European Cryogenics Days 2017
and the 2nd International Workshop on Cooling Systems for HTS Applications
Karlsruhe, Germany, September 13-15, 2017.

Turbo-Brayton Refrigerator of Yokohama HTS Cable Project

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MAYEKAWA

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Company Profile

MAYEKAWA MFG. CO., LTD.

Tokyo office

Established in:	**1924**
Capital:	**1 billion yen**
Sales:	**130 billion yen (group)**
Employees:	**4,500**
Manufacture:	**Gas compressor, Industrial freezer, Refrigerator**
Market:	**Food, Meat and Seafood processing, Distribution and Energy**

MAYEKAWA is doing business globally, having 60 domestic offices and 3 plants and 2 laboratories, and 102 overseas offices including 7 plants.

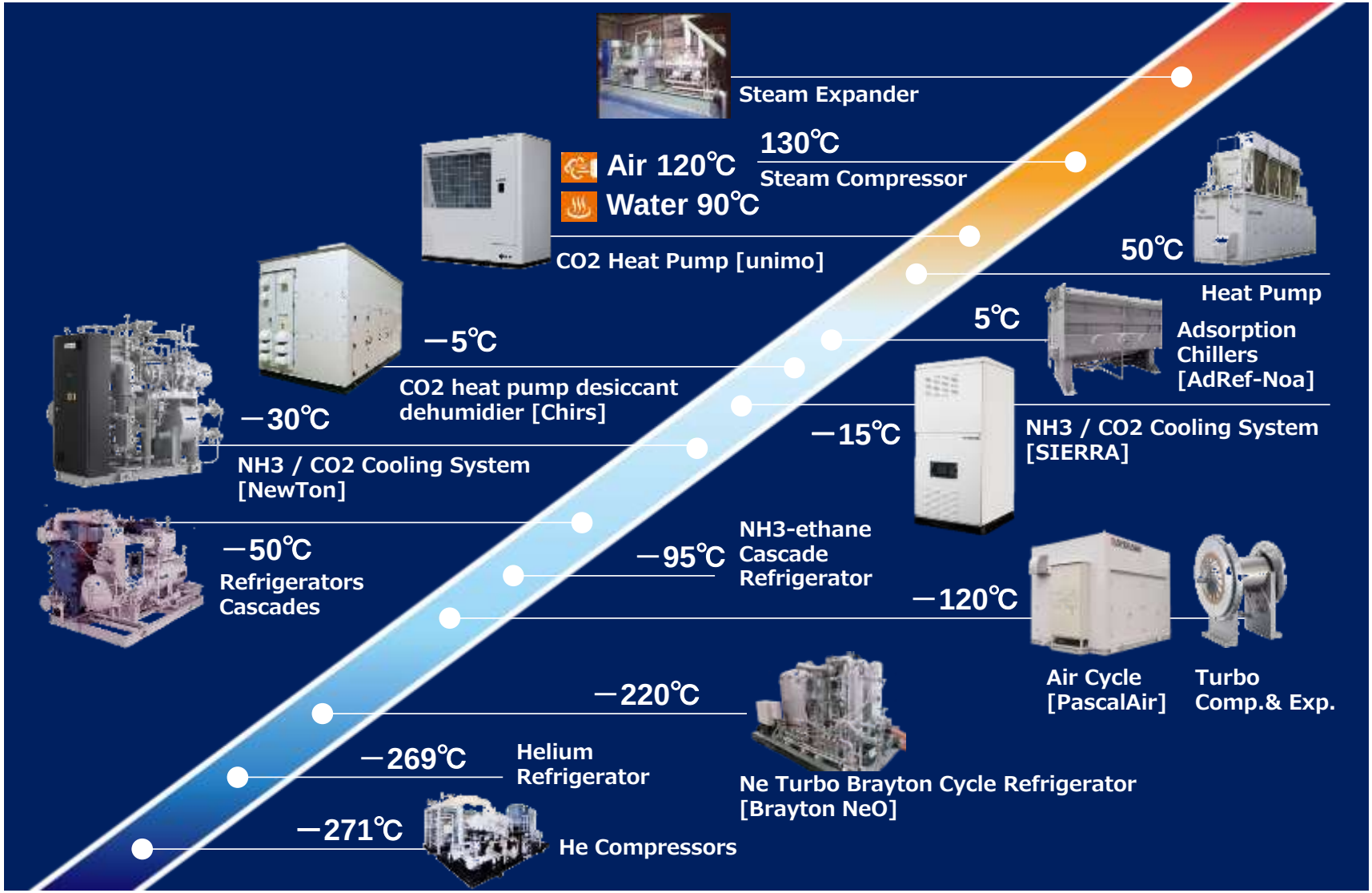
Plants

- Belgium
- India
- South Korea
- USA
- Mexico
- Brazil

Offices

- England
- France
- Spain
- Switzerland
- Germany
- Russia
- Turkey
- UAE
- Thailand
- Viet Nam
- Singapore
- Malaysia
- Indonesia
- Australia
- New Zealand
- Philippines
- China
- Taiwan
- Canada
- Venezuela
- Costa Rica
- Colombia
- Ecuador
- Peru
- Chile
- Argentina

Operation Rang of MAYEKAWA



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Outlines of the Yokohama Project

Project Outlines

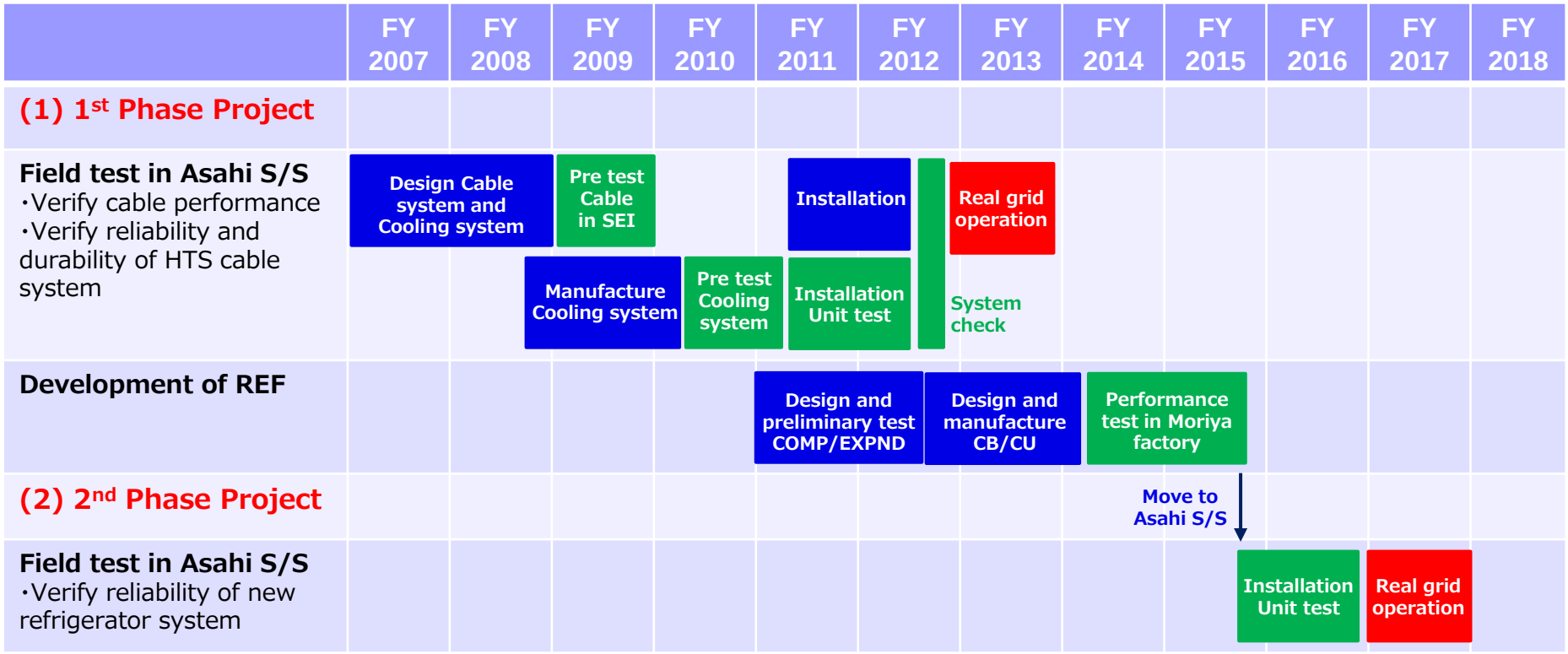
- Asahi S/S, Yokohama, TEPCO's power system
- 66 kV – 2 kA – 200 MVA class HTS cable with 1G DI-BSCCO wire
- Compact 3-in-One cable designed for 150 mm conduit
- Approx. 250 meter cable with a joint and terminations
- Project Member : TEPCO, SEI , MAYEKAWA supported by NEDO, METI

HTS Cable Specifications

Items	Specifications
Rated Capacity	230 MVA(66 kV, 2 kA)
Maximum Current	2.75 kA
AC Loss	1 W/m/ph at 2 kA
Withstand Voltage	AC 90 kV for 3 hours Imp ±385 kV 3 repetitions
Fault Current	1. No degradation against the F.C. of 31.5 kA, 2 sec. 2. The rated capacity can be transmitted immediately after F.C. of 10 kA, 2 sec.

HTS Cable

Project Schedule

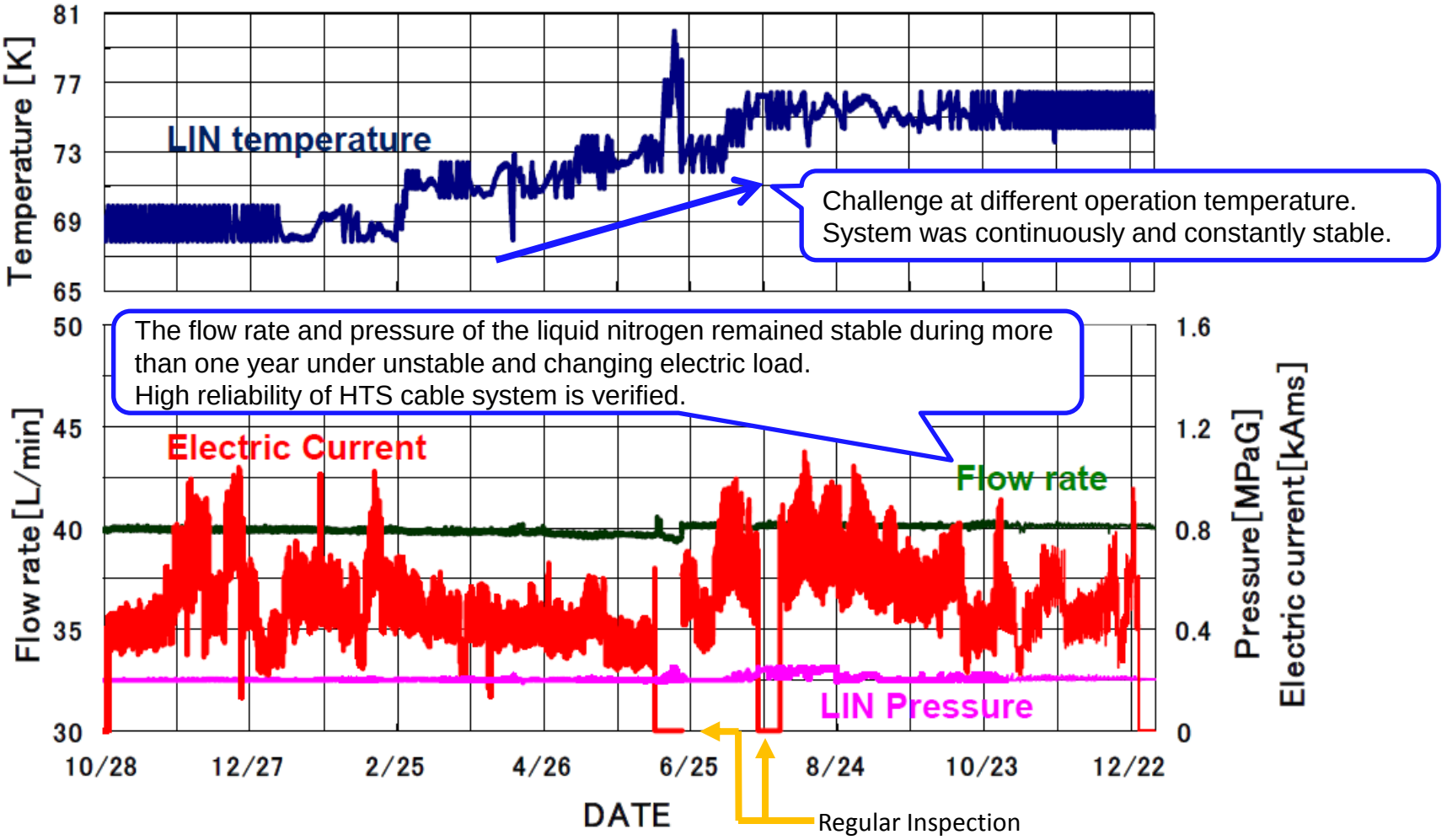


※REF: Refrigerator, COMP: Compressor, EXPND: Expander, CB: Cold Box, CU: Compressor Unit

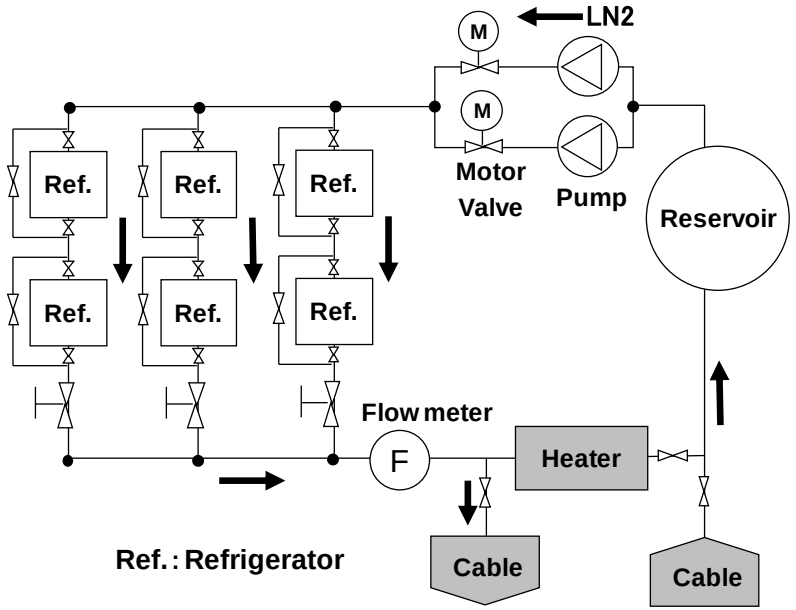
- Demonstration test of 1st Phase in real grid has started on October 29, 2012 and finished on December 25, 2013. More than 1 year continuous reliable operation has been verified with successful result.
- Demonstration test of 2nd Phase in real grid has started on March 31, 2017. Reliability of new refrigerator has been verified in the continuous operation.

Results of 1st Phase Operation Test

More than 1 year Continuous Reliable Operation has been verified with successful result.



Technical Issues of the Cooling System



Cooling System of 1st Phase Project

Tabke2. Improvement of Cooling Capacity

Items	Cooling capacity
Vacuuming	30 ~ 100 W / 1 unit
Overhauling	200 W / 1 unit
Working gas charge	40 W / 1 unit

Table1. Specifications

Items	Specifications	Unit(s)
Refrigerator (Stirling type)	1 kW @ 77 K	6 (Redundancy 1 unit)
Pump (Centrifugal type)	0.15 MPa 40 L/min	2 (Redundancy 1 unit)
Reservoir	1000 L	1

Technical Issues of the Refrigerator

- **Low Efficiency**
  Average COP of one year is 0.05 we measured. COP of a refrigerator is needed 0.1 for saving energy of HTS Cable.
- **Short Maintenance Interval**
  This refrigerator needed vacuuming every two weeks and replacing parts every 8,000 hours. Maintenance interval for the power system is required over tree years.

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Target performance of a new refrigerator

Requirements Performance of a Refrigerator for HTS Cable

(1) Large Capacity

Cooling systems of HTS cable are located every multiple km. The cooling capacity of one cooling station is needed 5 ~ 20 kW for reducing total cost.

First Target = 5 kW

⇩

Reverse Brayton Cycle

(2) High Efficiency

HTS Cable has advantage of saving energy. If COP of cooling system is 0.1, a ross of HTS cable is reduced 50 % compare with conventional cable.

COP = 0.1

⇩

High performance turbo-machine, multistage compressor

(3) High Reliability

OPEX is decreased long term maintenance interval and reducing troubles. A Target of maintenance interval is close to it of industrial refrigerator.

Maintenance Interval = 3000 ~ 4000 hours

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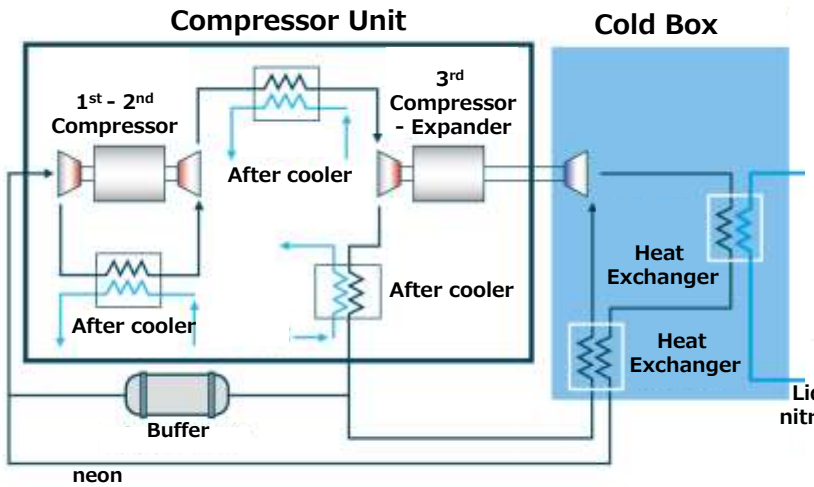
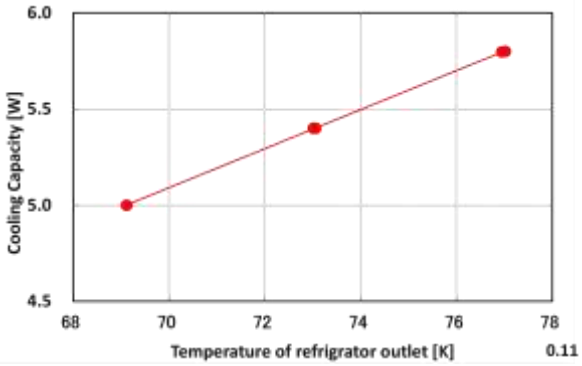
Magnetic bearing

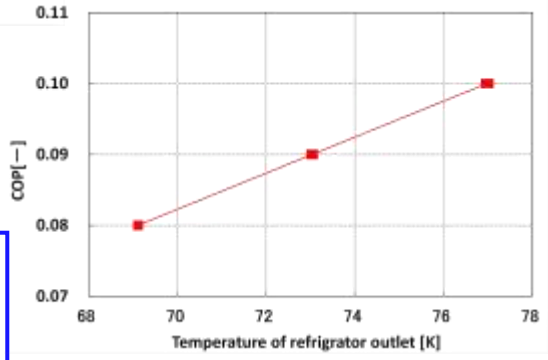
Turbo-Brayton Refrigerator



System Flow



Results of Cooling Capacity



Results of COP

- **High Efficiency**: Adiabatic efficiency of turbo-machine = 0.8
- **High Reliability**: Perfect contactless by using magnetic bearing

Impeller of Compressors, Expander

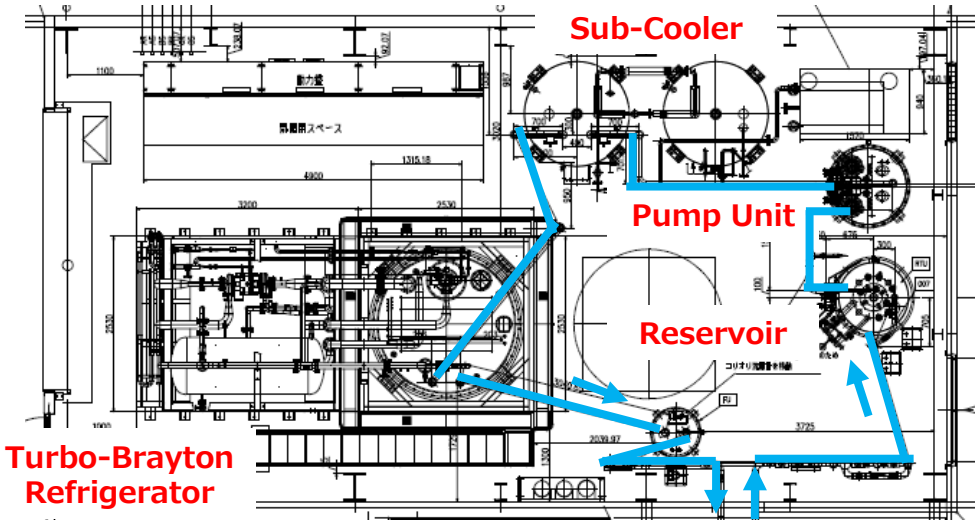
1st – 2nd Compressor

3rd Compressor - Expander

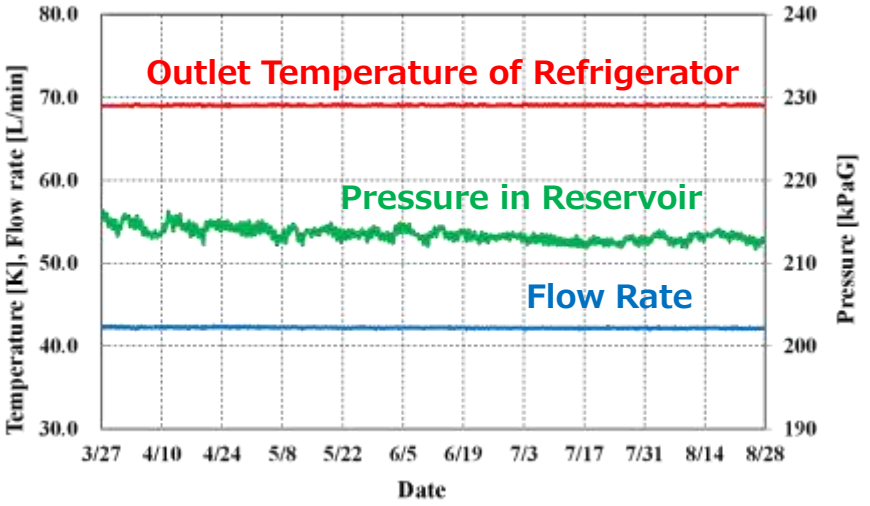
Turbo-Brayton Refrigerator

Cooling System of 2nd Project

10,000 hours has passed since starting operation of cooling system including the refrigerator.

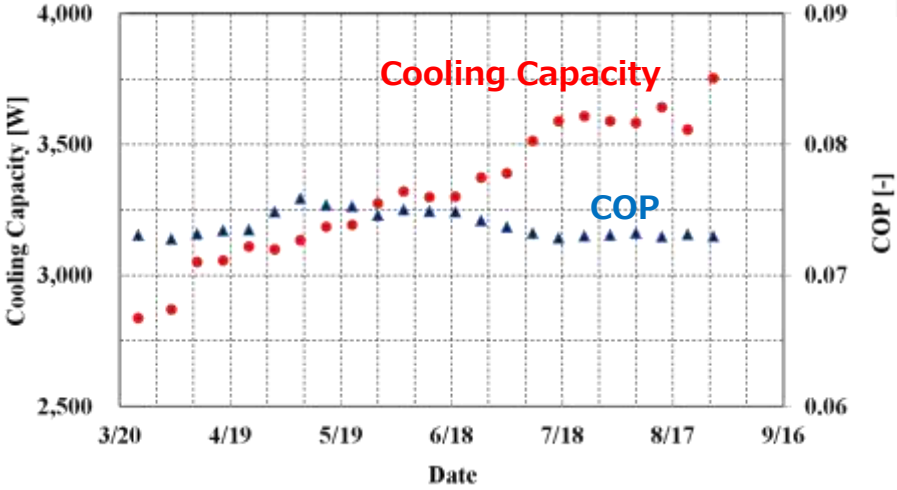


Layout of the cooling system



Turbo-Brayton Refrigerator

Pump Unit and Reservoir



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Turbo-Brayton refrigerator commercial base

The refrigerator is more compact and more easier operation.

Characteristic

- Compact (adapted marine container size)
- Easy operation
- Saving Energy by high efficiency
- Long in a maintenance interval
- Small burden on the environment (used Neon gas of Natural refrigerant)

Indoor Type

Table2. Specifications

Items	Specifications
Cooling capacity	5 kW @ 77 K
COP	0.1 @ 77 K
Dimensions (Outdoor)	2,200 × 3,600 × 2,200 mm
Weight (Outdoor)	5,500 kg
Power supply	AC380 ～ 480 V、75 kVA
Cooling water	200 L/min (Inlet temperature 32 ℃)

Outdoor Type

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Conclusion

1. Yokohama project of 1st phase, more than 1 year continuous reliable operation has been verified with successful result. For practical use of HTS Cable, a Turbo-Brayton refrigerator was developed in this project.

2. Turbo-Brayton refrigerator in Asahi S/S has been verified a reliability in the continuous HTS Cable system operation in a real grid.

3. Turbo-Brayton refrigerator commercial base was developed for practical use of HTS Cable. The refrigerator is more compact and more economical.

4. Practical use of HTS Cable will be soon realized by success of demonstration test and

Thank you very much.