Enhanced Helium Compressor Operation for Sensitive Measuring Instrumentation

T. Sayles, D. Martien, J. Diederichs, J. Sloan, D. Bird, S. Spagna

Quantum Design Inc.,
San Diego, CA 92121

ABSTRACT

The recent advances in the design of a new class of "energy smart" helium compressors are presented that reduces the operating cost of cryogenically cooled instrumentation. In these systems, the individual speed control of the compressor capsule and cold head motor provide for intelligent oversight and budgeting of the cooling power delivered to the cryostat based on the immediate user measurement needs. In this report, we describe important elements of the system design, which increase operational life time, yield power savings, as well as providing for a low vibration environment in which sensitive measuring instrumentation can operate without degrading its ultimate performance.

INTRODUCTION

Quantum Design has recently developed a new class of helium compressors for its cryogen free instruments performing physical property measurements[1] that utilizes a two-stage Gifford-McMahon (G-M) cold head with nominal cooling power of 1.5 W at 4.2 K. Over the course of this development, we have learned a great deal about the essential features of the compressor design that both optimize the performance, and reduce the operating cost of our instrument.

COMPRESSOR DESIGN

Figure 1 is a schematic of the HAC 4500 Helium Air Cooled compressor that will be used to describe our "instrumentation grade" design. The HAC 4500 is based around a 3Φ Hitachi scroll compressor capsule run via a variable frequency drive. The compressor is air cooled by a 1/2 hp fan and is powered from a 3Φ 380-480 VAC 50/60 Hz outlet.

Ambient air is drawn from the sides of the outdoor heat exchanger where it cools the helium and oil flowing through their respective cooling coils. The adsorber, surge volume, and microcontroller electronics together with the user interface are housed in an indoor Compressor Control Unit.

Other features of the QD compressor are: all stainless steel construction; electronic pressure, temperature, and oil level sensors; sophisticated firmware to control the state engine and detect/report subtle fault conditions. The compressor has full featured CAN / CANOpen and RS232 interfaces, so that it integrates fully with the other modules in our and other OEM instruments.

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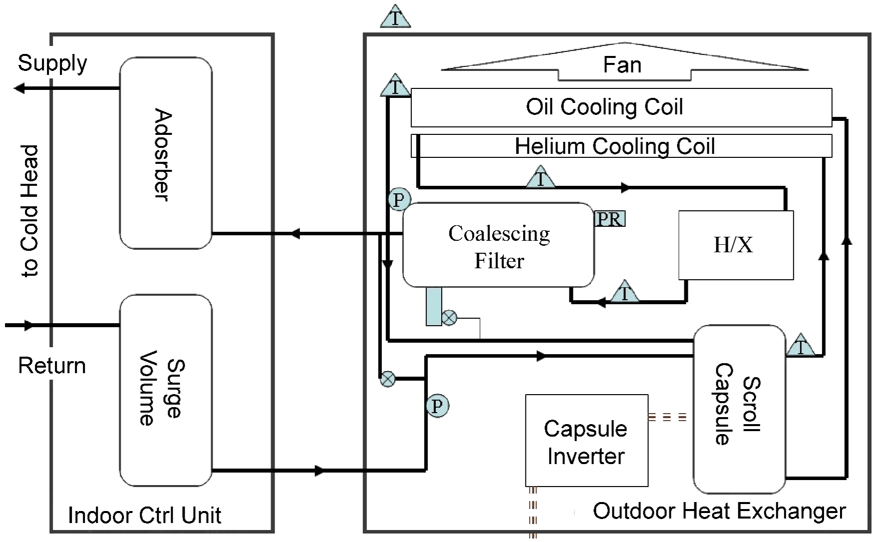

Figure 1. Schematic of the HAC 4500. Captions T=Thermistor, P=Pressure Sensor, PR= Pressure Relief Valve, H/X Heat Exchanger.

COOLING POWER VERSUS POWER CONSUMPTION

In the EverCool II, the compressor variable speed is used in a feedback mechanism to maintain a desired vapor pressure in the dewar. In practice, apart from the initial gas cool down, the system does not require the full rated cooling power of the cold head. Thus, rather than run the cooler at high power and put a heater on the 2nd stage, one can simply reduce the speed of the head/compressor motors. This scheme reduces power consumption as well as wear on the system.

Figure 2 compares the power consumption of a system in which a compressor is run at full power with a heater to throttle the cooling power of the cold head versus our variable speed compressor. For the purposes of this bench test a 30 W heat load is applied to the first stage of the Cold Head using power resistors.

The dotted line marks the steady state power consumption of an equivalent single frequency drive compressor such as the SHI CAN-61D. The data clearly shows the HAC 4500 offers a substantial operational cost reduction for our users. The power consumption ranges from less than 4 kW to about 8 kW (~0.55-0.7 P.F.) depending on the desired cooling power of the second stage. In the EverCool II, most of the experiments involving measurements of the physical properties of materials require cooling power less than 1 W at the second stage. This means that the compressor will be operating the cold head and capsule at frequencies less than 30 Hz, with an associated power consumption less than ½ that of the SHI CAN-61D. An additional benefit of the variable speed control, is the ability in some cases to drive the system at speeds faster than 60 Hz and extract more cooling power at the second stage, in an "on demand" basis.

INTELLIGENT OVERSIGHT OF OPERATION

The full featured micro-controlled diagnostic suite of the HAC 4500 provides for "intelligent oversight" of the compressor operating parameters which are known to be important[2] in reporting of fault conditions or need for service maintenance. For example, knowledge of the helium temperature and capsule speed enables us to more accurately model the adsorber accumulation rate. Preliminary experiments on a smaller variable speed compressor used in our VersaLab™ product

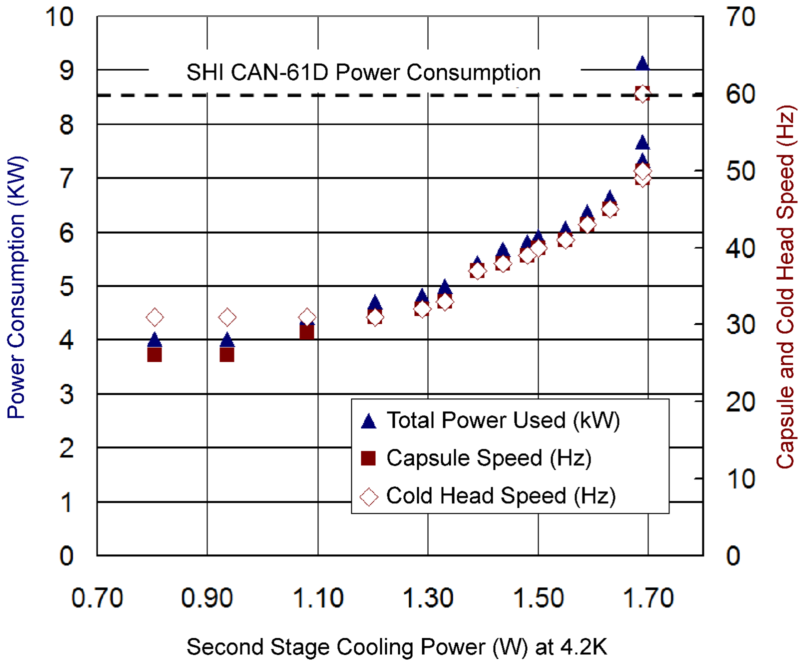

Figure 2. Power Consumption for the variable speed compressor

line indicate that the oil accumulation rate at a capsule speed of ~ 30 Hz is double the accumulation rate at a capsule speed of 15 Hz. Monitoring of the temperature of the helium flowing through the system also allows us to determine that a helium gas temperature of 36.5 °C results in twice the accumulation rate of helium running at 25 °C. Using these parameters will extend the service intervals for the adsorber and minimize the maintenance of our compressors.

CONCLUSIONS

The need for more efficient and versatile compressors for our applications has motivated us to develop an "energy smart" compressor. This system allows for intelligent oversight of the cooling power delivered to the second stage of a two stage G-M. We are confident that these new features are important now and in the future and our design should see a lot of good service.

REFERENCES

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2. Longsworth, R.C., "Helium Compressor for G-M and Pulse Tube Expanders in Advances in Cryogenic Engineering," *Adv. in Cryogenic Engineering*, Vol. 47B, Amer. Institute of Physics, Melville, NY (2002), pp. 691-698.