Experimental investigation of compact 2K GM cryocoolers

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Technology Research Center
Sumitomo Heavy Industries, Ltd.

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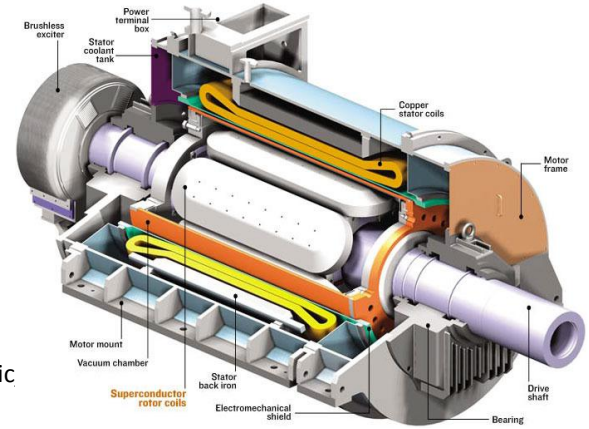
Cryogenic applications

http://en.wikipedia.org/wiki/Magnetic esonance_imaging



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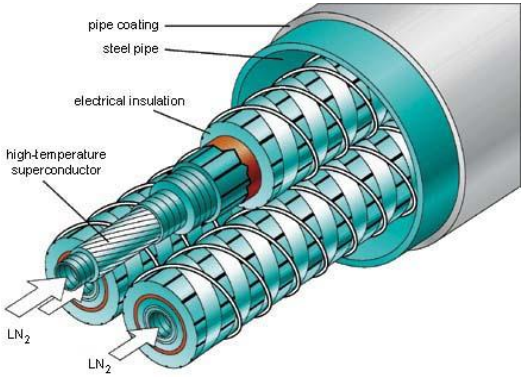

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Cryocoolers

Background

Sumitomo Heavy Industries

Rapid growth of superconducting electronic devices

Development of 2K GM cryocooler

Short supply of high reliability cryocoolers with bottom temperature under 3K

Item	Objective
1st Temperature with 1 W	60 K
2nd Temperature with 20 mW	2.3 K
Height reduction of expander comparing to the existing 0.1W 4K GM cryocooler	33.3%
Temperature oscillation displacement	<±20 mK

(Development target)

Progress of prototype unit

The world's smallest 4K GM cryocooler: RDK-101D

Performance Specifications

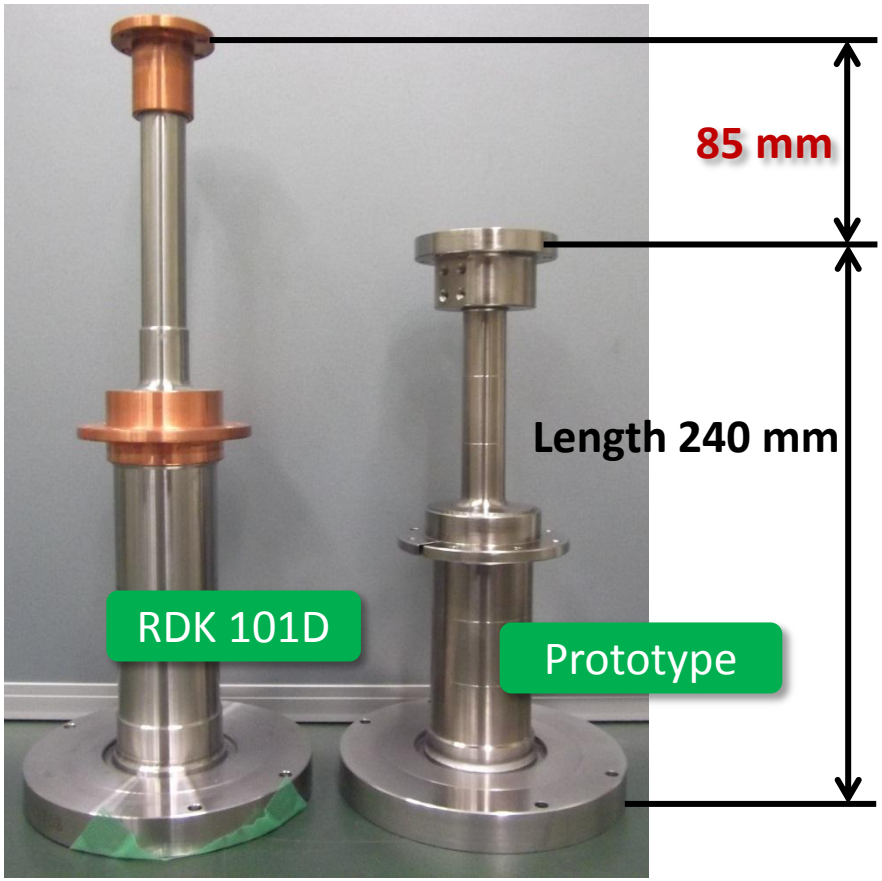
Power Supply Hz	50	60
2nd Stage Capacity Watts @ 4.2 K	0.1	0.1
1st Stage Capacity Watts @ 60 K	3.0	5.0
Cooldown Time to 4.2 K Minutes	150	150
Weight kg (lbs.)	7.2 (15.9)*	
Maintenance Hours	10,000	

*Cold head only. Drive unit weighs 1.0 kg (2.2 lbs.).

Standard Scope of Supply

- RDK-101D Cold Head
- CNA-11B/C Compressor
- 3 m (10 ft.) Helium Gas Lines

Progress of prototype unit



85 mm reduced in length

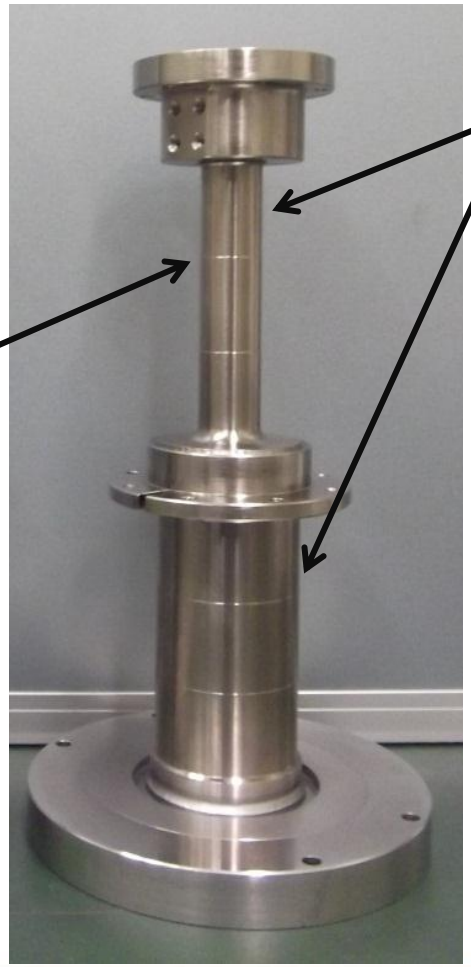
Lower reached temperature

Lower temperature oscillation

Background

Approaches to achieve higher cooling capacity

Second stage regenerator material (Gd_2O_2S)



Optimization of cylinder wall thickness

$$q = A \cdot \delta \cdot \nabla T$$

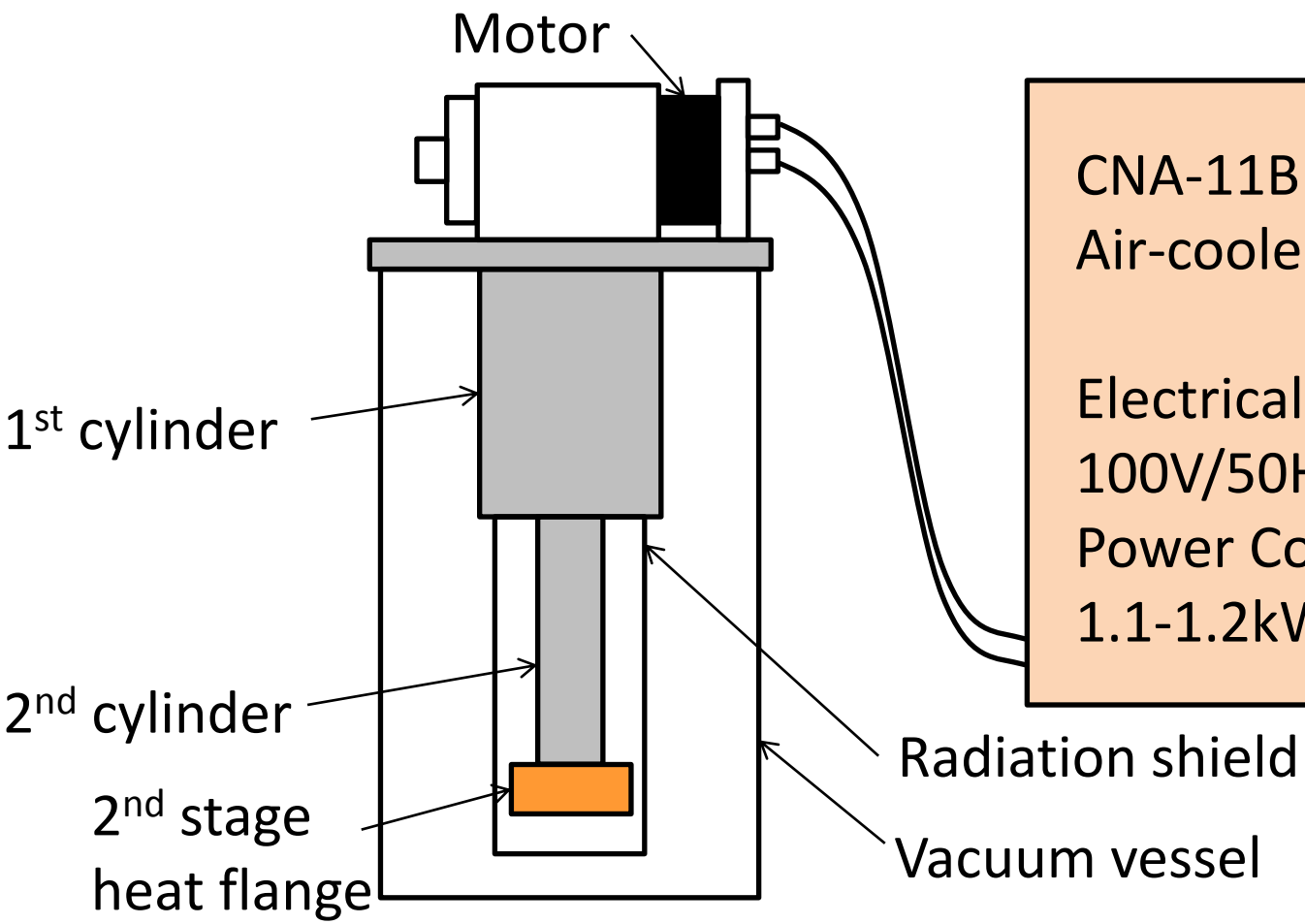
q – Heat flux
A – Cross section area
δ – Thermal conductivity

Experiment setup

Experiment items

1. Stabilized temperature under no-load condition.
2. Stabilized temperature under 0W-4W (for first stage), 0W-20mW (for second stage) thermal load.
3. Temperature oscillation under no-load condition.
4. Temperature oscillation under certain thermal load.

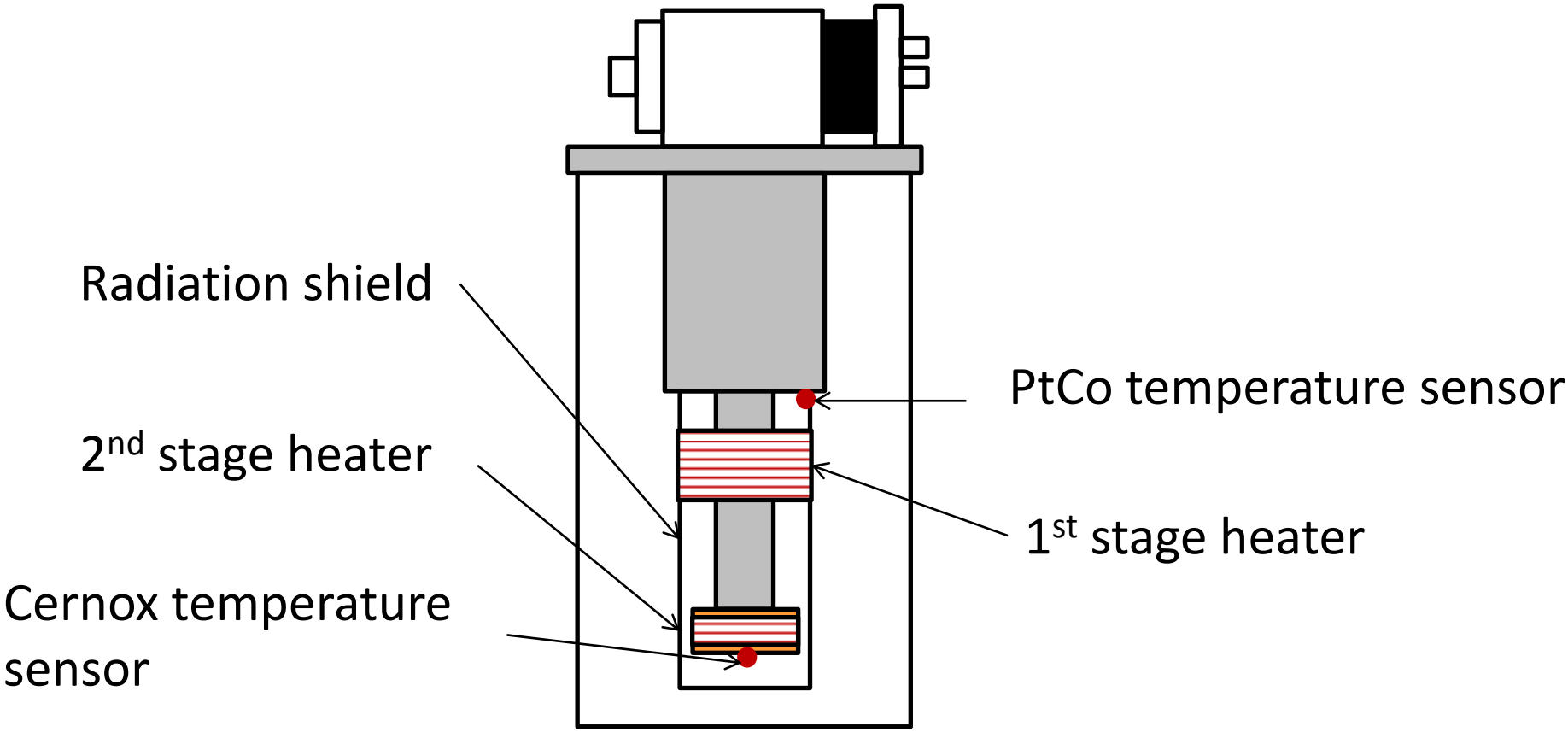
Experiment apparatus



CNA-11B
Air-cooled Compressor

Electrical Supply:
100V/50Hz
Power Consumption:
1.1-1.2kW @ 50Hz

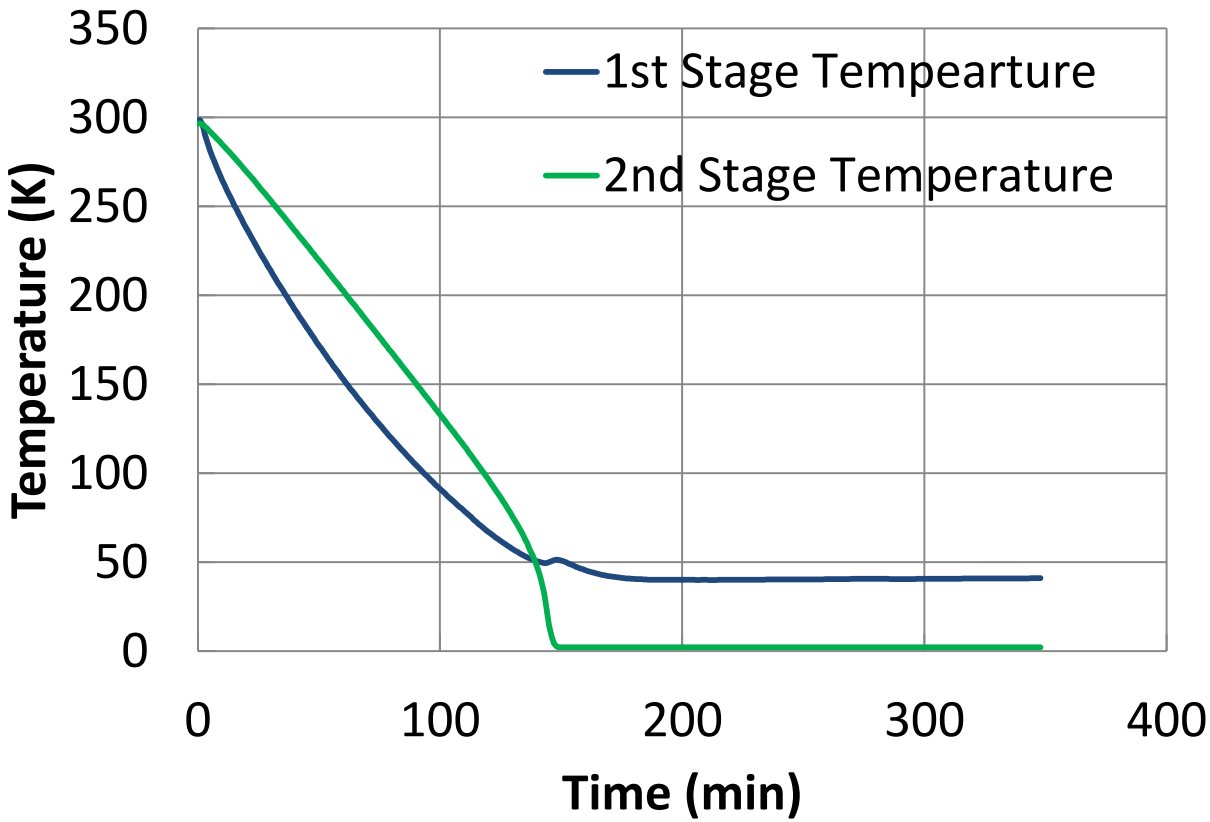
Temperature measurement



Experiment results

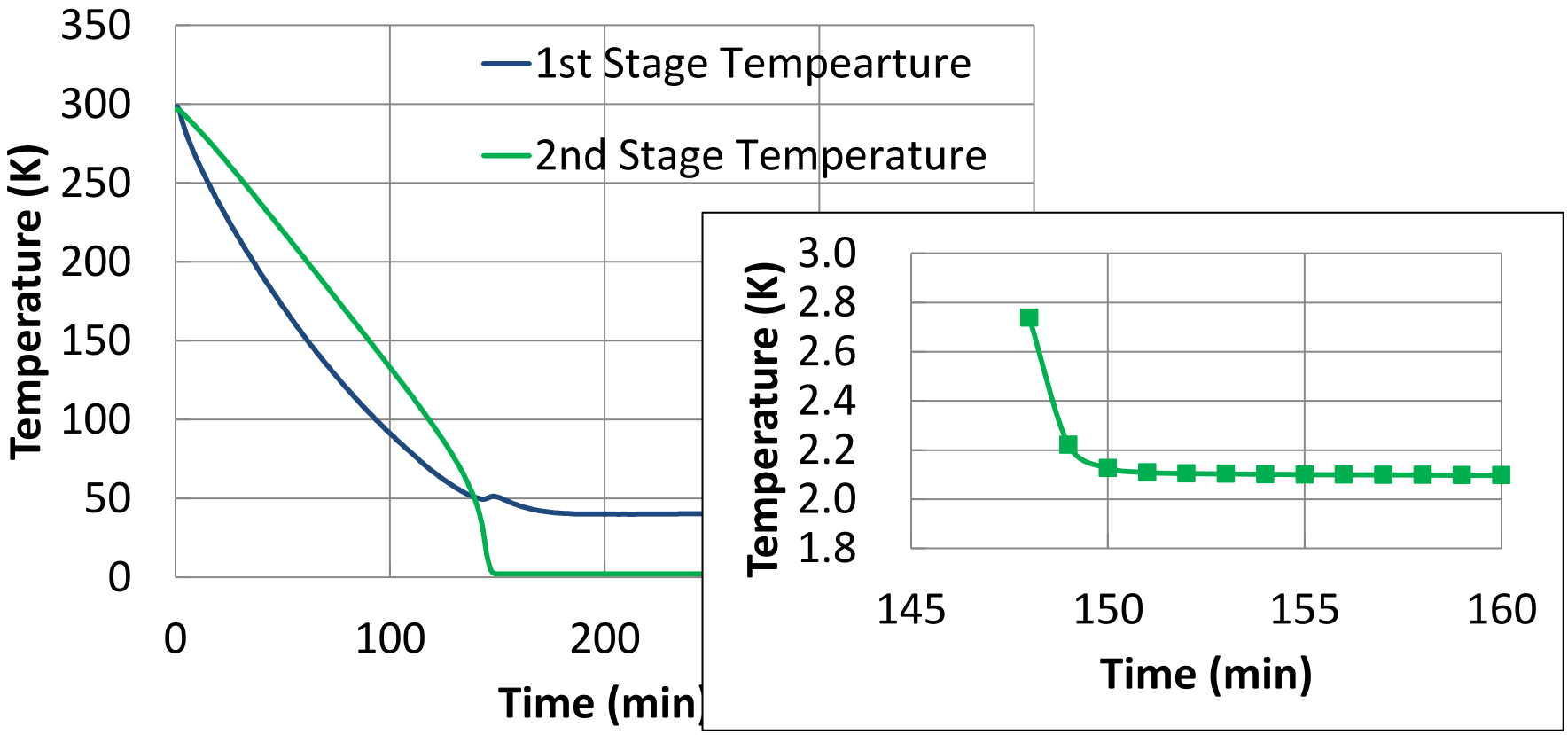
Cool-down curve

Typical cool-down process



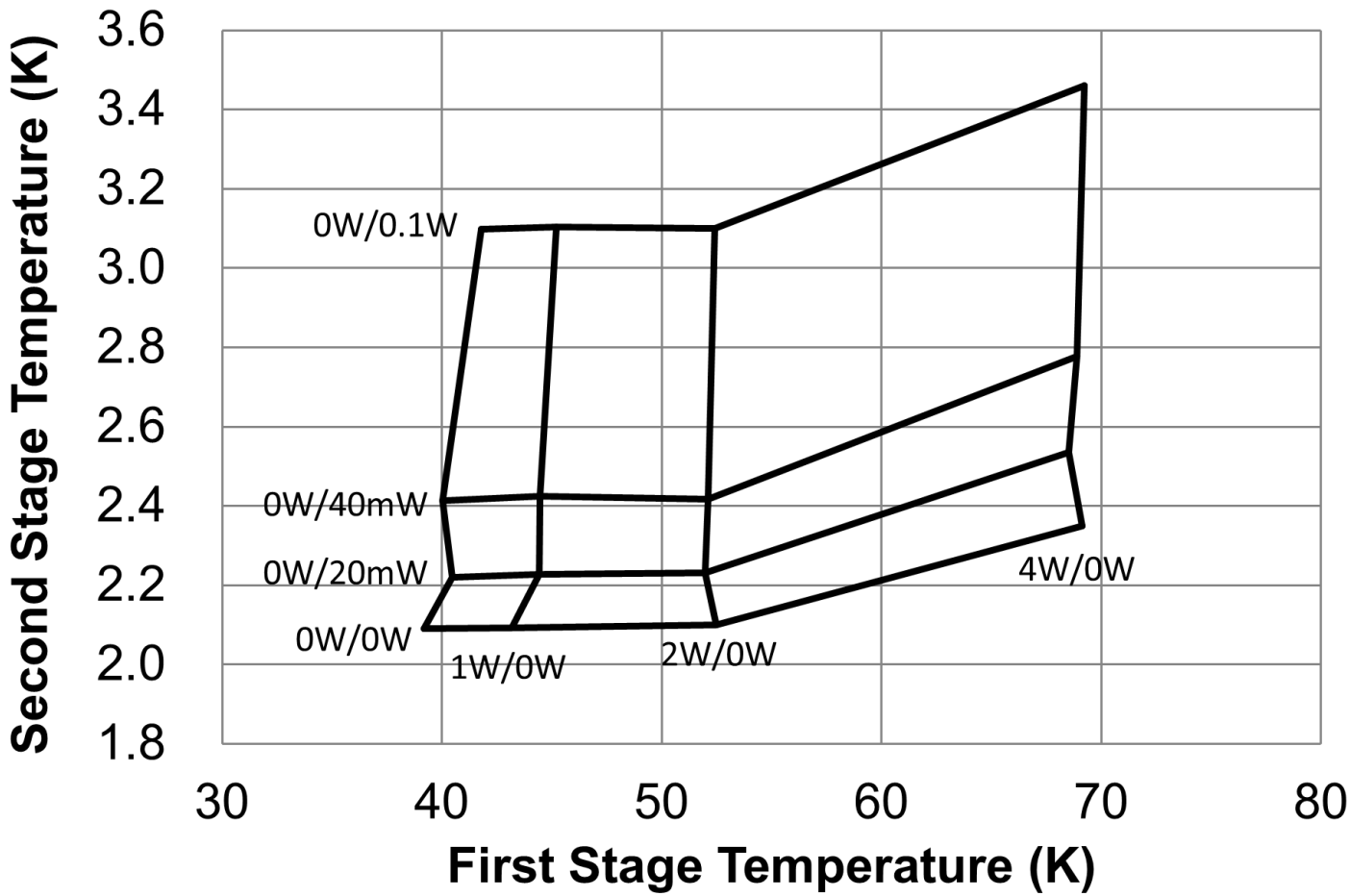
Cool-down curve

Typical cool-down process



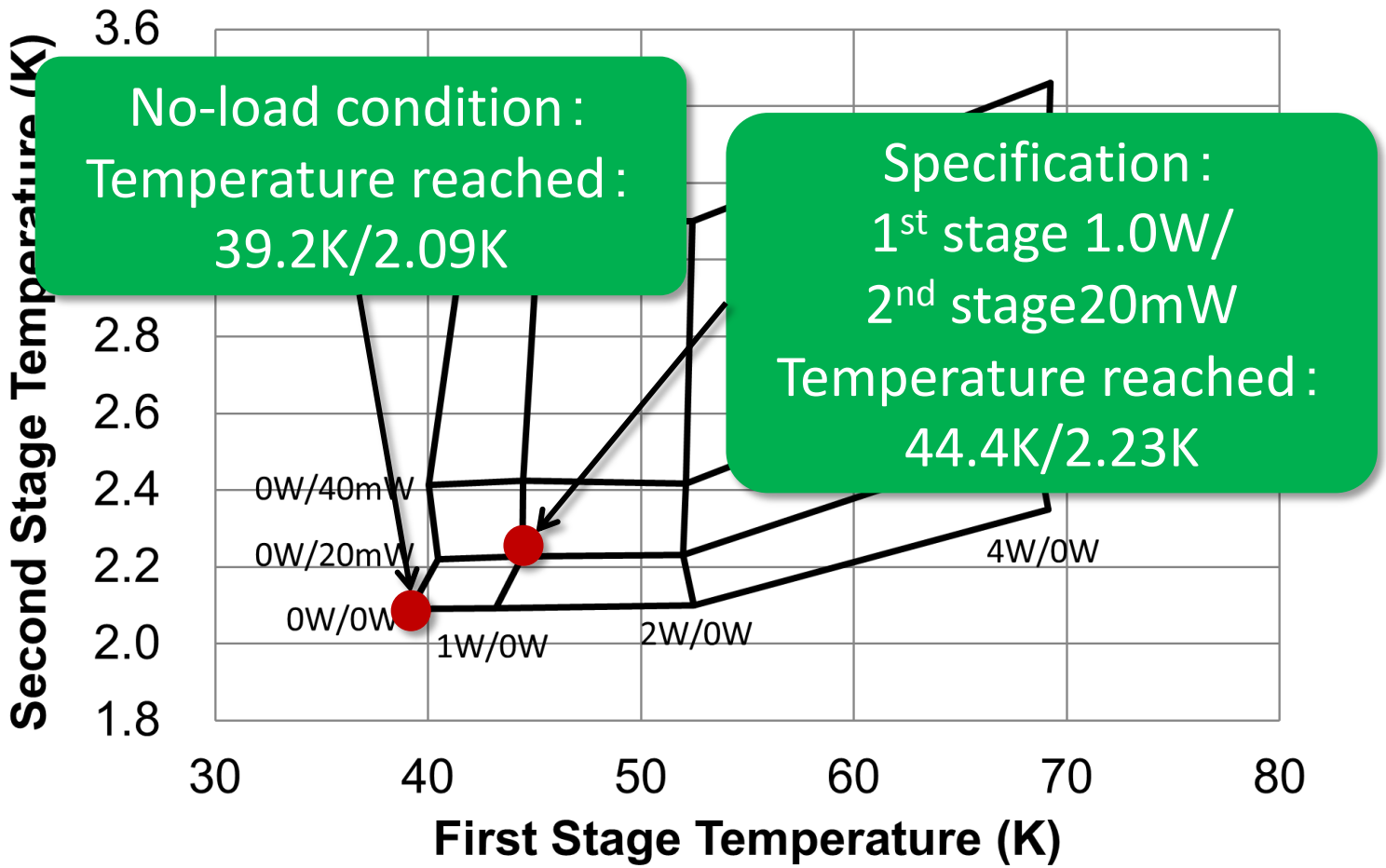
Load-map (Prototype)

Considerable capability under 3K



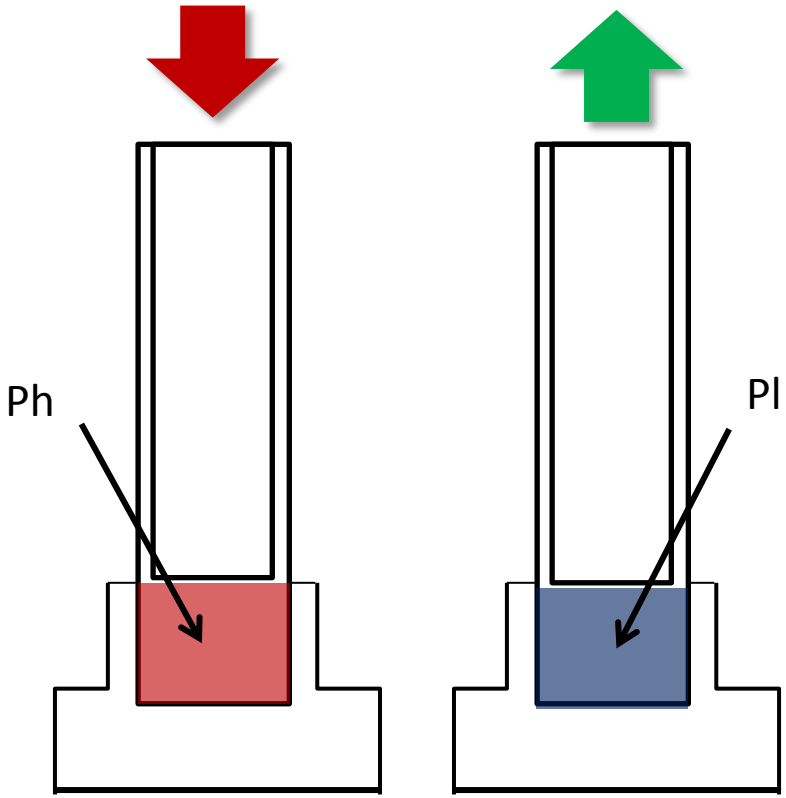
Load-map (Prototype)

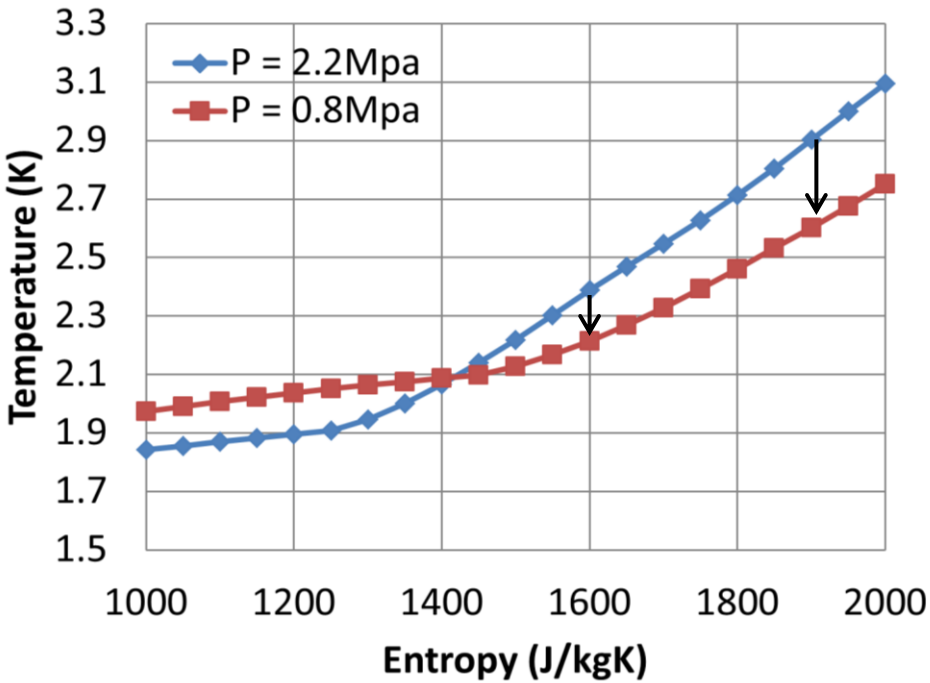
Considerable capability under 3K



Temperature oscillation

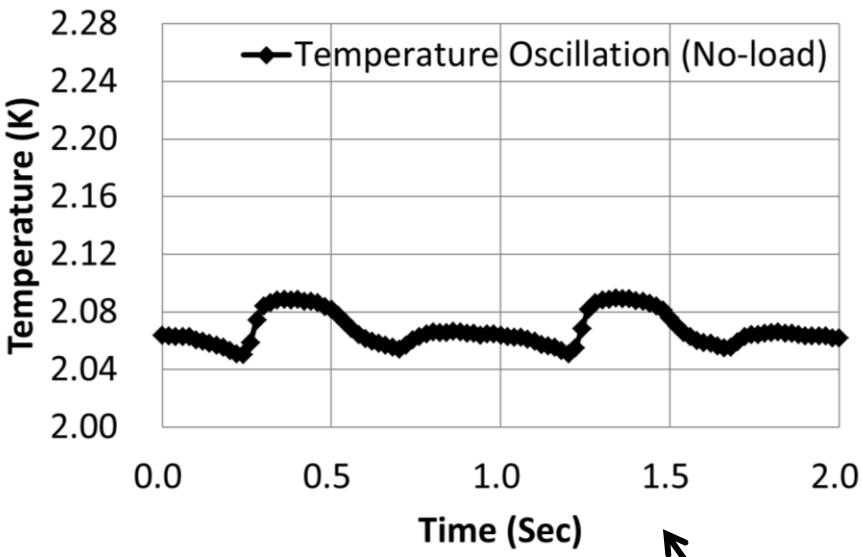
A theoretical analysis

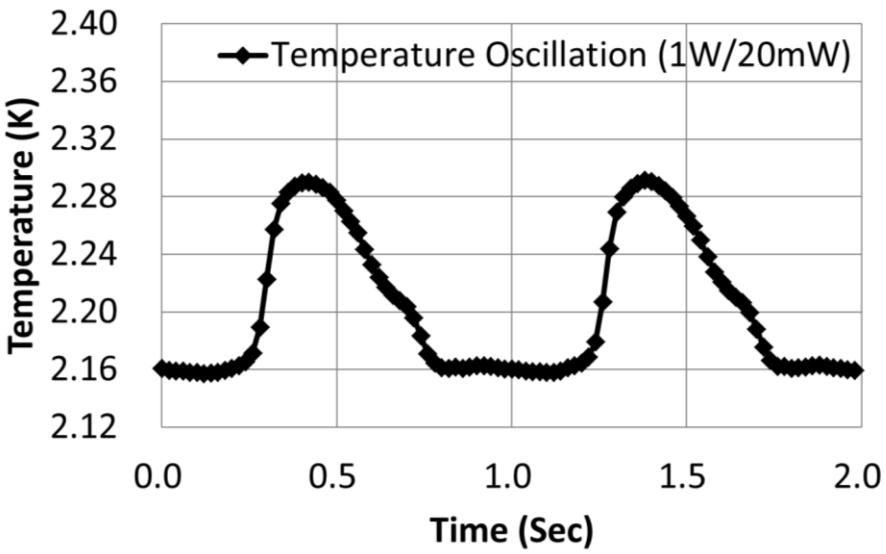




Temperature oscillation

Temperature oscillation suppressed..





Temperature oscillation less than ±20mK has been achieved

Conclusion

Summary

Sumitomo Heavy Industries

1. A new, compact 2K GM cryocooler has been developed and the cooling capacity of prototype unit was tested in this study.
2. The prototype unit showed sufficient cooling capability and can meet a wide range of thermal-load:

No-load condition: 39.2K / 2.09K

1W/20mW: 44.4K / 2.23K

3. Temperature oscillation displacement under no-load condition was less than ±20mK.
4. Future work: A completely new designed cooling system including cryostat, cryocooler, compressor for small scale applications.

Acknowledgement

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Thank you!