Heat load study of cryomodule in STF

KEK

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Contents

Introduction

- Cold test of the STF cryomodule with 4 cavities have been done from May 20 May to now with being warmed up twice.
- The heat load measurements;
  - 28 May ~ 6 June : DC heat load measurements without warm couplers
  - 8 Oct. ~ 17 Oct. : DC heat load measurements
  - 5 Nov. ~ 7 Nov. : Q_0 measurements

Measurement method of heat load

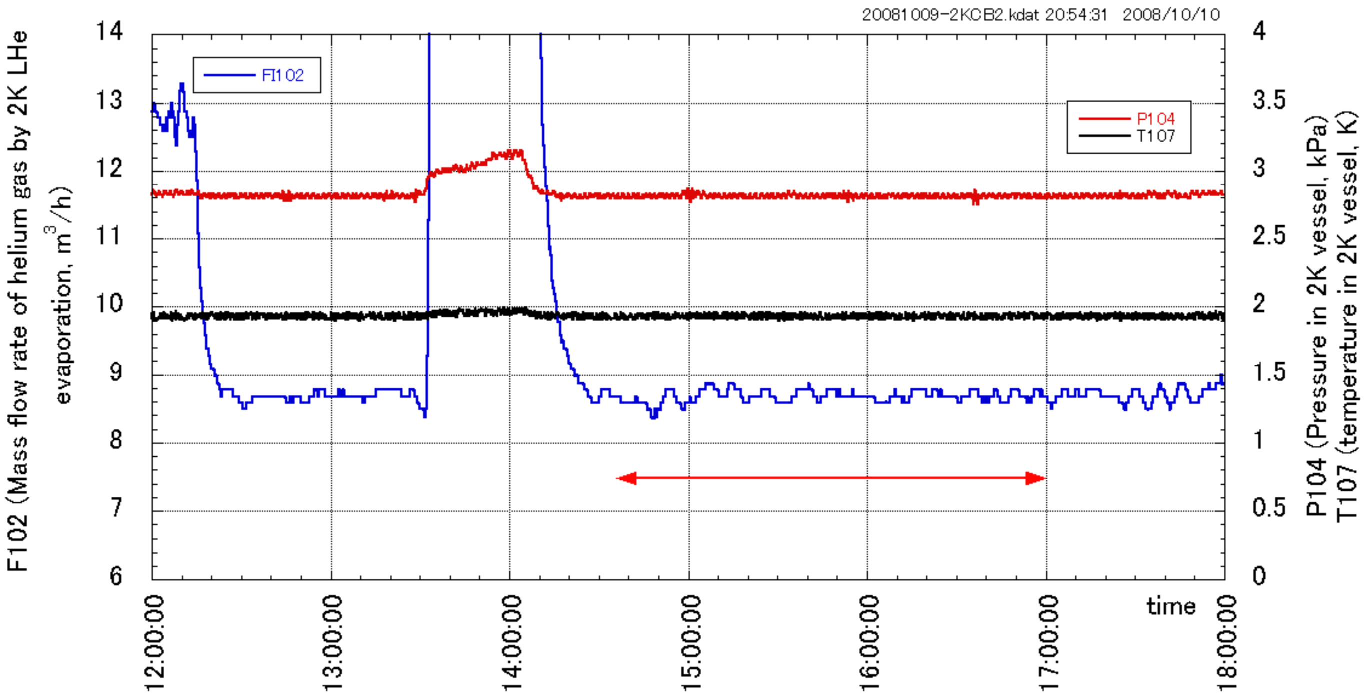
- Total heat load at specific temperature level
  - 2K : evaporation rate of 2K liquid helium
    - Measurement of the mass flow rate of the evaporated 2K LHe.
    - Keeping the liquid helium level in the 2K LHe supply pipe and the cavity-vessels, and attaining the steady state condition for the evaporation rate of 2K LHe and temperature profile in the module.
  - 5K : temperature rise of 5K shield
    - Measuring the speed of the temperature rise of the 5K shield after stopping cooling.
  - 80K : temperature rise of 80K shield
    - Measuring the speed of the temperature rise of the 80K shield after stopping cooling.
- Heat load of the component at specific temperature level
  - Calculation from the measured temperature profile in the cryomodule

Instrumentations for thermal measurements

- Mass flow meter
  - 2 volumetric flow meter (at the discharge side of the pump and at the ambient pressure)
- Pressure sensor
  - 3 absolute pressure sensors (at 2K LHe vessel in the 2K cold box and GRP)
  - 4 pressure sensors
- Temperature sensors for cryomodule

	Cernox (1.5K<T<100K)	PtCo (4K<T<300K)	CC thermocouple (70K<T<300K)
Cavity	8 × 4	1 × 4	
Input coupler	2 × 4		2 × 4
Support post		3 × 2	3 × 2
5K shield		12	
80K shield			12
Beam pipe		1	1
GRP	6		6
Total	46	23	33

Heat load measurement by 2K LHe evaporation



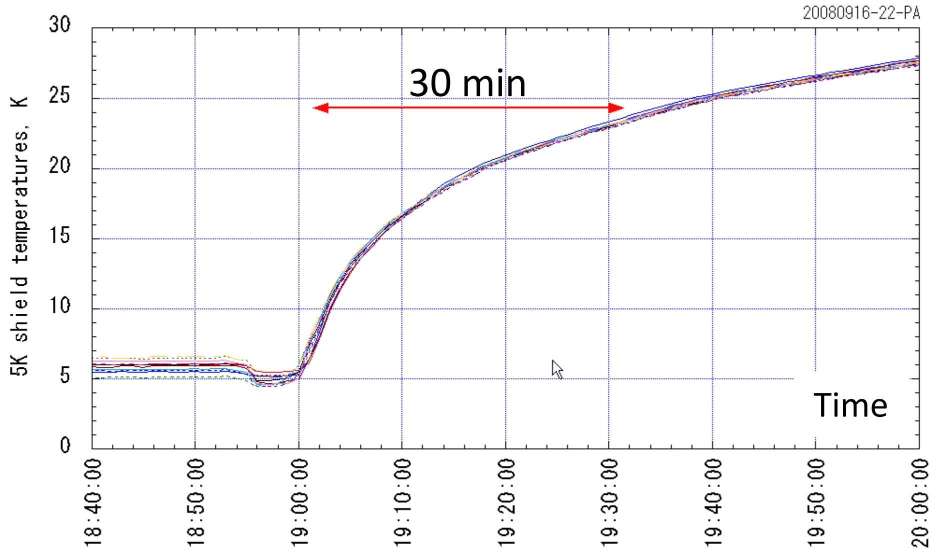
Thermal condition of the system during measurement

- No supply of LHe
- Controlling the pressure of 2K LHe constant
- The LHe level changed but stayed in the supply pipe.

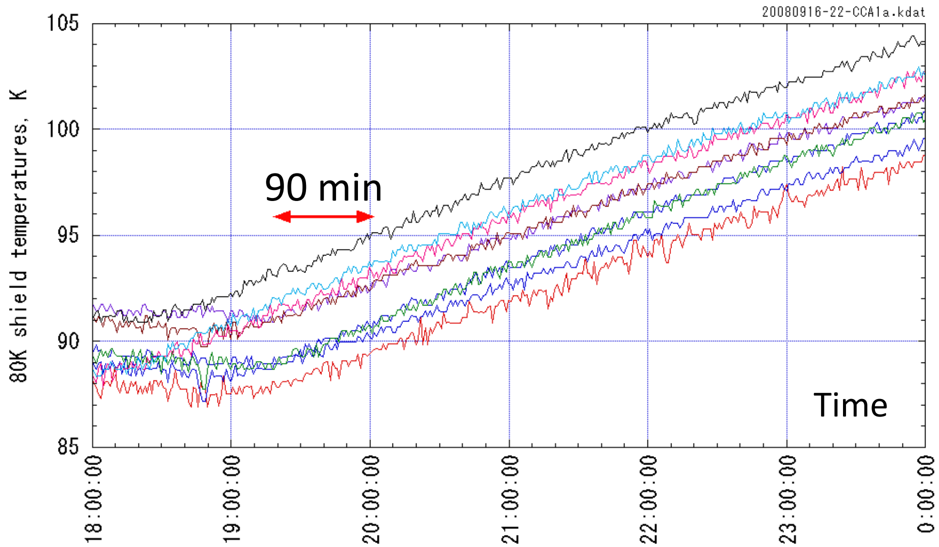
Measured mass flow rate during the measurement = 8.67 m^3/h (=0.40 g/s)

- Heat load = 9.21 W
  - (including 2K cold box and transition between the 2K cold box and the cryomodule)
- Heat load of cryomodule = 4.94 W

Heat loads measured by temperature rises of the 5K and 80K shields



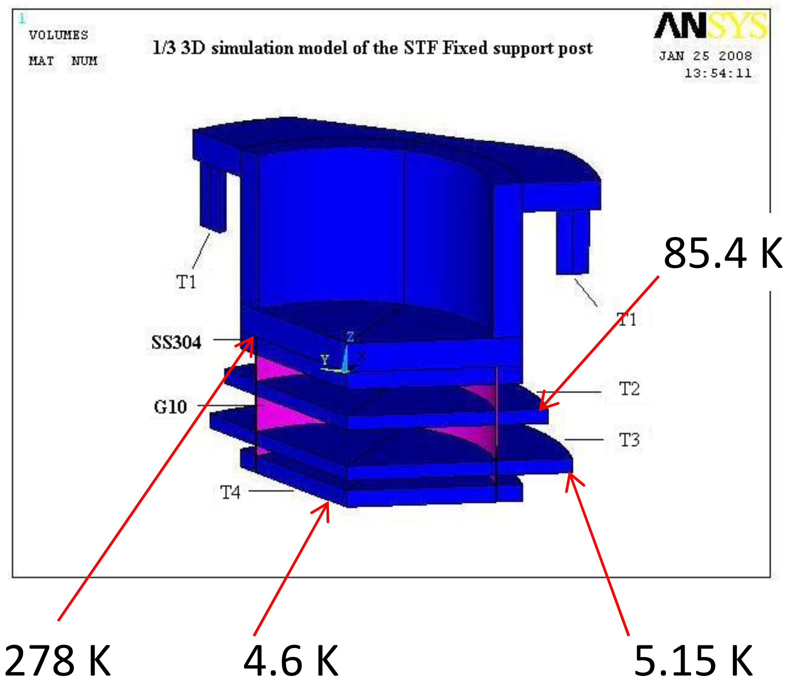
Average temperature rise of 5K shield
6.7K -> 22.9 K for 30min
Cold mass of 5K shield= 190 kg
Heat load at 5K shield=8.21 W



Average temperature rise of 80K shield
89.45K -> 92.76 K for 90min
Cold mass of 80K shield= 220 kg
Heat load at 80K shield=64.9 W

Heat load: Support posts

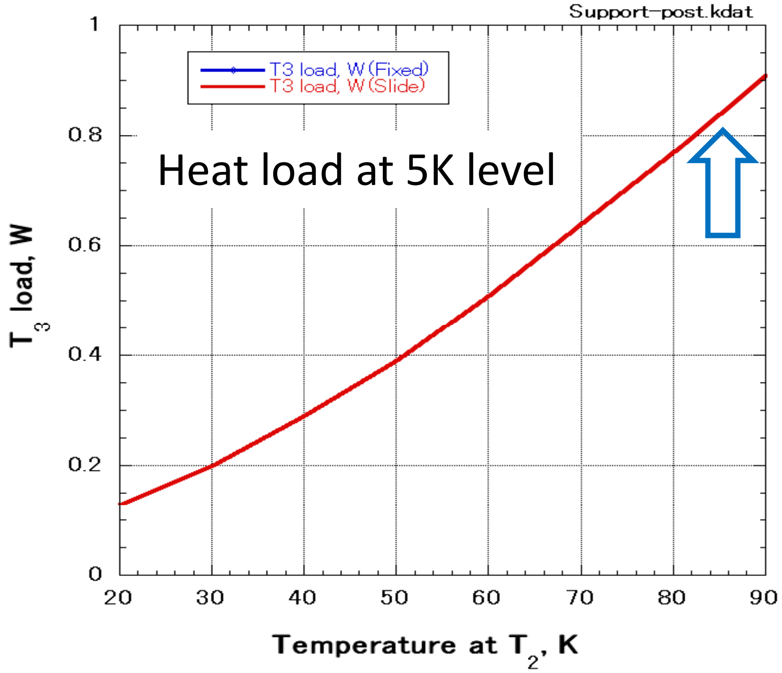
Measured temperature profile of STF module



GRP upper surface = 3.82 K
GRP lower surface = 2.02 K

Condition of the calculation

- T_1 = 300K, T_3 = 5K, T_4 = 2K (Fixed)
- T_2 = parameter for calculation

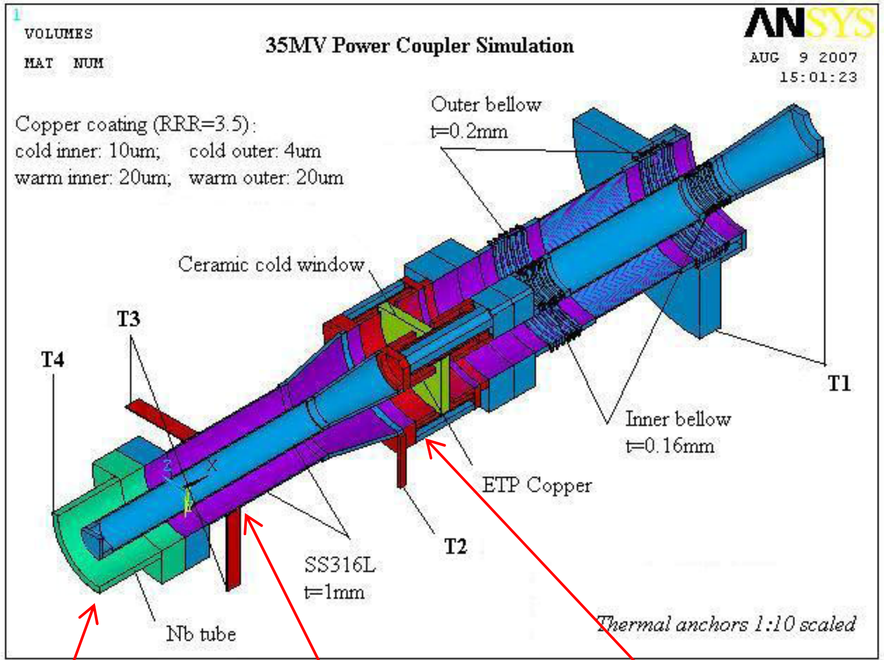


T_2=85.4 K

80 K : 5.4 W
5 K : 0.77 W
2 K : 0.12 W

Heat load: Input Coupler

Measured temperature profile of STF module



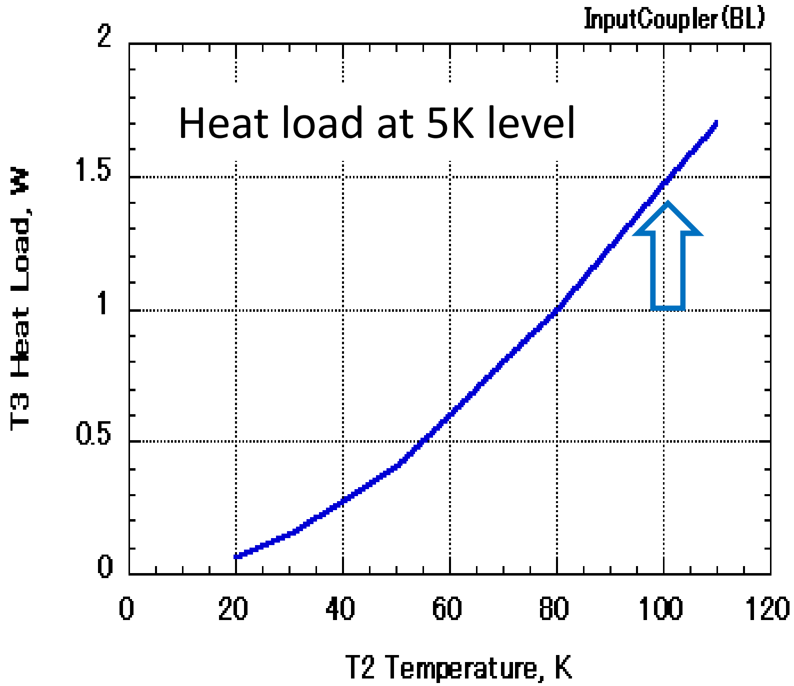
2.9 K

12.7 K

101.3 K

Condition of the calculation

- T_1 = 300K, T_3 = 5K, T_4 = 2K (Fixed)
- T_2 = parameter for calculation



T_2=101.3 K
- 80 K : 1.64 W
- 5 K : 1.5 W
- 2 K : 0.04 W

Heat load: Cables

- RF cables
  - 2 HOM couplers and 1 monitor (thermal anchored with 80K shield)
  - 1 input coupler monitor (connected to the part at 80 K)
- Piezo and load sensor cables
  - Cables to cavity-vessel (no-thermal anchored with 80K shield)
- Temperature sensor cables
  - Cernox sensors for cavities (no-thermal anchored with 5K and 80K shields)
  - Cernox sensors for input couplers (thermal anchored with 5K and 80K shields)
  - PtCo sensors (thermal anchored with 5K and 80K shields)
  - CC sensors for GRP (thermal anchored with 5K and 80K shields)

Average temperatures of 5K and 80K shields

5K shield= 5.11 K , 80K shield= 86.5 K

Heat loads of cables at specific temperature levels for 4 cavities (W)

	2K	5K	80K
RF cables	2.48	NA	7.92
Peizo cables	1.68	NA	NA
Temp. cables	0.08	0.55	0.42

Static heat loads of the STF cryomodule (4 cavities), W

	2 K	5 K	80 K
Measured	4.9	8.2	64.9
RF cables	2.48	0	7.92
Piezo cables	1.68	0	0
Temp. cables	0.08	0.55	0.42
Input couplers	0.17	5.98	6.56
Tuner drive shafts	0.48	0	0
Beam pipe	0.01	0.14	0.70
Thermal radiation	~0	0.76	20.4
Support posts	(0.24)	1.54	10.8
Sum. of comp.	4.90 (5.14)	8.97	46.8

Thermal flux density by thermal radiation:

from 80 K to 5 K with 10 layers of MLI = 0.05 W/m^2

from 300 K to 80 K with 30 layers of MLI = 1.0 W/m^2

Recalculation of static heat loads of the 9-cavity-module, W

	2 K	5 K	80 K
RF cables	5.58	0	17.82
Piezo cables	3.78	0	0
Temp. cables	0.18	1.24	0.95
Input couplers	0.38	13.46	14.76
Tuner drive shafts	1.08	0	0
Beam pipe	0.01	0.14	0.70
Thermal radiation	~0	1.71	45.9 / 91.8
Support posts	0.36	2.31	16.2
Sum. of comp.	11.37	18.86	96.3 / 142.2

Comparison between RDR and STF

	RDR	STF-exp
Supports	0.6	0.36
Input Couplers	0.17	0.38
HOM cables and coaxial cables	0.13	9.54
HOM absober	0.14	
Current leads	0.28	
Tuner drive shafts		1.08
Moters		
Sum	1.32	11.37

2K Level

0.05 W/m^2

Radiation	1.41	1.71
Supports	2.4	2.31
Input Couplers	1.73	13.46
Diagnostic cables	1.39	1.24
HOM absober	3.13	
Current leads	0.47	
HOM cables	0.29	
Sum	10.82	18.86

5K Level

1~2 W/m^2

Radiation	32.49	45.9/91.8
Supports	18	16.2
Input Couplers	16.47	14.76
HOM cables	1.84	17.82
Current leads	4.13	
Diagnostic cables	5.38	0.95
Sum	75.04	96.3/142.2

40~80K Level