

# 10 K Pulse Tube Cooler Performance Data

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## ABSTRACT

The 10K EM Pulse Tube cooler is a three-stage pulse tube cooler for space applications. The staged cooler uses the same compressor and parallel staging configuration for the 1<sup>st</sup> and 2<sup>nd</sup> stages previously employed in NGST's Flight Qualified High Capacity Cryocooler (HCC Qual). The addition of the third stage extends the performance of this cooler to operating temperatures below 10 K.

The cooler performance has been mapped under a wide range of operating conditions. This paper presents the test data collected with the cooler at different input power levels, heat rejection temperatures and cooling conditions.

## INTRODUCTION

Northrop Grumman has manufactured a large number of flight cryocoolers designed to operate over a wide range of temperatures and cooling capacities. Our single and two-stage pulse tube coolers have demonstrated excellent efficiency and capacity at temperatures of 25 K and above. The 10K EM pulse tube cooler was developed to provide a long life, low mass, and high cooling capacity space cryocooler for use in cooling Si:As focal planes operating at 10K and below. This 10 K EM cooler maintains the heritage of the higher temperature two-stage HCC cooler that is now in life test at AFRL.

The performance of the 10 K Engineering Model (EM) pulse tube cooler has been measured for a wide range of operating conditions and the results are reported in this paper.

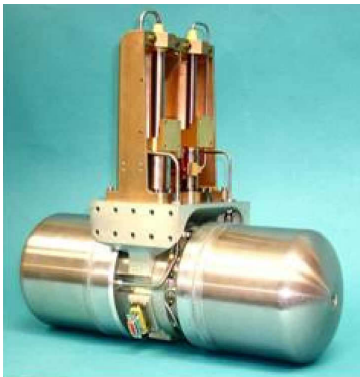
## CRYOCOOLER

The 10K EM Cooler<sup>1,2</sup> is based on the delivered two-stage HCC cooler (Figure 1) that is currently in life test at AFRL<sup>3</sup> and the HCC Qual cooler (Figure 2).<sup>4</sup> All these coolers employ a flexure bearing back to back compressor that is scaled from the flight proven HEC cooler (Figure 3).<sup>5</sup>

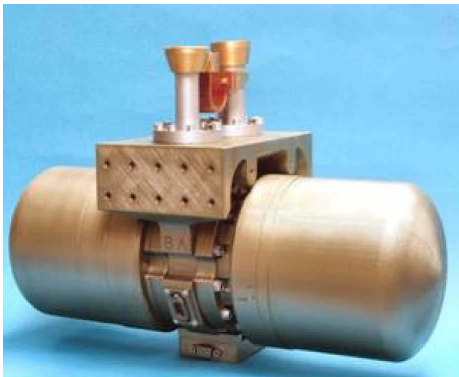
The 10K EM pulse tube cooler, shown in Figure 4, consists of a three-stage pulse tube cold head mounted integrally to the compressor. The 1<sup>st</sup> and 2<sup>nd</sup> stages use a parallel coaxial 2 stage cold head to precool the gas to approximately 40 K. The 3<sup>rd</sup> stage is a U-tube cold head which cools the gas to 10 K.

The 10 K EM cooler performance has been mapped at different input power levels, heat rejection temperatures and cooling loads at the 2<sup>nd</sup> and 3<sup>rd</sup> stages.

Figure 5 shows the load lines at input powers of 200 W, 300 W and 370 W. As the input power changes, the cooling load at 10 K increases from 125 mW to 212 mW and 255 mW respectively. The cooling capacity increases with increasing input powers as expected. Figure 6 plots the spe-



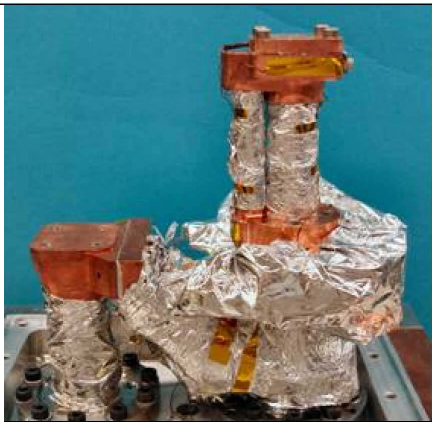
**Figure 1.** Two-stage high capacity cryocooler (HCC)



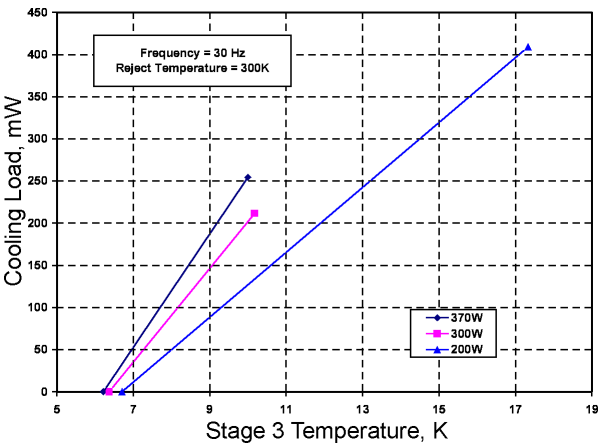
**Figure 2.** High Capacity Cooler Qualification (HCC Qual)



**Figure 3.** High Efficiency Cooler (HEC)



**Figure 4.** 10 K EM Cooler



**Figure 5.** 10 K EM Cooler load line as function of input power

cific power at different cold block temperatures as a function of the input power. The specific power changes from 1453 W/W at 10 K to 466 W/W at 18 K. Since changing the input power primarily affects the slope of the load line, the specific power remains fairly constant as the input power increases from 200 W to 370 W. The specific power plot shows that the 10K EM cooler is efficient over a wide range of input powers.

Figure 7 shows the load lines as a function of the heat rejection temperature at constant input power and operating frequency. As the reject temperature changes from 313 K to 280 K, the cooling load at 10 K increases from 185 mW to 230 mW at a constant input power of 300 W. The specific power is plotted against the reject temperature in Figure 8. The cooler efficiency increases as the reject temperature is reduced as expected.

Figure 9 plots the cold block temperature as a function of the operating frequency at different heat rejection temperatures. The optimal frequency of the 10 K EM cold head is 30 Hz over a wide range of reject temperatures.

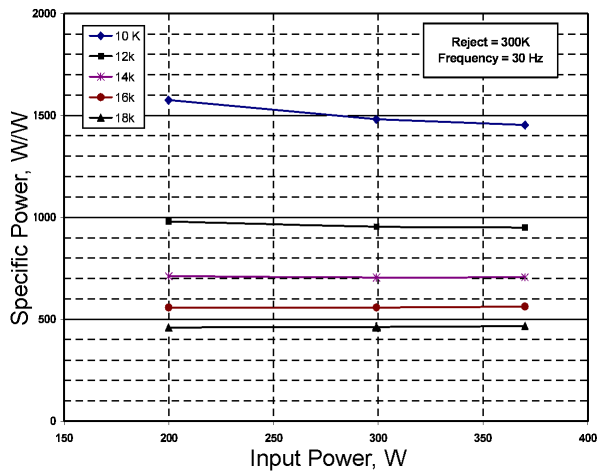


Figure 6. Specific Power at different input powers and cooling temperatures

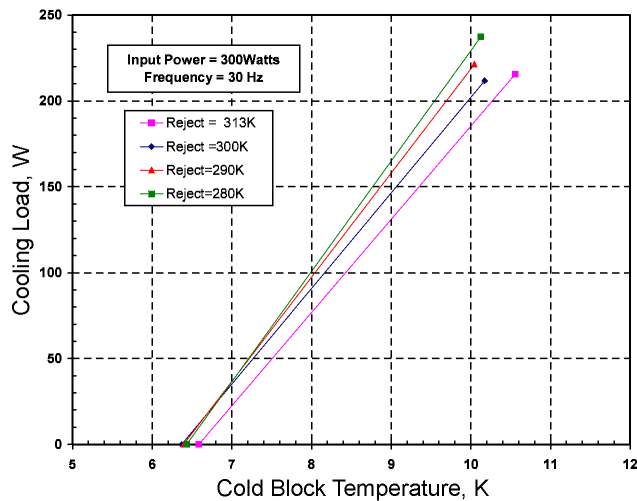


Figure 7. 10 K EM cooler load line as function of heat rejection temperatures

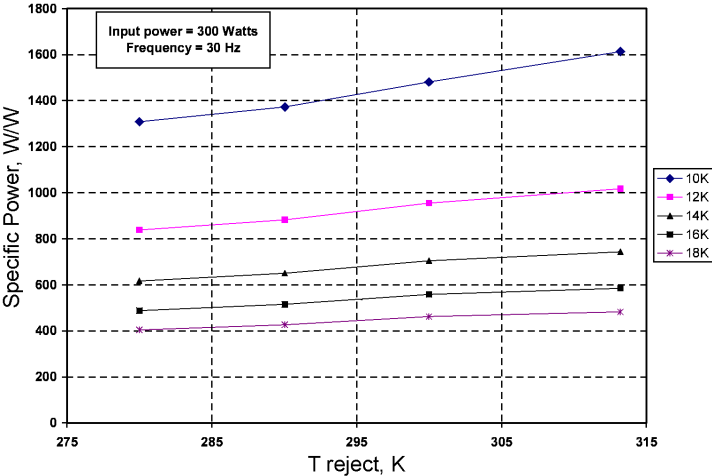


Figure 8. Specific Power as function of heat rejection temperatures and cooling temperatures

The performance of the cooler was also mapped with simultaneous cooling loads applied to the 2<sup>nd</sup> and 3<sup>rd</sup> stages. Performance data are plotted as isotherms of the 2<sup>nd</sup> and 3<sup>rd</sup> stages. Isotherms are useful mapping tools because they define the cooler capability to provide simultaneous cooling at the focal plane and at the thermal shield. Performance data at 300 W input power are plotted in Figure 10. In Figure 10, the intersection of 2 isotherms will define the temperatures and cooling loads that this cooler can support. For example, the cooler can provide simultaneous cooling loads of 700 mW and 180 mW at 49 K and 10 K for an input power of 300 W. These cooling loads are representative of a typical large focal plane at 10K with shield cooling at 49K. Isotherms for input powers of 200 W and 370 W are plotted in Figures 11 and 12. Figures 10 to 12 show that the 10K EM cooler can provide good cooling at the 10K focal plane (up to 250 mW at 10K) while support a shield cooling load as high as 1 W at 50 K.

ACKNOWLEDGMENTS

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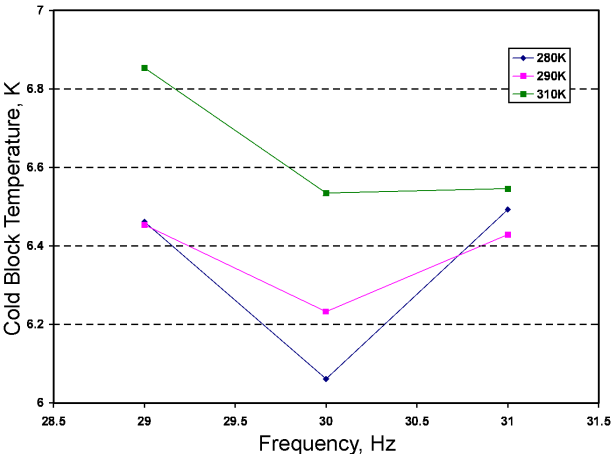


Figure 9. Effect of cooler operating frequency on cold block temperatures at different frequencies

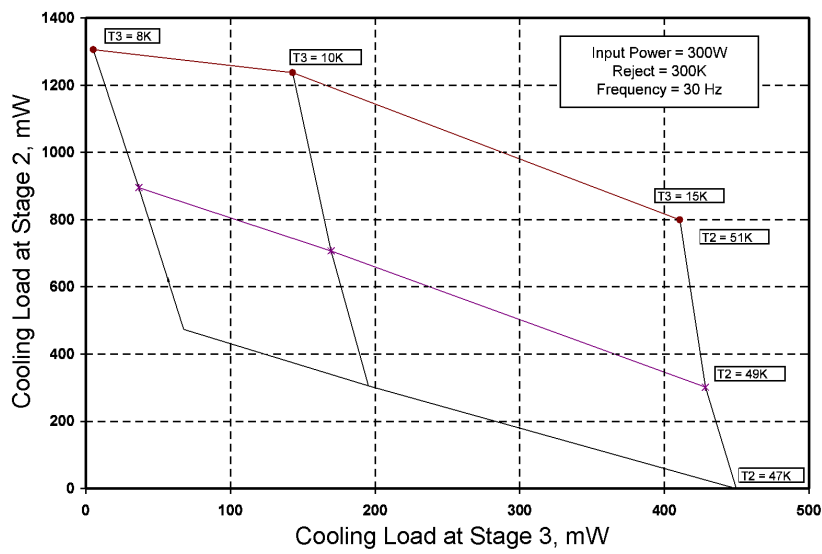


Figure 10. 10 K EM Cooler isotherms at a reject temperature of 300 K and 300 W input power

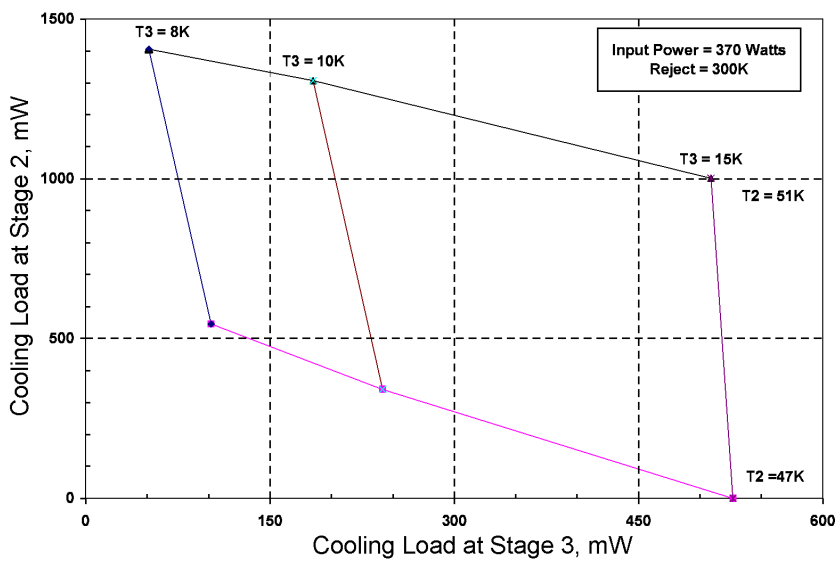


Figure 11. 10 K EM Cooler isotherms at a reject temperature of 300 K and 370 W input power

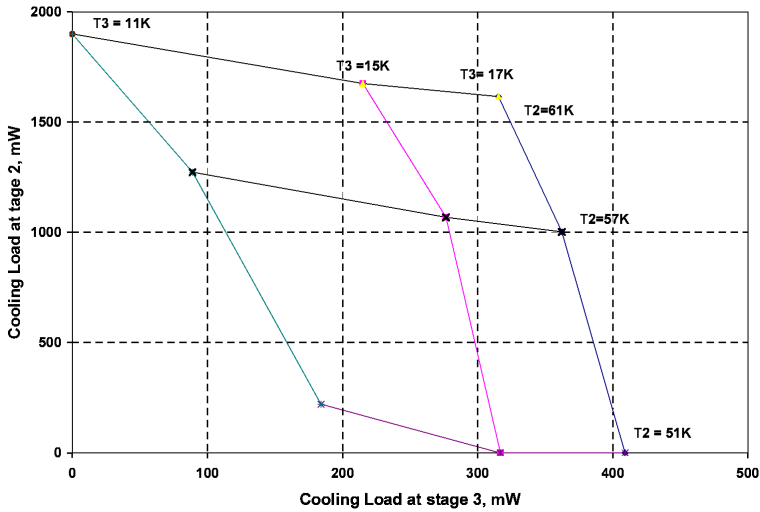


Figure 12. 10 K EM Cooler isotherms at a reject temperature of 300 K and 200 W input power

## CONCLUSION

The 10K EM Cooler performance has been measured as functions of the input powers, heat rejection temperatures and operating frequency. The performance data show that the cooler can provide simultaneous cooling up to 200 mW at 10 K with a substantial cooling at the intermediate stage (1 W at 50 K).

## REFERENCES

1. Jaco, C., Nguyen, T., Colbert, R., Raab, J., "10 K EM Pulse Tube Cooler," *Adv. in Cryogenic Engineering*, Vol. 53, Amer. Institute of Physics, Melville, NY (2008), pp.659-664.
2. Nguyen, T., Colbert, R., Durand, D., Jaco, C., Michaelian M., Tward E., "10 K Pulse Tube Cooler," *Cryocoolers 14*, ICC Press, Boulder, CO (2007), pp. 27-31.
3. Jaco, C., Nguyen, T., Harvey, D., Tward E., "High Capacity Staged Pulse Tube," *Cryocoolers 13*, Kluwer Academic/Plenum Publishers, New York (2005), pp. 109-113.
4. Jaco, C., Nguyen, T., Tward, E., "High Capacity Two-Stage Coaxial Pulse Tube Cooler," *Adv. in Cryogenic Engineering*, Vol. 53, Amer. Institute of Physics, Melville, NY (2008), pp.530-537.
5. Tward, E., et al., "High Efficiency Cryocooler," *Adv. in Cryogenic Engineering*, Vol. 47B, Amer. Institute of Physics, Melville, NY (2002), pp.1077-1084.