A cooling system for practical HTS applications

ColdTech Associates

Yasuharu Kamioka

ColdTech Associates, 1-2330 Ogawa, Kodaira, Tokyo 187-0032, Japan

Waseda University, 3-4-1 Okubo, Shinjuku, Tokyo 169-8555, Japan

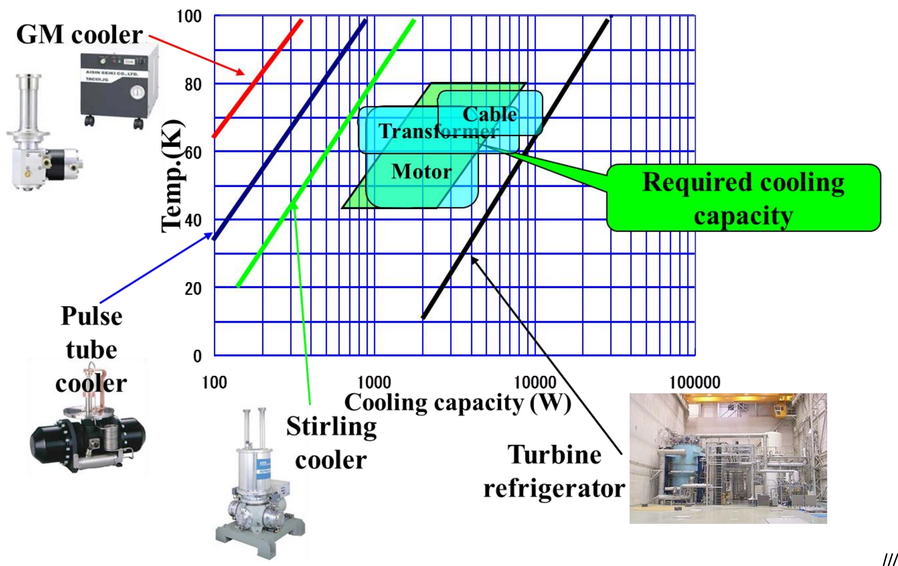
Background

- The cooling system is a key component for realizing practical HTS applications. The HTS application is ready for commercial use today but its cooling system is still experimental stage.
- There are several test sites of HTS cables but these cooling systems are not suited for practical applications.
- Several types of refrigerators are selected in HTS cooling systems such as a G-M cryocooler, a Stirling refrigerator and a Turbo Brayton refrigerator.
- Most components of the cooling system have not long enough maintenance interval for practical HTS applications.
- There is not a pump which has enough specification required by HTS cooling.

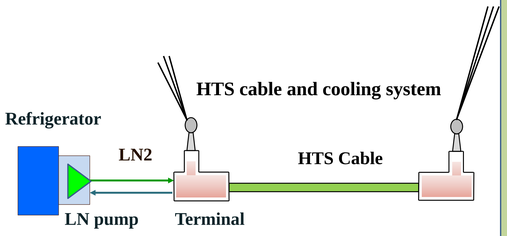
Objectives

- Required cooling power of HTS cooling system.
- Available refrigerators for the system.
- Pump with specifications required by HTS system.
- Components of the system

Required cooling capacity for HTS applications



Cooling capacity	
Cable	2 - 20 kW @65K
Transformer	2 - 5 kW @65K
Motor	0.5 - 5 kW @65K
Size	Compact
Maintenance interval	30,000h
Efficiency	High >0.06 @65K



Conclusion

1. To cool HTS application and to keep HTS application cold are big disadvantage of HTS application. So that the development of the cooling system for HTS application is the one of the most important issue.
2. Some of HTS applications have been developed and are very close to practical use in our society. However; the cooling system used in the HTS applications are still experimental stage.
3. The refrigerators in these applications are developed for the other applications such as cryogenic experiments, helium liquefier etc.
4. The best fit refrigerator for HTS applications did not exist up to now. Refrigerators are too small or too large in cooling power at required temperature. Also the maintenance interval is too short for the machine used in our society.
5. Recently Turbo-Brayton type refrigerators have been developed and this refrigerator can be used in HTS power cable, HTS power transformer, HTS motor and HTS generator.
6. A bellows type pump is the candidate of a liquid nitrogen pump to deliver liquid nitrogen to HTS power cable.

Characteristics of refrigerators

Refrigerator /cooler	Cooling power	Maintenance interval	Weight
			Cooler / compressor
G-M cooler	600W @80K	10,000hrs	41.8kg / 213kg
Stirling refrigerator	1kW @80K	6,000hrs	600kg total
Turbo-Brayton refrigerator	2kW @65K	>4years	2,800kg total

Available refrigeration power

Refrigerator	Temp. range K	Cooling Capacity Watt
G-M	3 - 100	0.1 – 600
Stirling	50 - 100	0.1 - 1,000
Pulse Tube	4 - 100	0.1 - 1,000
Turbo Brayton	4 - 100	100 – 100,000

Turbo-Brayton Refrigerator3)

Components of HTS cooling system

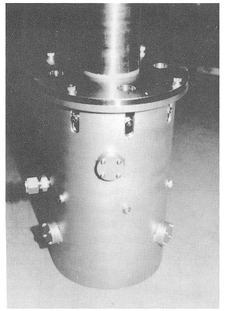
	Refrigerator	Cryogen		Heat exchanger	Pump
Cable	Turbo-Brayton	Subcool LN	LH2	○	○
Transformer	Turbo-Brayton	LN Subcool LN		○	△
		Conduction		×	×
Current limiter	G-M cooler	LN Subcool LN		○	×
		Conduction		×	×
Motor	G-M cooler Stirling cooler Turbo-Brayton	Subcool LN	GHe	○	○
Generator	G-M cooler Stirling cooler	LN Subcool LN	LH2	○	○
	Turbo-Brayton	Conduction		×	×
SQUID	G-M cooler PTR	LN		○	○
		Conduction		×	×

Refrigerator	Production of Cold
Pump	Delivering of cryogen
Heat exchanger	Exchanging heat
Vacuum chamber	Keeping cold by thermal insulation
Transfer tube	Piping of cryogen
Others	Valves, thermometers etc.
Control system	Controlling of whole system

LN pump specifications required by HTS power cable

Flow rate	5L/min～100L/min
Operating pressure	0.1 - 0.2MPa
Outlet pressure	0.2 - 1.2MPa
(pressure difference)	0.1 - 1.0MPa
Heat load	3W
Maintenance interval	30,000h

LHe Bellows pump 6)7)



Flow rate	15L/min
Pressure difference	0.1 - 1.0MPa
Heat load	0.2W

Centrifugal pump 8)

References

1) Y. Suzuki, S. Yoshida and Y. Kamioka,: "Subcooled liquid nitrogen refrigerator for HTS power systems," Cryogenics 43 (2003)597-602
2) Y. Kamioka,: Cryogenic cooling systems for a HTS application -Their status quo and the development trend-," TEIONKOUGAKU 44 (2009) 447-454(in Japanese)
3) H.Hirai, Y. Suzuki, M. Hirokawa, H. Kobayashi, Y.Kamioka, M. Iwakuma and Y. Shiohara,: "Development of a turbine cryocooler for high temperature superconductor applications," Physica C. ISS21 (2009)
4) Sumitomo Heavy Industries, Ltd. Home page, http://www.shi.co.jp/english/products/medical/cold/index.html
5) STIRLING CRYOGENICS Home page, www.stirlingcryogenics.com/
6) Y.Kamioka etal,:"A double acting bellows type liquid helium pump," ICEC10 (1985)578-581
7) Y.Kamioka etal,:"A bellows type liquid helium pump," TEIONKOUGAKU 20(1985)35-41(in Japanese)
8) BarBer Nichols Home page, www.barber-nichols.com/ and CryoZone Home page, www.cryozone.nl/