Cryomodule Plans at KEK

KEK

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1) Target of the cryostat R&D in KEK

- Gaining the experience of the long cryostat for the S.C. cavity.
- R&D of a high performance and low cost ILC cryostat.
- Cooling two types of the cavities of 35 MV/m and 45 MV/m down to 2 K in STF, and performing high power and beam tests.

2) Strategy of the cryostat R&D

- Starting point of the STF cryostat design: TESLA design
- R&D and study items for the STF cryostat
  - Understanding the TESLA design from the cryogenic hydrodynamic point of view.
    - Heat transfer of the superfluid helium, pressure drop, and temperature distribution in the system.
  - R&D component
    - SUS-Ti joint between the helium vessel and cryogenic lines.
  - Magnetic shield
    - Measurement of the remanent field in the shield and the magnetic characteristics of the shield material.
  - Low cost vacuum system for the STF cryostat
  - Survey of the low cost quadrupole magnet system

3) Status of the cryostat R&D in KEK

- FY2005
  - Finalizing the conceptual design of the cryostat for the STF in KEK.
    - The design of the overall assembly has been completed.
  - Making a contract with a company for the construction of the cryostat.
    - The company will be decided at the 24th of August.
- FY2006
  - Design and construction of the tools for assembling the cavities into the cryostat.

4) Technical issues in the STF phase-1 cryostat

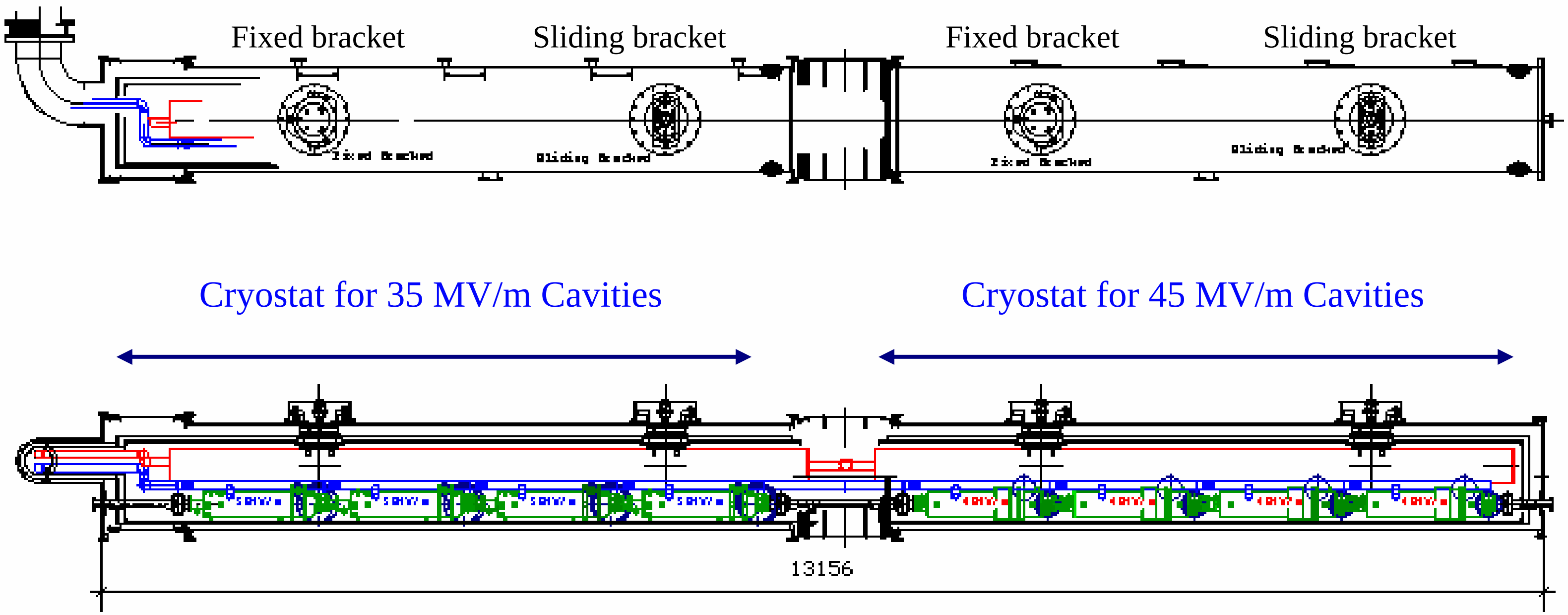
- Connection of pipes
  - Appling automatic welding as much as possible.
- Material of the cryostat components

– Vacuum vessel	Carbon Steel
– Pipes for cryogenics	SUS304L or 316L (Ti for the 35 MV/m cavity)
– Thermal radiation shield	Al 1050
– Vacuum seal at room temp.	O-ring
– MLI (super-insulation)	Polyester film

- Tuning resolution of cavity alignment < 50 m

STF cryostat

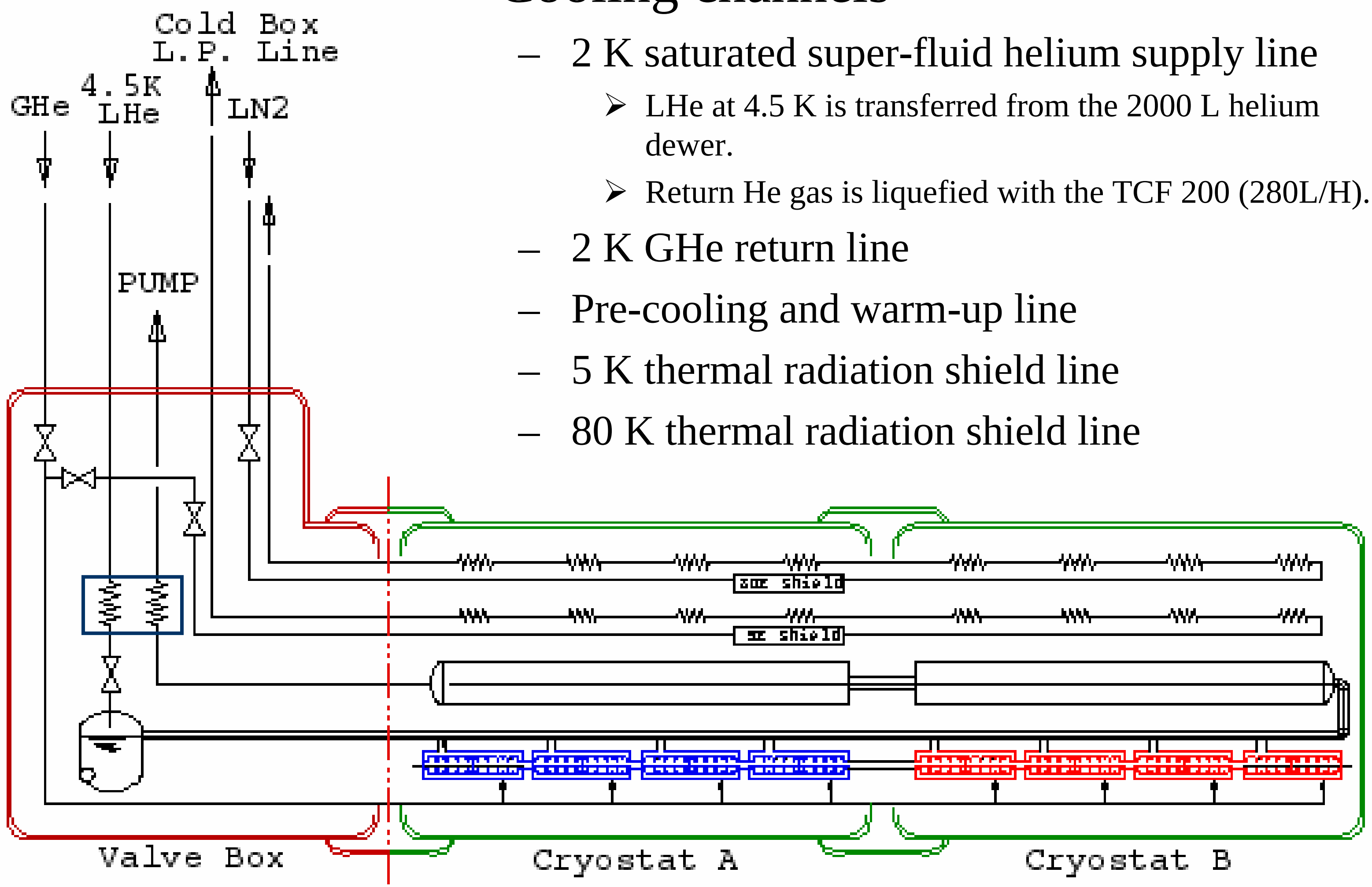
Overall design



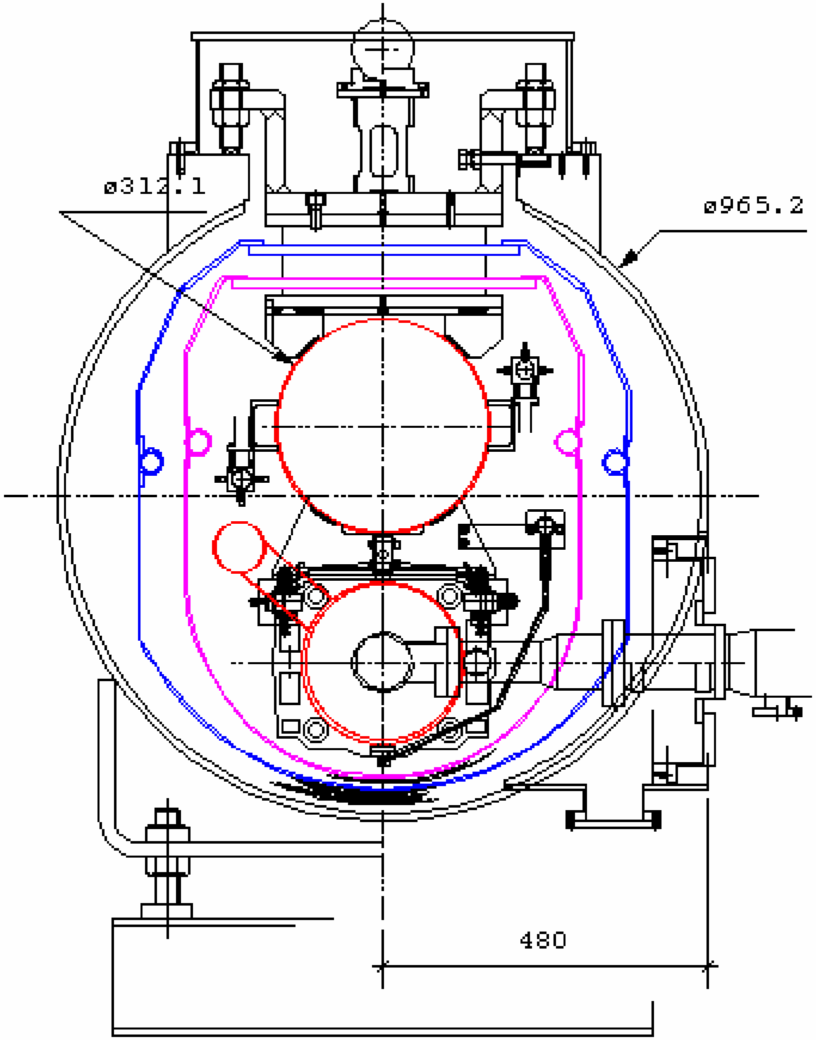
- Total weight of cryostat = around 5.6 ton.
- The lengths of the vacuum vessels for 35MV/m cavities and 45 MV/m cavities are 5545 mm and 5907 mm, respectively .
- The lengths of the 2K Gas return pipes for two cryostats are identical, 5830 mm.
- The most up-stream cavity-jacket is fixed for each cryostat by the support near the fixed bracket for each cryostat, and the other supports are free in the axial direction.
- The position of the jacket with respect to the input coupler is kept at almost constant with a Invar rod during cool-down.

Cooling circuits

- Cooling channels
  - 2 K saturated super-fluid helium supply line
    - ➢ LHe at 4.5 K is transferred from the 2000 L helium dewer.
    - ➢ Return He gas is liquefied with the TCF 200 (280L/H).
  - 2 K GHe return line
  - Pre-cooling and warm-up line
  - 5 K thermal radiation shield line
  - 80 K thermal radiation shield line

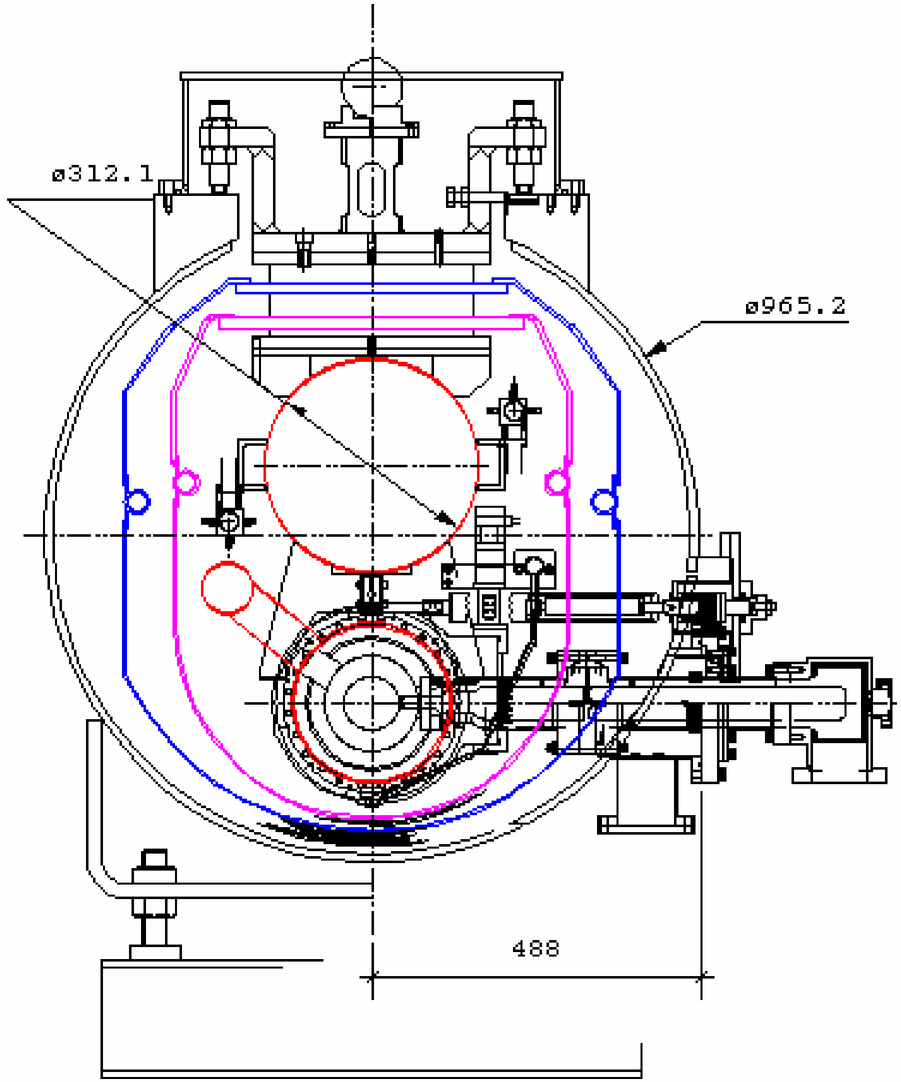


Cross section of the 35 MV/m cryostat



- Outer diameter of the vacuum vessel is same as the diameter of the TESLA cryostat.
- Support system of the cavity is slightly different from the TESLA system.
- The distance between the vacuum vessel and the input coupler is around 10 mm.
- The thermal radiation shields have the cooling pipes in the left and right symmetry.

Cross section of the 45 MV/m cryostat



- Support system of the cavity is same as the TESLA system.
- The distance between the vacuum vessel and the input coupler is around 10 mm.

Thermal contraction

Cooling pipe (SUS: L/L=-0.265%)

	Pipe end @valve box	GHe pipe end @up-stream	Fixed support bracket	Sliding support bracket	GHe pipe end @down-stream
Position (mm)	2571	1376	0	-3153	-4454
L (mm)	-6.8	-3.7	0	-8.4	-11.8

Thermal radiation shield (Al : L/L= -0.33%@80K, L/L= -0.368%@5K)

	Shield end	Fixed support bracket	Sliding support bracket	Shield end
Position (mm)	1858	0	-3153	-4454
L for 80 K shield (mm)	-6.1	0	-10.4	-14.7
L for 5 K shield (mm)	-6.8	0	-11.6	-16.4

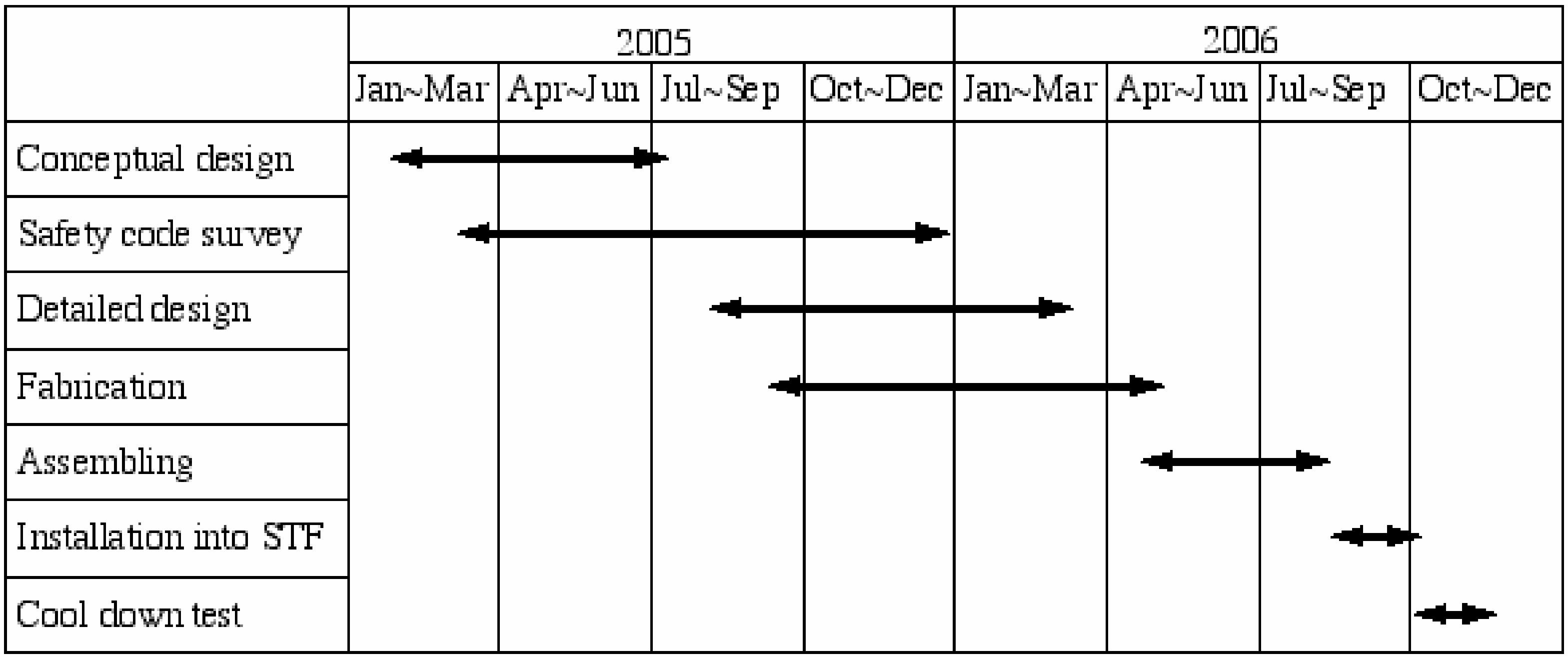
Components

	Support post 300-4K L/L=-0.338%	**Cavity (Nb)** 300-4K L/L=-0.129%	**Ti jacket** 300-4K L/L=-0.134%	**SUS jacket** 300-4K L/L=-0.265%	**Invar rod** 300-20K L/L=-0.034%
L (mm)	140 (in vertical)	1260	1260	1260	5000
L (mm)	-0.47	-1.63	-1.69	-3.34	-1.7

Cryostat pipe size

	STF-phase1	TESLA	Material
Vacuum vessel	965.2, t 12	965.2 , t 9.52	carbon steel
2 K He Gas return	318.5, t 6.5	312 , t 6	SUS
2 K two-phase supply	76.3 , t 2.1	76 , t 2.0 (60 , t 1.5)	Ti or SUS
Cool down/warm up	27.2 , t 1.65	42.2 , t 1.65	SUS
5 K shield supply	30 , t 4	60.3 , t 2.76	SUS
5 K shield return	30 , t 4	60.0 , t 5	SUS
80 K shield supply	30 , t 4	60.3 , t 2.76	SUS
80 K shield return	30 , t 4	60 , t 5	SUS

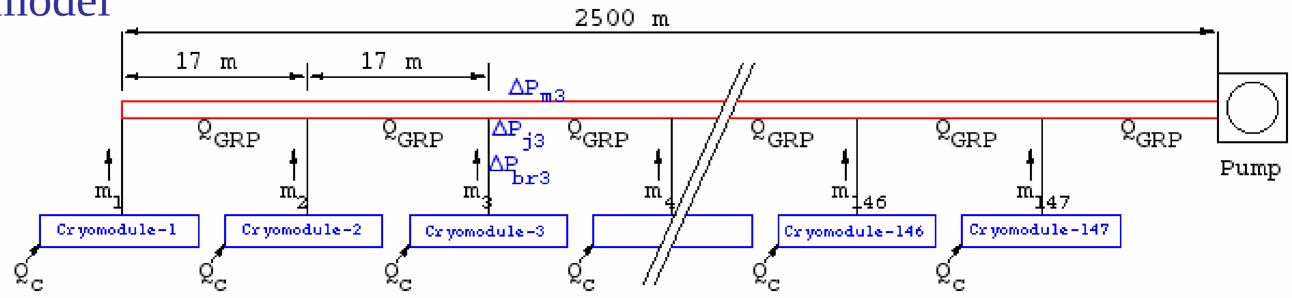
Construction schedule of the STF cryostat



Hydrodynamic study

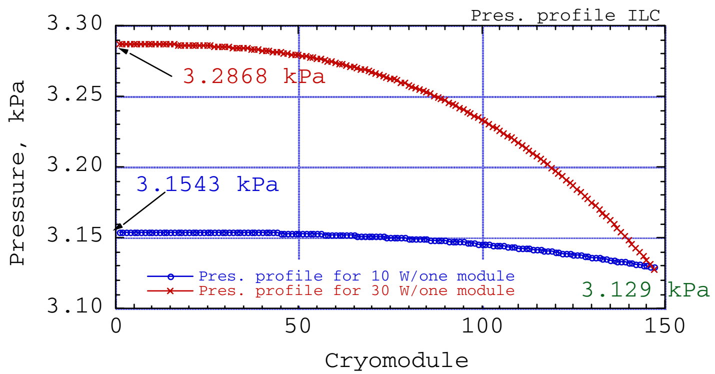
ILC model (Pressure and temperature profile along the GRP of 300)

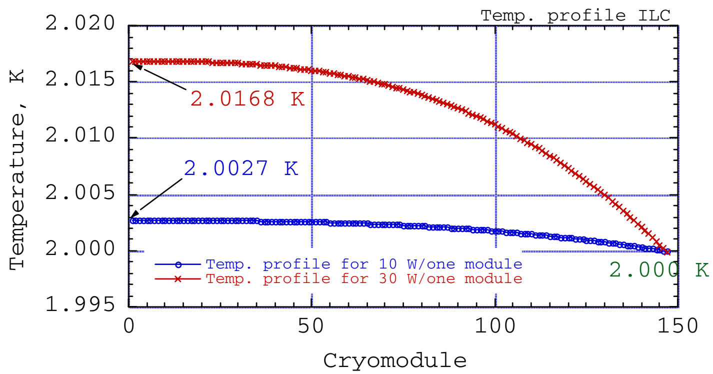
Calculation model



Q_c: 10 W or 30 W
Q_{GRP}: 1 W
m_n: evaporated helium gas at n-th module

P_{mn}: P by mass flow along n-th section
P_{jn}: P by confluence at n-th section
P_{brn}: P along n-th branch pipe



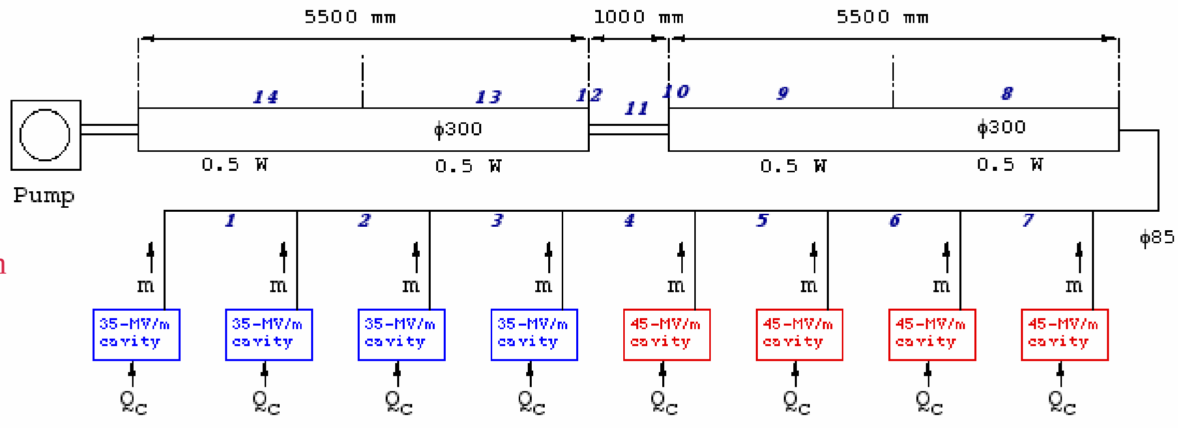


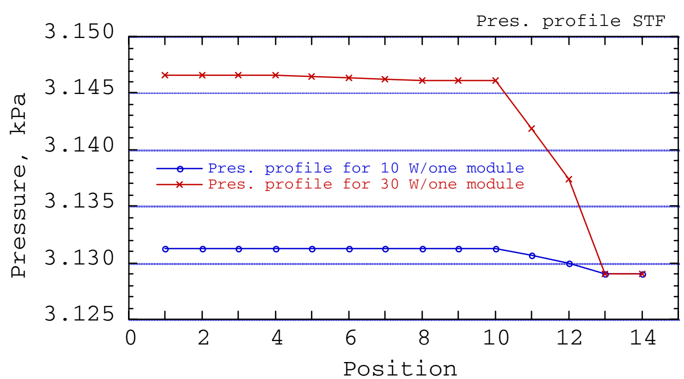
- Pressure drop along the 2.5 km GRP = 25 Pa for 10 W, 158 Pa for 30W
- Temperature difference along the 2.5 km GRP = 3 mK for 10 W, 17 mK for 30W

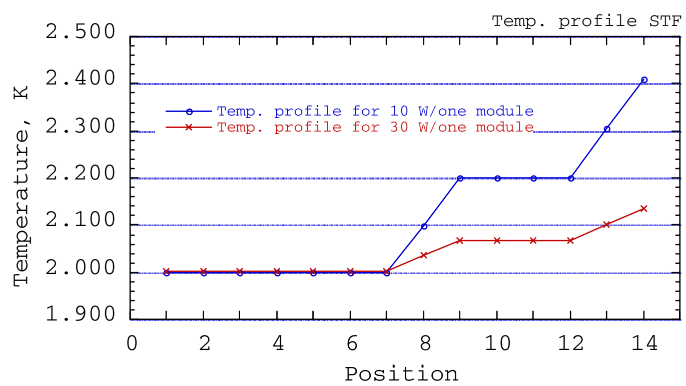
STF phase-1 model

Calculation model

Q_c: 10/8 W or 30/8 W
m: evaporated helium gas
Pipe diameter of section 11 : 30 mm







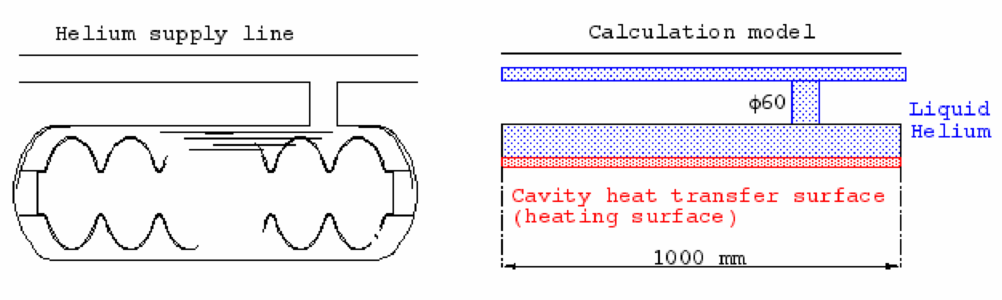
- Pressure drop along the system = 2.27 Pa for 10 W, 17.59 Pa for 30W
- Temperature at each cavity = 2.000 K for 10/8 W, 2.002 K for 30/8 W

Temperature profile in the helium jacket

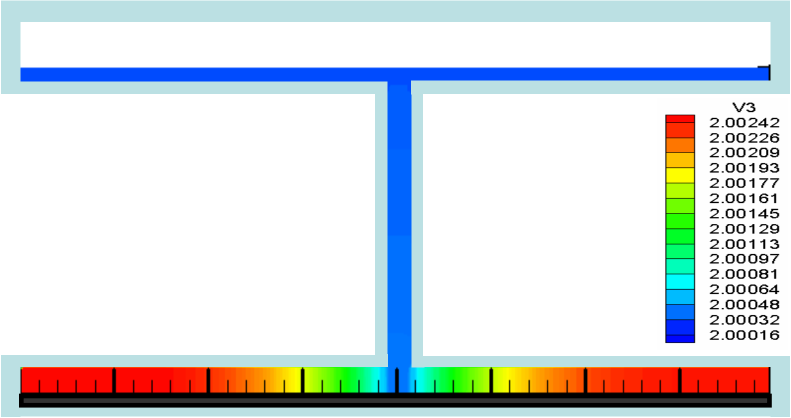
(calculation of temperature profile in LHe to confirm the maximum temperature less than Lambda temperature)

Calculation model

- Pipe diameter between LHe supply line and cavity jacket = 60 mm
- Cavity jacket length = 1000 mm
- Distance between cavity heating surface and jacket inner surface = 6 mm
- Heat load = 30.0 / 4 W



Temperature profile after 4.6 seconds



- The diameter of 60 mm for the pipe between the LHe supply line and the cavity jacket is enough to keep the LHe temperature below the Lambda temperature.

SUS-Ti joint R&D

- Joining by HIP (Hot Isostatic Pressing)
  - Important concern : diffusion of Fe, Cr and Ni into Ti
    --> degradation of strength at low temperature
  - Manufacturing samples with the insert materials
    - V on the surface of Ti and Cu on the SUS
    - The following tests will be performed in this year.
      - Tensile tests at room temperature and liquid nitrogen temperature.
      - Charpy V-notch impact tests at room temperature and liquid nitrogen temperature.
      - Helium leak tests at 2 K.

- Friction pressure welding
  - Diffusion rates of Fe, Cr and Ni into Ti are less than the rates by HIP.
    - Need to measure the strength of the joint.
  - The manufacturing method of the samples is under investigation.

Magnetic shield

- Remanent field in the vacuum vessel
  - Survey of the measuring system for weak magnetic field
  - Calculation of the distribution of remanent magnetic field in the cryostat
  - Study of the magnetization in the manufacturing process of the cryostat
- Measurement of the magnetic characteristics of the shield material
  - Temperature dependence
  - Effect of machining process
  - Effect of heating process

Cryogenic sensors and heat load measurement

- Cryogenic sensors
  - Selection of cryogenic temperature sensors; Cernox, CGR and TVO
  - Liquid helium sensor; behavior of the sensor around the Lambda point
- Heat load measurement of the cryomodule
  - Measurement of the heat load from each component in the module
  - Separation between the static and dynamic heat loads

Quadrupole magnet

- TESLA design
  - The magnet is cooled by super-fluid helium in the jacket.
  - Ceramic insulators are required for the current leads.
    - In case of applying the HTC current leads, the insulators are installed on the metal jacket.
  - Magnet assembly in the cryostat is complicated

- Study of the alternative magnet system
  - The possibility of the magnet system cooled by conduction
    - Optimization of the operation temperature
    - Simulation of the cool-down process after magnet quench (cool-down time)
    - System configuration

Summary

- The design of the cryomodule for the STF phase-1 is based on the TESLA design.
- This cryomodule will have been manufactured in 2006, and in October of 2006, we will start various tests of the cryostat and the RF system in the STF.
- R&D items for the cryomodule
  - Study of thermal and hydrodynamic behavior of the R&D cryostat
  - SUS-Ti junction
  - Magnetic shield
  - Vacuum system
  - Survey of the quadrupole magnet system cooled by thermal conduction