Dry Compact 1 kW Compressor for GM and Pulse Tube Cryocoolers

J. Höhne

Pressure Wave Systems GmbH
Munich, Germany

ABSTRACT

Pressure Wave Systems GmbH has developed a dry and compact 1 kW compressor system for the operation with Gifford-McMahon and pulse tube cold heads.

The compression unit consists of two metal bellow based “cylinders” of 500 cm^3 driven by electro-hydraulics. As compared to flexure-bearing compressors, the system runs at a much lower frequency between 0.5 and 2 Hz. The compressor is air-cooled, low-vibration, orientation-independent and uses single-phase electrical power. Technology, performance and application of the compressor system will be discussed.

INTRODUCTION

Recent advances in superconducting sensor and electronics technology e.g. (single) photon detectors create a demand for commercial low power, compact and mobile 4K and sub-4K cooling systems. Today, to our knowledge the smallest commercial 4K cold head on the market is the Sumitomo RDK-101 with around 100 mW cooling power at 4.2K and a no-load temperature of around 2.5K [1]. It is available with a 1.2 kW single-phase air-cooled compressor (CNA-11). This unit is well suited for many of the applications mentioned above. Nevertheless, many of these applications are currently run with no thermal load at the cold head base temperature of around 2.5K or actively heated at much higher temperatures up to 10K. As a consequence, a smaller cold head / compressor combination with reduced cooling power resulting in reduced electrical input power in the range of 500 W or smaller would be sufficient. For this and other applications we have developed a new dry compressor technology that can be scaled to serve the input power requirements described above.

TECHNOLOGY

Our compressor technology is based on a metal bellow driven by electro-hydraulics. Figures 1a and 1b illustrate the working principle. When the electric motor drives the hydraulic gear pump to move the hydraulic oil towards the metal bellow, the bellow and the gas inside are compressed (Figure 1a). Moving oil in the other direction (Figure 1b) allows the bellow and the gas to relax.

This set-up already has many advantages compared to the conventional scroll technology: the working gas only gets in contact with metal surfaces. Oil separator technology as used in scroll systems is not needed. Furthermore, our metal bellows are guaranteed for 80 million cycles. This corresponds to 5 years of continuous running at a frequency of 0.5 Hz. The gear pump itself is a

Cryocoolers 19, edited by S.D. Miller and R.G. Ross, Jr.

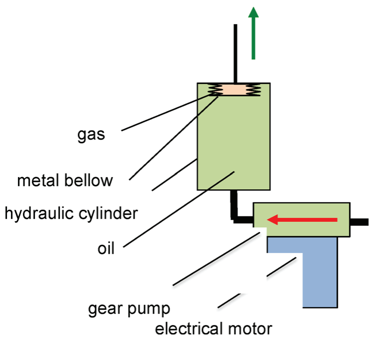

Figure 1a. Compression of the metal bellow and resulting compression of the gas volume

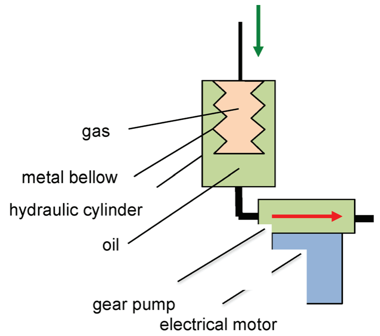

Figure 1b. Relaxation of the metal bellow and resulting relaxation of the gas volume

standard part and has shown the same reliability as needed for the bellow. We expect to exceed the maintenance intervals of conventional scroll units with this technology.

COMPRESSOR DESIGN

To make efficient use of this technology it is favorable to arrange the two bellows connected to one gear pump and drive the oil back and forth between the two bellows as shown in Figure 2. This has the additional advantage that the oil is always kept in a closed loop. In this way contamination of the hydraulic oil can be ruled out.

Two check valves on each cylinder control the gas flow. Our proprietary check valves have been tested to over 100 million cycles which translates to 6 years of continuous running time at 0.5 Hz. Buffer volumes in the range of liters are needed to keep the pressure fluctuations at reasonable values. Commercially available flex-lines (3 m) have been used to connect the compressor to the cold head.

Figure 3a shows a picture of the actual compression unit. In Figure 3b the complete 19” rack-mountable compressor package is shown.

PERFORMANCE / TEST RESULTS

The compressor was run with the Sumitomo RDK-101 cold head as depicted in Figure 2. The cold head motor was driven by the compressor electronics. Tests were performed with 230V / 50 Hz European grid voltage and frequency with electrical input powers of 1000 W, 750 W and 500 W. Figure 4a shows a typical cool down curve with 750 W electrical input power. The first and second

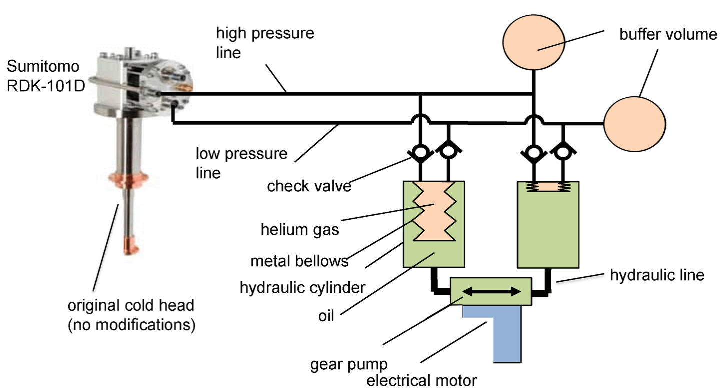

Figure 2. Compressor set-up

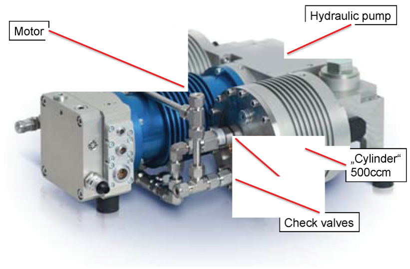

Figure 3a. Compression unit

Figure 3b. 19" compressor package

stage of the cold head reached no-load temperatures of 43K and 2.5K, respectively. Figure 4b shows the no-load temperatures for the three cases.

For 1000 W and 750 W the cold head still reaches its nominal no-load temperature although with increased 1st stage temperature in the case of 750 W. For 500 W of electrical input power a no-load temperature of 6K is reached. This would still be sufficient to run a sensor at 10K with some remaining cooling power.

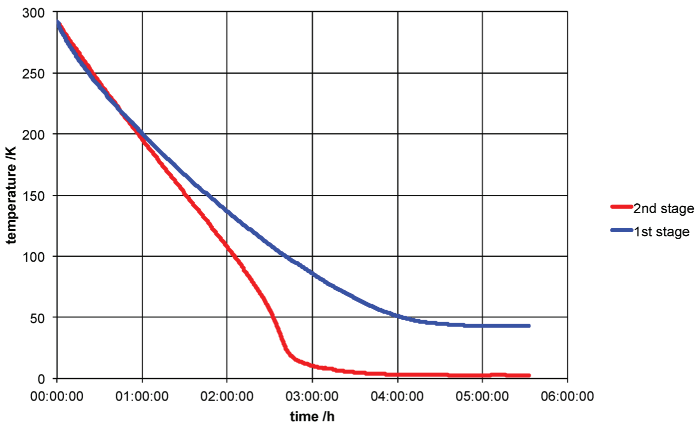

Figure 4a. Typical cool down with 750W of electrical input power

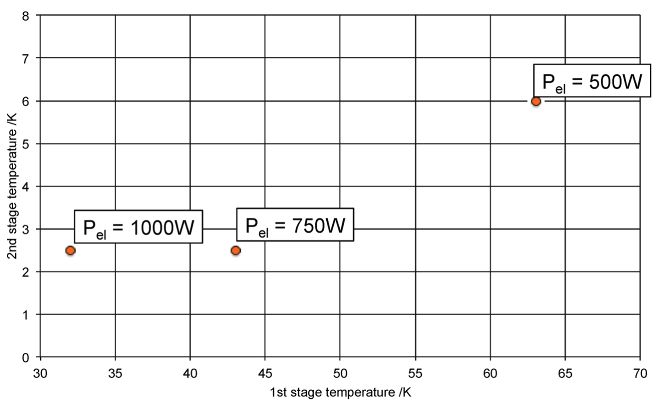

Figure 4b. No-load temperatures for different input powers

CONCLUSIONS AND OUTLOOK

A dry and compact 1 kW compressor has successfully been built and tested with a commercially available GM cold head. Desired base temperatures of around 2.5K could be reached with reduced electrical input power down to 750 W.

The performance results give rise to the assumption that low frequency 4K GM and pulse tube cryocoolers can be run with smaller input powers (e.g. 500 W or less) given the availability of smaller 4K cold heads. This would enable a much broader use of this technology and strengthen the acceptance of cryocoolers in daily use applications.

ACKNOWLEDGMENT

The author would like to thank M. Bühler from Low Temperature Solutions UG, Ismaning, for the many discussions. The challenging ideas and requirements of Vikas Anant from Photon Spot, Inc. have strongly influenced this work. The speed and accuracy in making mechanical parts by G. Töpelt is greatly appreciated. This work was happily supported by WMH, FH and JH.

REFERENCES

1. Sumitomo Heavy Industries, Ltd., Cryocooler Product Catalogue, 05/12