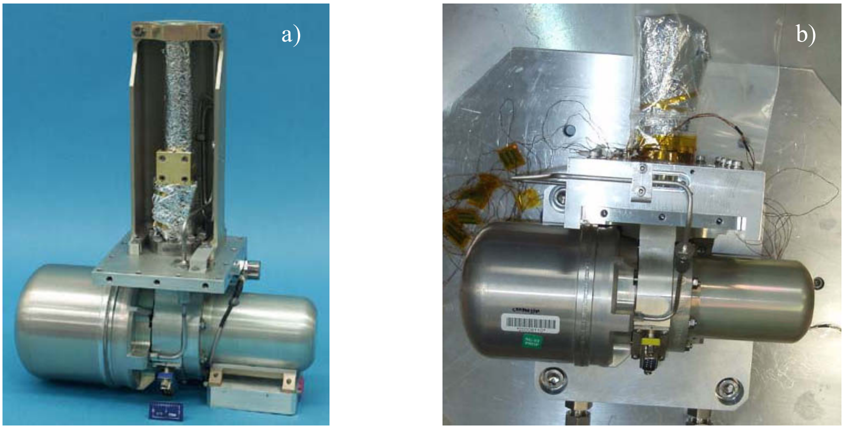


**Figure 1.** Single Stage HEC cooler with a) Linear and b) Coaxial Cold Head

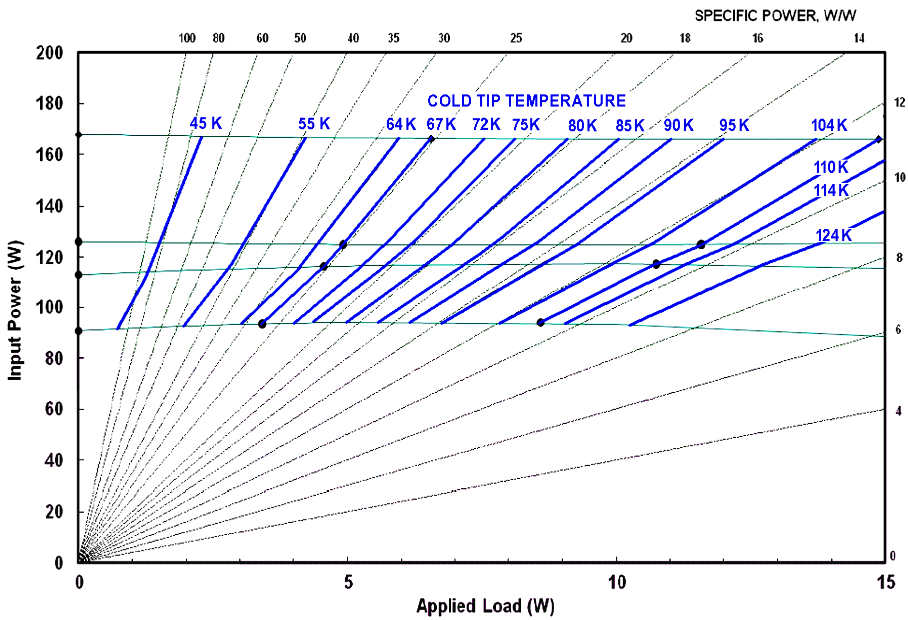


**Figure 2.** Coaxial HEC cooler performance map

## SINGLE STAGE COOLER PERFORMANCE

The single stage coaxial HEC cooler was tested at input powers up to 180 watts. Figure 2 plots the input power vs. the cooling load along isotherms. The dotted lines in Figure 2 are lines of constant specific powers. By overlaying the isotherms on top of the lines of constant specific power, the performance map provides a graphical view of the cooler efficiency at different temperatures. The performance map shown is for a 300 K reject temperature. The cooler was tested at compressor input powers between 80 W and 180 W.

Figure 3 shows the performance of the coaxial HEC cooler at high temperatures and cooling loads. Since the cooler was tuned for operation at 100 K, the measured cooling capacity at 150 K and above is lower than expected due to a mismatch of the impedance between in the cold head and the compressor. The measured cooling load of 22 W at 140 K can be increased to at least 25 W with a proper cold head tuning.

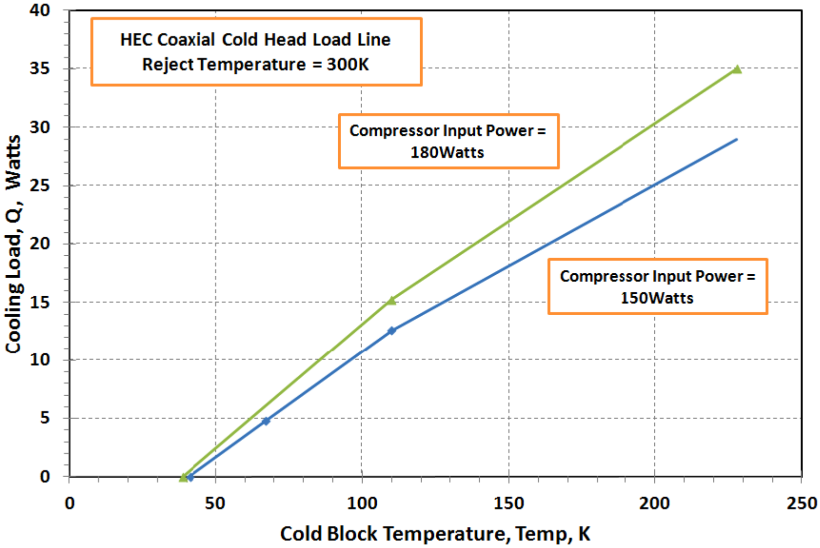


**Figure 3.** Performance of the coaxial HEC cooler at high cooling temperatures and loads

## TWO STAGE COOLER PERFORMANCE

Figure 4 shows the test setup of the 2 stage coaxial HEC cooler in the integral configuration. The two cold heads are mounted on the existing TRL 9 HEC compressor with an interface plate. The two-stage cold heads are configured in a parallel configuration with heat intercept along the 2nd stage regenerator to improve its efficiency.

Figure 5 shows a performance map of the 2 stage HEC cooler which plots at constant input power the temperature of the $2^{nd}$ stage vs. the temperature of the first stage. Lines of constant cooling power for the first and second stage are drawn on the map. A cooling load of 1.55 W at 35 K was measured for a compressor input power of 180 W. The 2 stage HEC cooler configuration extends the cooling capacity of this flight proven cooler to 35 K and below. Performance of the 2 stage cooler has been optimized over a wide range of frequency from 51 Hz to 63 Hz. Figure 6 shows that the cooler can be tuned to maintain a constant cooling capacity over the range of frequencies tested. The wide range of operating frequencies will allow flexibility in the cryogenic system design.

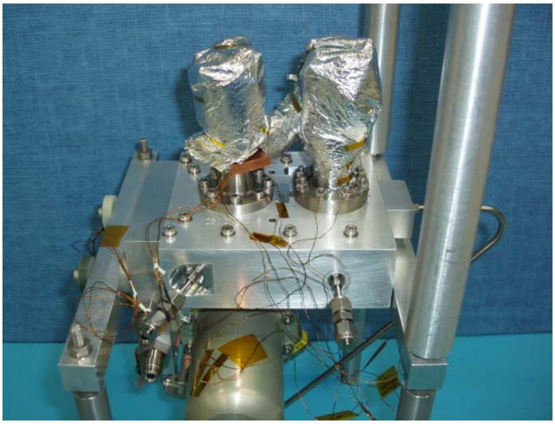

**Figure 4.** Integral configuration 2 stage coaxial HEC cooler

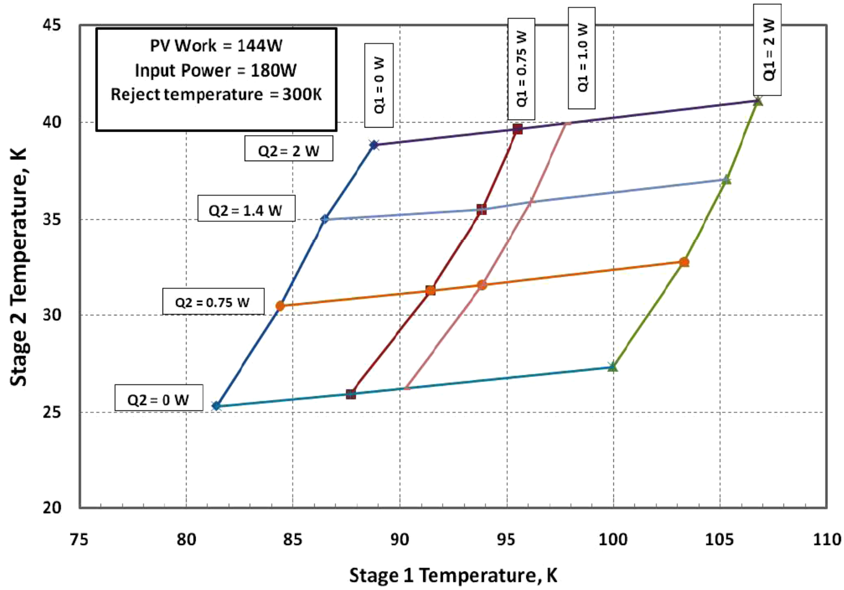


**Figure 5.** Performance map of the 2 stage HEC cooler at 300K reject

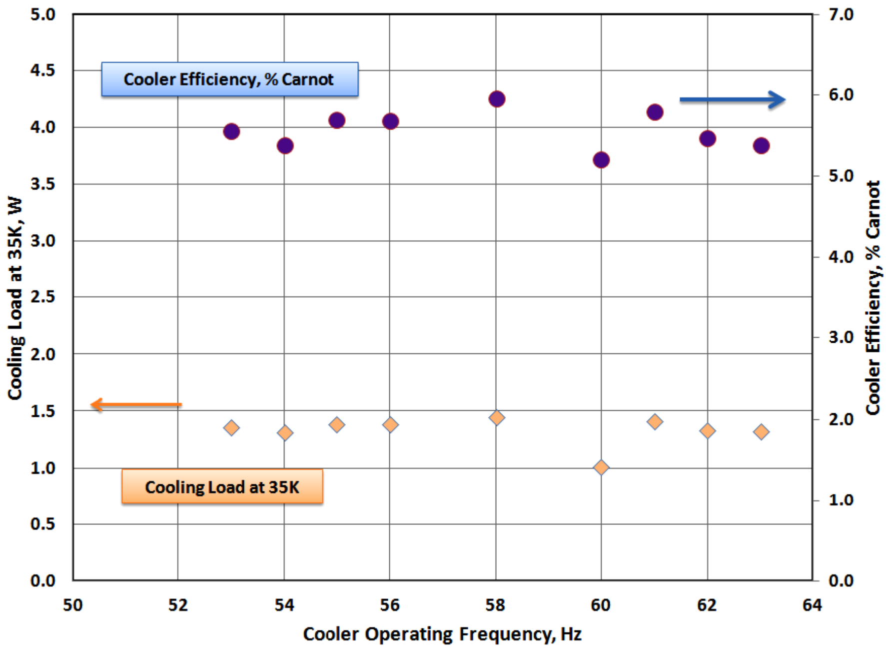


**Figure 6.** Performance of 2 stage HEC cooler over a wide range of frequencies

## CONCLUSION

The single and 2 stage coaxial HEC cooler performance has been measured. The single stage HEC coaxial cooler provides efficient cooling at temperatures of 40 K and above. It also has a high cooling capacity at temperatures above 100 K. The two-stage coaxial HEC cooler provides cooling loads at temperatures as low as 30 K with additional upper stage cooling for thermal shields or optics. The cooler can operate over a wide range of frequencies.

## ACKNOWLEDGEMENTS

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## REFERENCES

1. Tward, E., et al., "High Efficiency Cryocooler," *Adv in Cryogenic Engineering*, Vol. 47B, Amer. Institute of Physics, Melville, NY (2002), pp. 1077-1084.