Performance estimation of an oil-free linear compressor unit for a new compact 2K Gifford-McMahon cryocooler

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Introduction

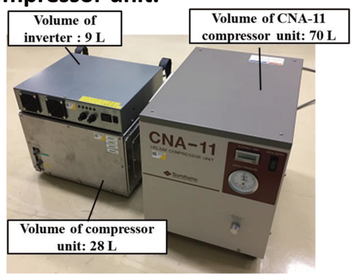
- ✓ In order to reduce the size of superconducting single photon detectors (SSPD) system, a compact 2K GM expander together with a low bottom-temperature of about 2.3 K, and oil-free linear compressor unit have been developed, respectably.
- ✓ The targeted cooling capacity of 20 mW at 2.3 K were successfully achieved with an electric input power of only 1.1 kW.
- ✓ The performance evaluation test of the linear compressor was carried out using a commercially-available RDK-101 expander. Also, the sound noise and vibration characteristics, and the effect of the compressor unit inclination and the environmental temperature on the cooling performance, were evaluated.

Conclusion

- ✓A similar cooling capacity of 19.2 mW at 2.3 K using a commercially-available RDK-101 was achieved with either a linear or a CNA-11 compressor. But, when temperature was lower than 2.3 K, a cooling performance with a linear compressor was than with a CNA-11 compressor.
- ✓There is almost no influence on the temperature of the first and the second stages when the compressor unit was rotated by 90 ° .
- ✓Moreover, the second stage temperature was stable and remained at the same temperature of 2.06 K during a continuous operation of about one month.

Performance of a RDK-101 expander with a linear compressor

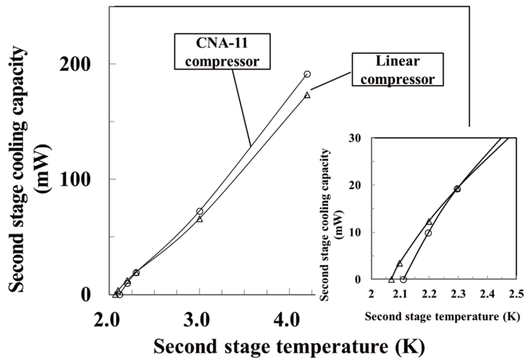
Photos of a linear and a CNA-11 compressor unit.



Operating pressures and mass flow rates at the second stage temperature of 2.3 K.

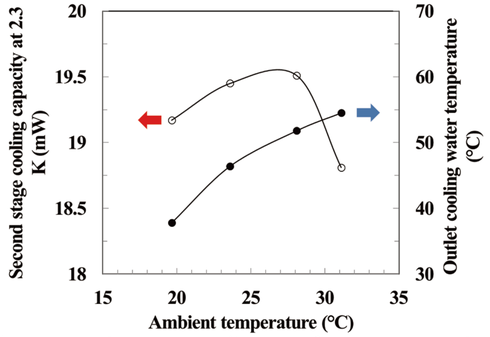
	CNA-11	Linear compressor
High pressure Ph (MPa)	2.24	3.0
Low pressure Pl (MPa)	0.73	1.2
Ph/Pl	3.07	2.50
Ph-Pl (MPa)	1.51	1.8
Mass flow rate (g/s)	1.2	1.16

Cooling performance of a RDK-101 expander using a linear or a CNA-11 compressor unit.



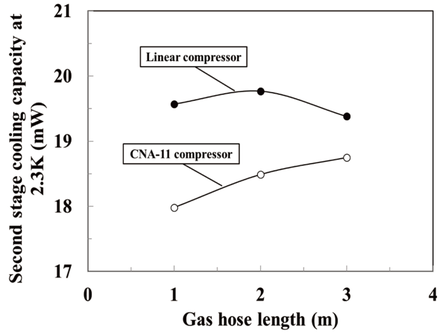
- ✓A similar cooling capacity of 19.2 mW at 2.3 K was achieved with either a linear or a CNA-11 compressor.
- ✓Below 2.3 K, a better performance was achieved with a linear compressor.
- ✓The lower no-load temperature was achieved with a linear compressor, owing to its higher operating pressures.

Influence of the ambient temperature on the second stage cooling performance with a linear compressor unit.



- ✓ The second stage cooling performance gradually increased until the ambient temperature reached 28° C, and then decreased.
- ✓ Since the upper limits of the ambient temperature for both the pump and the inlet cooling water temperature are 40° C, it is desirable for the ambient temperature to be lower than 28° C.

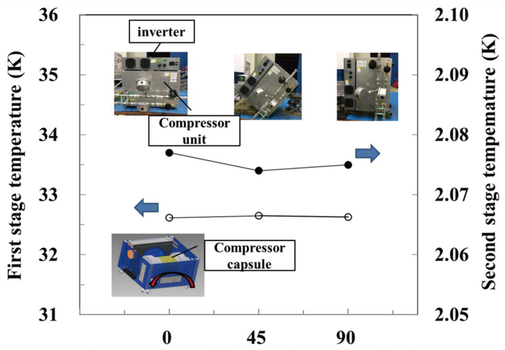
Influence of the length of the gas hose on the cooling performance.



- ✓ With a CNA-11 compressor, as the hose length decreases, the cooling performance also decreases, but with a linear compressor, the performance change is relatively small.

Compressor inclination

Influence of the compressor inclination on the no-load temperature at the first and the second stages.

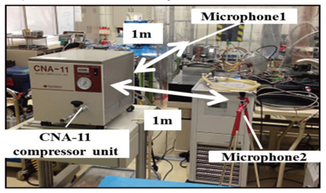


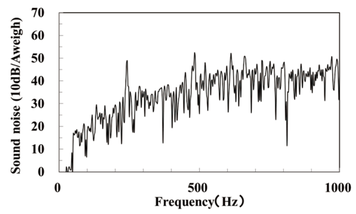
- ✓There is almost no influence on the temperature of the first and the second stages when the compressor unit was rotated by 90 ° .

Sound noise measurement

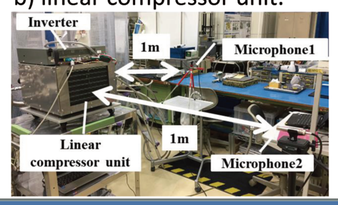
Experimental setup and measurement results of the sound (A weigh).

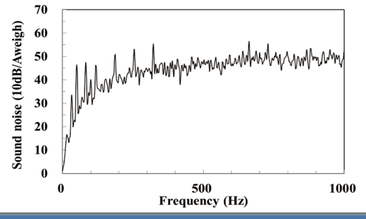
a) CNA-11 compressor.





b) linear compressor unit.



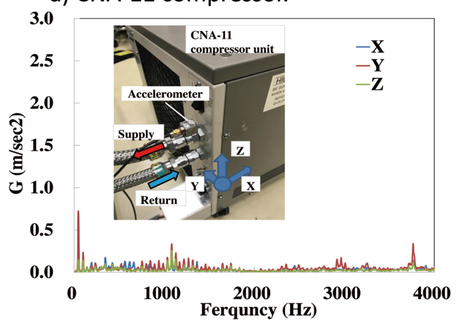


- ✓The sound noise of a linear compressor is somewhat higher than that of a CNA-11.
- ✓This large sound noise frequency is a multiple of 70 Hz, which is the compressor operating frequency.
- ✓Thus, it is considered that the sound noise is caused by the knocking sound of the valve and the vibration of the gas transfer tube.

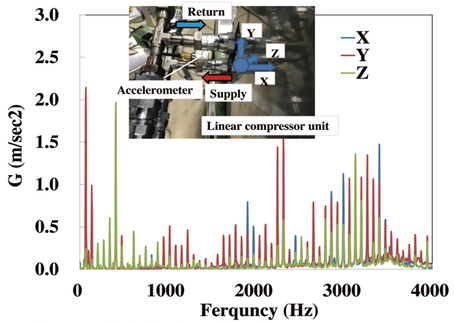
Vibration measurement

The vibration measurement results at the compressor side of the supply hose (high pressure).

a) CNA-11 compressor.



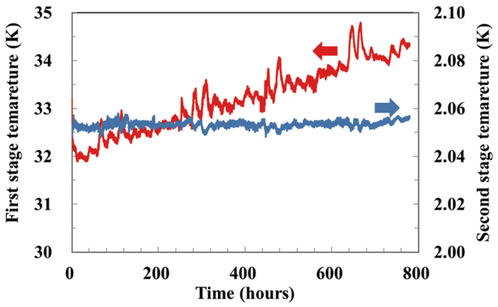
b) linear compressor unit.



- ✓The vibration of a linear compressor unit (maximum 2.2 G) is still higher than that of a CNA-11 unit (maximum 0.75 G), and should be further reduced in the future.

Short-term operation test

Experimental results of short-term operation test.



- ✓The second stage temperature was stable and remained at the same temperature of 2.06 K.
- ✓The first stage temperature gradually rose.

Acknowledgements

This work was supported by “Development of a Compact SSPD System for Photon-Quantum Information and Communication”, the National Institute of Information and Communications Technology (NICT), JAPAN.