HEC Pulse Tube Coaxial Cold Head Coolers

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ABSTRACT

A large number of NGAS high efficiency coolers (HEC) have been manufactured for six different space payload designs using a linear configuration cold head that is integrally mounted to the compressor. One of the payloads has been in orbital operation since 2005 and a second since 2009. For some applications it may be desirable to have a different cold head mechanical and thermal interface in order to ease integration into the system. For that purpose we have developed both one and two stage HEC coolers that incorporate coaxial cold heads that are integrally mounted to the compressor. The single thermal and mechanical mounting interface of this integral configuration eases integration with a payload and reduces its complexity compared to a split cold head version that requires two warm interfaces rather than one. In this paper we present the measured performance of the single stage HEC coaxial cold head cooler in its integral configuration and compare its performance with the linear cold head version. We also present the measured performance of the parallel cold head two-stage version of the cooler designed for the simultaneous cooling of both focal planes at temperatures above 35 K and optics and filters at temperatures greater than 75K.

INTRODUCTION

This paper reports on development tests on one- and two-stage coaxial cold head versions of our HEC flight cooler.[1] The one-stage cooler that is reported in this paper is a variant of the HEC flight coolers (Figure 1) previously delivered for the Japanese Advanced Meteorological Imager (JAMI) payload launched in 2005, and the Thermal And Near Infrared Sensor for Carbon Observations (TANSO) payload launched on the GOSAT satellite in 2009. This integral configuration pulse tube cooler contains a vibrationally balanced back to back pair of flexure spring supported compressors driving a linear configuration pulse tube cold head. In this efficient configuration the cold block is located near the midpoint of the cold head that is mechanically supported for launch by an aluminum H-bar. The two-stage versions of this cooler that were delivered for flight on the HTP[2], NEWT and Advanced baseline Imager (ABI) three payloads used the identical single stage HEC cooler with the linear cold head for the lower temperature cooling and added a split second stage coaxial cold head for cooling optics and/or filters at higher temperatures. The ABI version of the 2-stage cooler is shown in Figure 2.

Figure 1. Single-stage TRL 9 HEC cooler with linear cold head

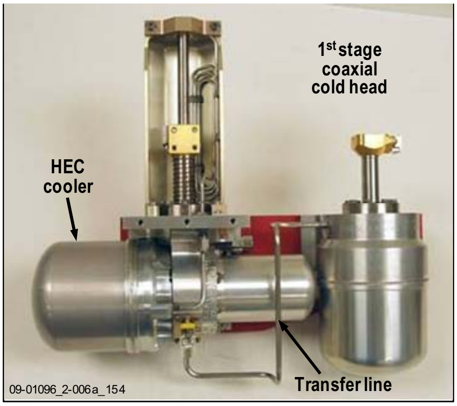

Figure 2. Two-stage ABI cooler with both linear and coaxial cold heads

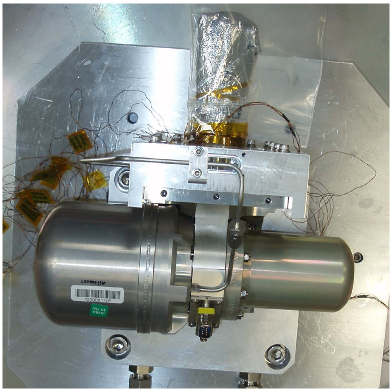

Figure 3. Single-stage HEC cooler with coaxial cold head

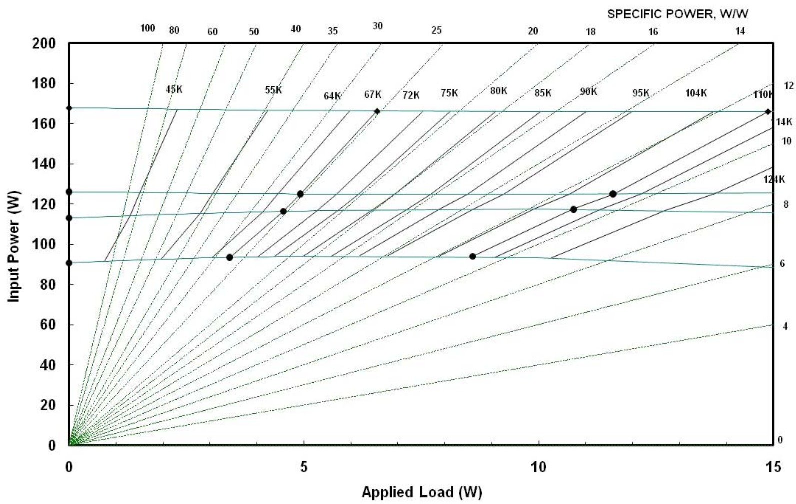

Figure 4. Coaxial HEC cooler performance map

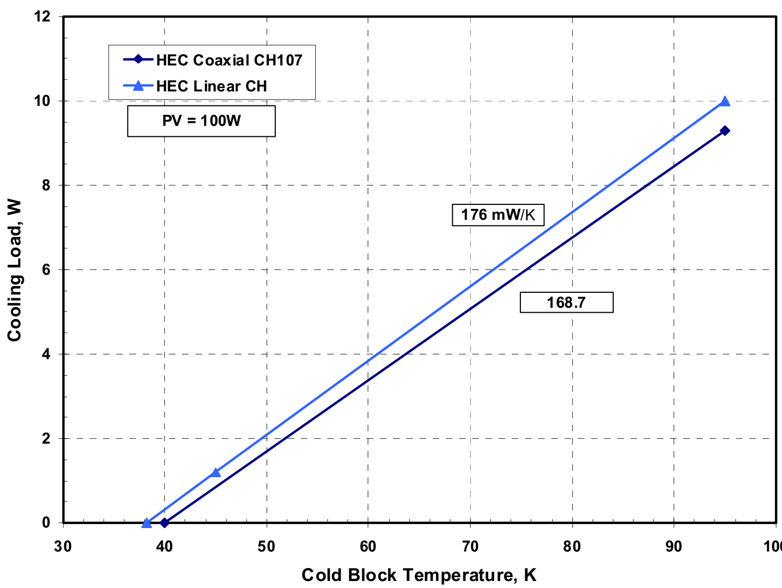

Figure 5. Comparison of the linear and coaxial cold head HEC coolers

SINGLE STAGE COAXIAL COLD HEAD COOLER PERFORMANCE

The single stage coaxial 5 kg HEC cooler that is shown in its test setup in Figure 3 was tested at input powers up to 180 watts. To adapt the linear cold head interface to the coaxial cold head interface, an interface plate was attached to the TRL9 HEC compressor. Figure 4 gives a map of input power to the compressor vs. cooling power with interpolated isotherms (lines of constant temperature) and lines of constant specific power (input power/cooling power) overlaid over the measured data points. 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. Note that at 180W input power, the cooling capacity can reach 4.5W at 55K or 15W at 104K. Figure 5 compares the

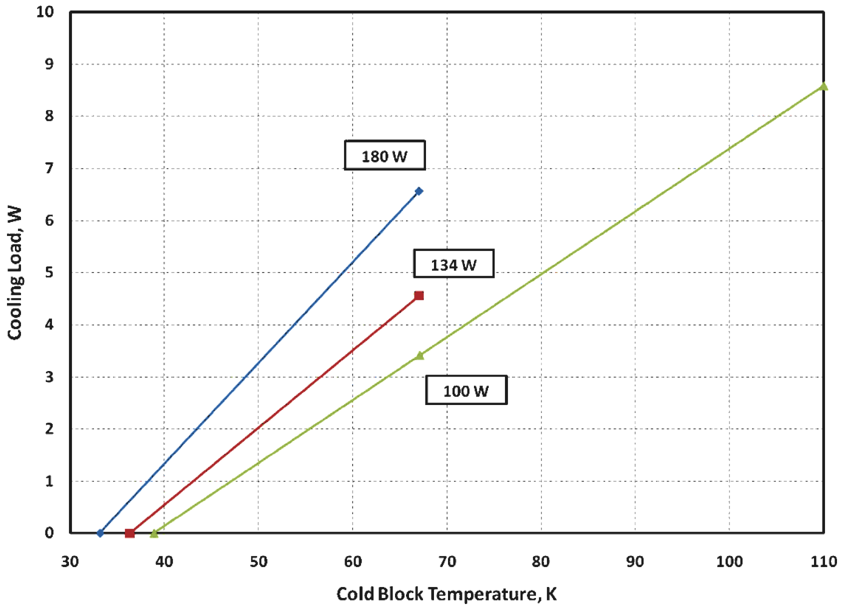

Figure 6. Cooler performance as a function of input power

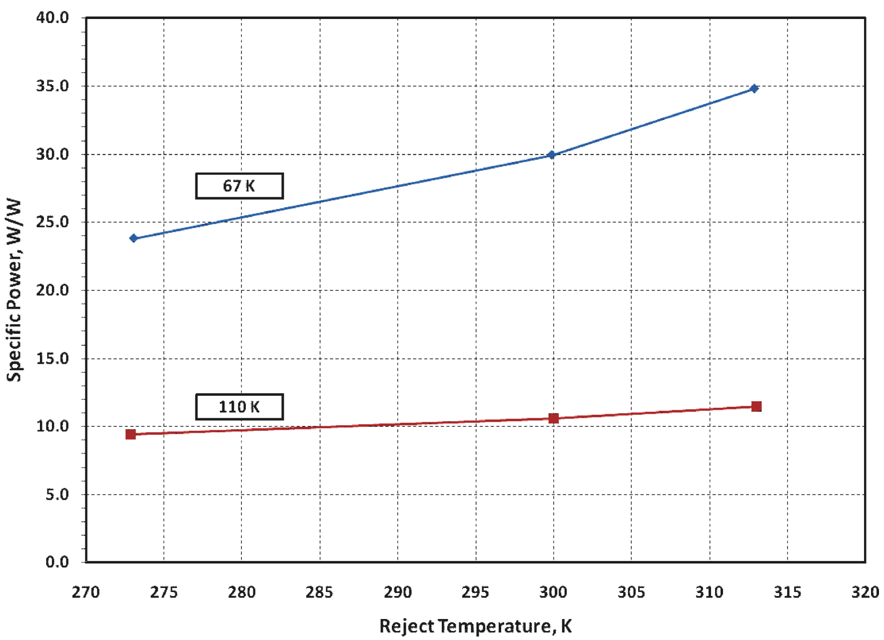

Figure 7. Effect of reject temperature on cooler performance

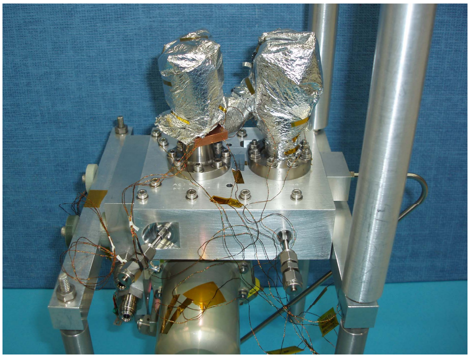

Figure 8. Integral configuration two-stage coaxial cold head HEC in test fixture

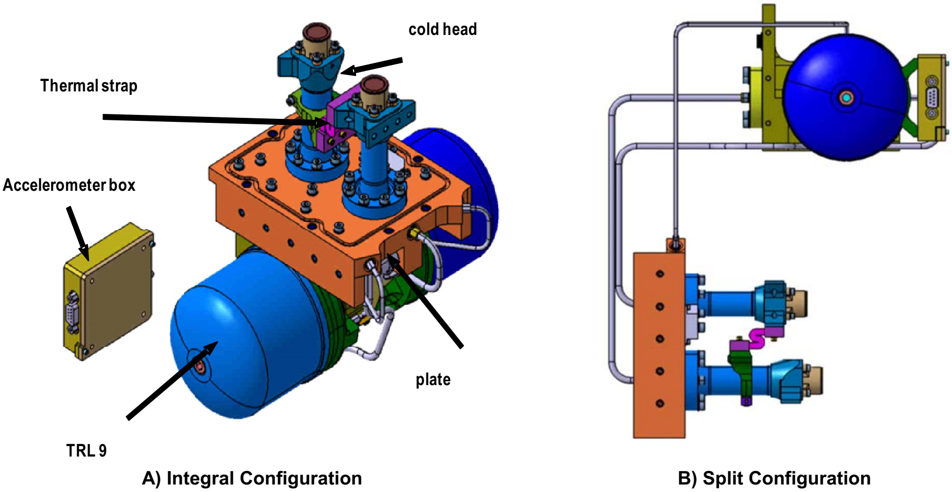

Figure 9. Two-stage cooler with coaxial cold heads

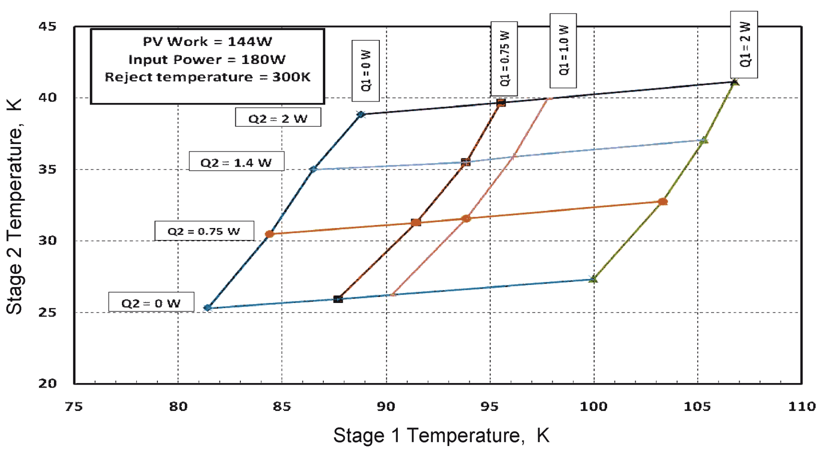

Figure 10. Performance map of the coaxial HEC cooler at 300 K reject temperature

linear cold head and coaxial cold head versions of the single stage HEC cooler. Both coolers have similar performance with the lower coaxial cold head performance attributable to the losses associated with flow turning at the cold block. Figure 6 shows three of the load lines in the temperature regime below 110K. Figure 7 plots the cooler specific power vs. heat rejection temperature between 273K and 313K for the two operating temperatures at 67K and 110K. As expected the lower reject temperature results in improved performance because of the Carnot factor, since the heat is being pumped over a smaller temperature difference.

TWO STAGE COOLER PERFORMANCE

The two-stage coaxial HEC cooler that is shown in its test setup in Figure 8 was tested at input powers up to 180 watts. This integral configuration cooler was configured by adapting the existing TRL 9 HEC compressor to the dual coaxial cold heads with an interface. This tested integral configuration is illustrated in Figure 9A. The delivered two-stage flight coolers shown in Figure 2 were configured as both an integral and split configuration. Should a split configuration be required for a particular payload requirement, the interface plate and cold heads could be remotely located as shown in Figure 9B. The two cold heads are configured in a parallel configuration with a heat strap between the 1st stage cold block and the 2nd stage regenerator to improve its efficiency. Figure 10 shows a performance map of the two 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 1.55W at 35K was measured for a compressor input power of 180W. The two-stage HEC cooler configuration extends the cooling capacity of this flight proven cooler to 35K and below.

CONCLUSION

Use of single and two-stage coaxial cold heads provides two additional cooler configurations for use with the space proven HEC compressor and drive electronics. The single stage HEC coaxial cooler provides efficient cooling at temperatures of 40 K and above. 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.

ACKNOWLEDGEMENTS

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