Cryostat For TRISTAN Superconducting Cavity

S.Mitsunobu, T.Furuya, K.Hara, K.Hosoyama, E.Kako, Yuuji Kojima,
K.Kubo, H.Nakai, S.Noguchi, T.Ogitsu, T.Tajima and T.Takahashi
KEK, National Laboratory for High Energy Phyisics
Oho, Tsukuba, Ibaraki, 305 Japan
K.Ohkubo
Mitsubishi Heavy Industries, LTD.
Wadasaki, Hyogo-ku, Kobe, 652 Japan

Abstract

Superconducting cavities generate rather high heat load of hundreds watts in one cryostat and have high sensitivity for pressure. We adopted usual pool-boiling type cooling for its stable pressure operaition. Two 5-cell Nb cavities were installed in one flange type cryostat. Tuning mechanics actuated by a pulse-motor and a Piezo-electric element are set at outside of vacuum end flange. The design and performance of the cryostat for TRISTAN superconducting cavities are described.

Design and Construction of the superconducting cavity cryostat for TRISTAN

Following the experience of our storage ring experiment with two 5-cell superconducting cavity in TRISTAN accumuration ring (AR) [1] [2], we designed cryostat for TRISTAN main ring (MR). Main structures are almost same as the AR cryostat and the MR one. The MR cryostat contains two 5-cell cavities as shown in Fig.1.

A superconducting cavity cryostat using pool boiling type cooling has a simple structure but the cavities are consisting an inner wall of pressure vessel of liquid helium (LHe). And a superconducting cavity made of Nb sheets has a soft mechanical property like a kind of bellows. So mechanical design of cavity and hydraulic balance between cavities and beampipe bellows are important for tuning cavity (Fig.2). The calculated stress of the KEK cavity shows maximum stress of 4.9 Kg/mm^2 at room temperature and that of 5.7Kg/mm^2 at operating temperature of 4.2K and pressure of 0.3 KgG/cm^2. This stress value at operating temperature is sufficiently small compared with a tensile strength value of 90 Kg/mm^2 for Nb. But our preliminary impact sharing test of high pure Nb shows low sharing force at 4.2° K. So we handle Nb cavities very carefully to avoid a local stress.

Another important feature of cryostat is remountable or not for superconducting cavity. We adopted remountable type cryostat for easy to assemble cavity at clean condition and possibly to retreat the surface by electro-polish and UHV heat treatment at 700 ℃.

The frequency of cavity is tuned by adjusting cavity length. The tuning mechanics consisted of pulse motor and piezo electric element were set on outside of both end flange of the cryostat vacuum vessel (Fig.3).

<u>He vessel</u>

Two 5-cell cavities were combined and installed in one He vessel.

The He vessel was made of stainless steel (SUS 316L) and welded by electron beam welder and laser beam welder. The diameter of He vessel is 700 mm and the length is 4000 mm. As early stage of development of the AR cryostats, we tested low temperature metal seals using indium and Hericoflex metal O rings. Hericoflex is very reliably used for a large flange under line force density of 200 Kg/cm and the surface of the flange is a mirror like plane without any visible scratches. Total number of Hericoflex for one He vessel is 25.

The indium seal is also reliable but its handling should be rather skillfully. So only for Nb to stainless steel joints and Nb to Nb joints we used indium seal of 1 mm x 3 mm indium preformed ribbon or that of 1 mm diameter indium wire. Fifteen indium joints were used in one cryostat.

The He vessel is supported by adjustable supports shown in Fig.4 . Eight supports of both side have sliding plane to absorb thermal shrinkage of He vessel at cooling down. The He vessel is fixed to vacuum vessel for longitudinal direction at center by two fixing support to withstand the tuning force of 500 Kg of the mechanical tuners. Fig.5 shows fixing support. The difference between the sliding support and the fixing one is a pin at sliding plane.

The calculated static heat load to LHe is 30 W of which a half is due to input couplers. The measured static heat load of 28 W is acceptable.

<u>Magnetic shield and liqued nitrogen thermal shield</u>

Frozen-in magnetic flux causes a Q degradation of superconducting cavity. The calculated surface resistance by Frozen-in magetic flax [3] in external field Hdc (Gauss) is

$$Rs = 1.30 \times 10^{-6} \text{ Hdc } (\Omega)$$

for cavity resonant frequency of 508 MHz. So earth magnetic field of about 500 mG should be more than 10 times reduced by magnetic shield. The He vessel is surrounded by 2 mm thick Permalloy. The measured shielded magnetic field profile is shown in Fig.6.

The magnetic shield was combined with liqud nitrogen thermal shield of 1 mm thick copper plate with brezed-on copper piping. And these were supported by G10 roller supports in the vacuum vessel.

The calculated static heat load to liqued nitrogen thermal shield is 49 W.

Protection and monitoring systems for superconducting cavities

For a large system of superconducting cavities the protection and monitoring systems are very important to operate safely and to protect for possible accidental vacuum failure of many kinds. Table 1 shows protection and monitoring systems for the MR cavities and Fig.7 shows the tempratures monitoring points in the cryostat. Fig.8 shows safety valve for ultra-high vacuum [4] to release a condensed gas on the inside surface of the supercondacting cavity when vacuum pipe or input coupler are broken.

Etched-foil film heater for dynamic load compensation

Superconducting cavities have rather high heat load of hundreds watts in high field (5 MV/m) operation. But at injection period cavity field should be decreased to less than 1 MV/m and the dynamic heat load also decreased to few watts. For stable operation of cryogenic system especially for pressure sensitive superconducting cavities constant heat load is demanded. So at injection period and at occasional stop of RF sources, heaters can be used to compensate decreasing of heat load. A etched-foil film heater shown in Fig.9 was developed for good response. And this heater was also operated safely in He gas condition without local heating, when the cryostat is warmed up.

Summary

Sixteen MR cryostats have been finished and eight cryostats had been operated in TRISTAN tunnel successfully. Large amount of LHe (810 ℓ) for each cryostat shoud be reduced by some filler or fitted jacket for future larger application.

Acknowledgements

We would like to thank former Director T.Nishikawa, Director H. Sugawara, Professors S.Ozaki and Y.Kimura for their continuous encouragements. The support of the RF-group and machine shop is greatly appreciated.

References

1) Yuzo Kojima, Proc. XIth International Conference on Cyclotrons and their Applications, Tokyo, October 13-17, (1986).

2) S.Noguchi, et al., Proc. Third Workshop on RF Superconductivity, 1987, Argonne, Illinois, USA (1988) 605.

3) B.Piosczyk, P.Kreisel, O.Stoltz, J.Halbritter, IEEE Trans. Ns-20, No.3, (1973) 108.

4) H.Ishimaru and T.Furuya, Private Communication.

Table 1 **PROTECTION & MONITORING SYSTEMS FOR SUPERCONDUCTING CAVITIES**

1. Safety Valves for Superconducting Cavities

Liquid Helium Vessel	**Working Pressure**	
Safety Valve 40A	0.3	kg/cm^2
Rupture Disks 80A, 65A	1.0	kg/cm^2
Vacuum Vessel		
Spring-Loaded Flange	~ 0.1	kg/cm^2
Beam Tube		
Safety Valve for Ultra High Vacuum	~ 0.3	kg/cm^2

2. Temperature Measurements

Cavities	Pt-Co Alloy	2	4.2 K ~ 300 K
Cryostat	Pt-Co Alloy	2	4.2 K ~ 300 K
RF Input Couplers	Pt-Co Alloy	2	4.2 K ~ 300 K
Safety Valve Thermoswitch			-5 °C

3. Cavity Vacuum System

Gate Valves Interlocked by Vacuum	2
Vacuum Gauges	
CCG	2
Pirani Gauge	1

4. Cryostat Vacuum System

Convectron Gauge	1
Solenoid Vacuum Valve	

5. Liquid Helium Levelmeter 2

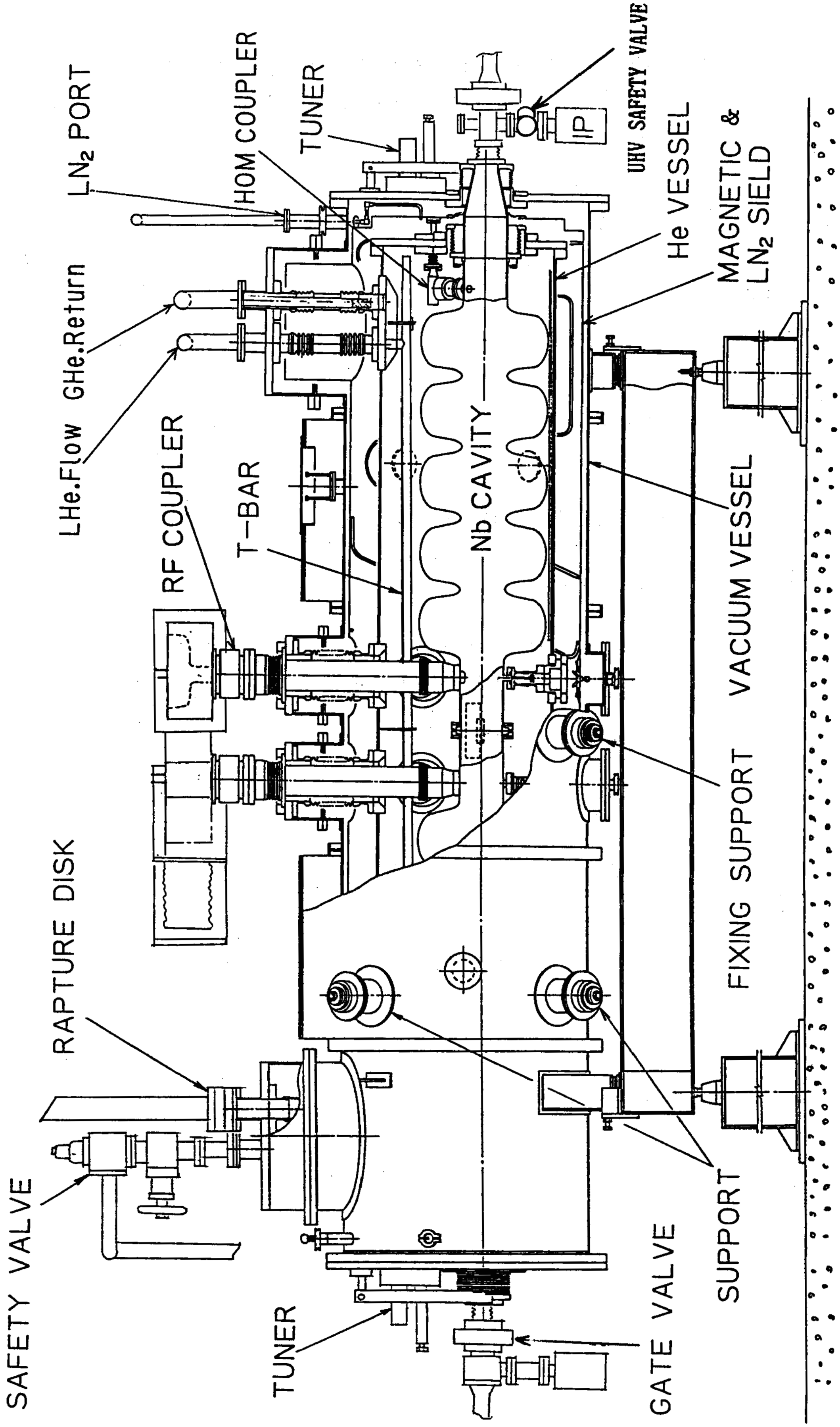


Fig. 1 TRISTAN Superconducting Cavity Cryostat

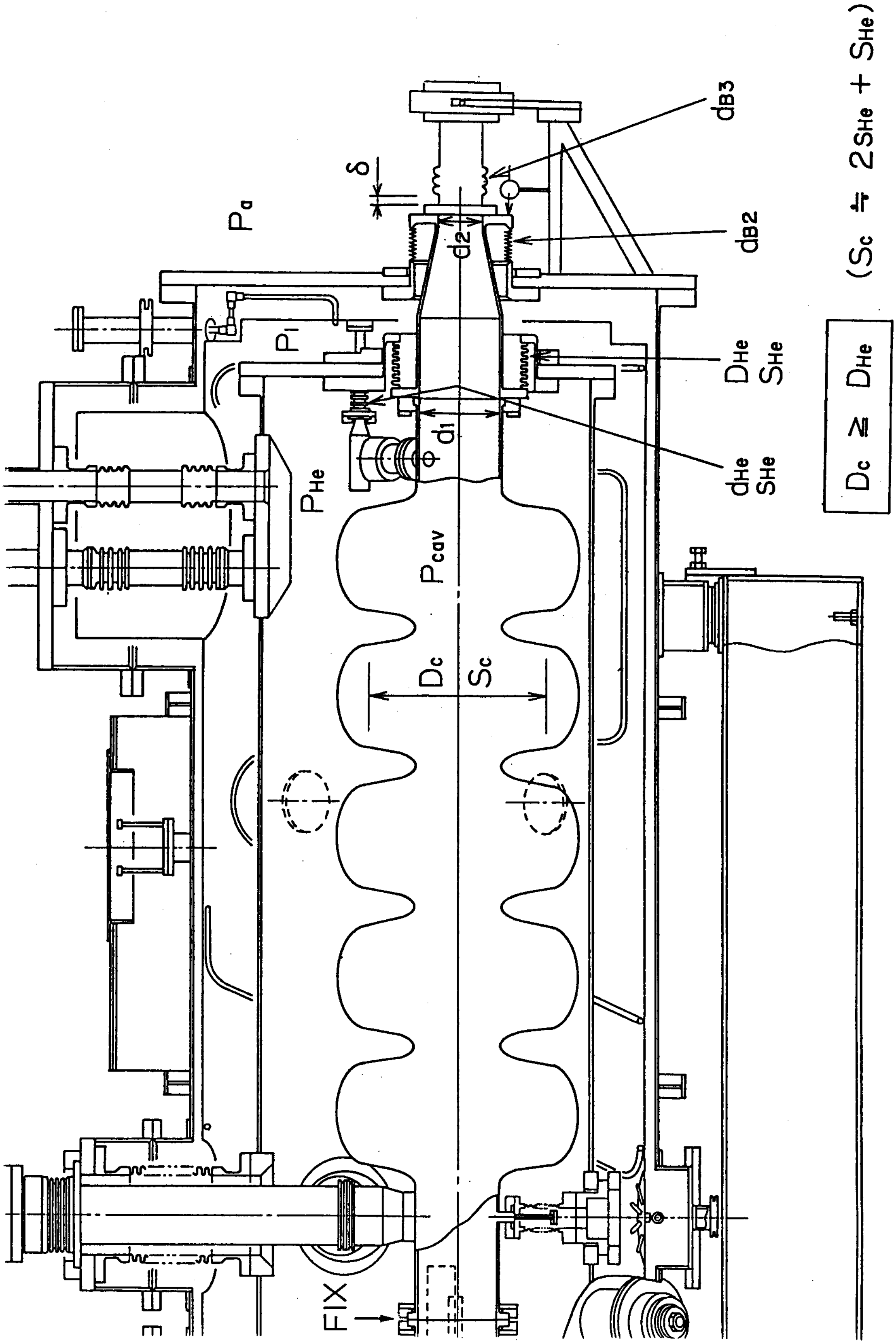
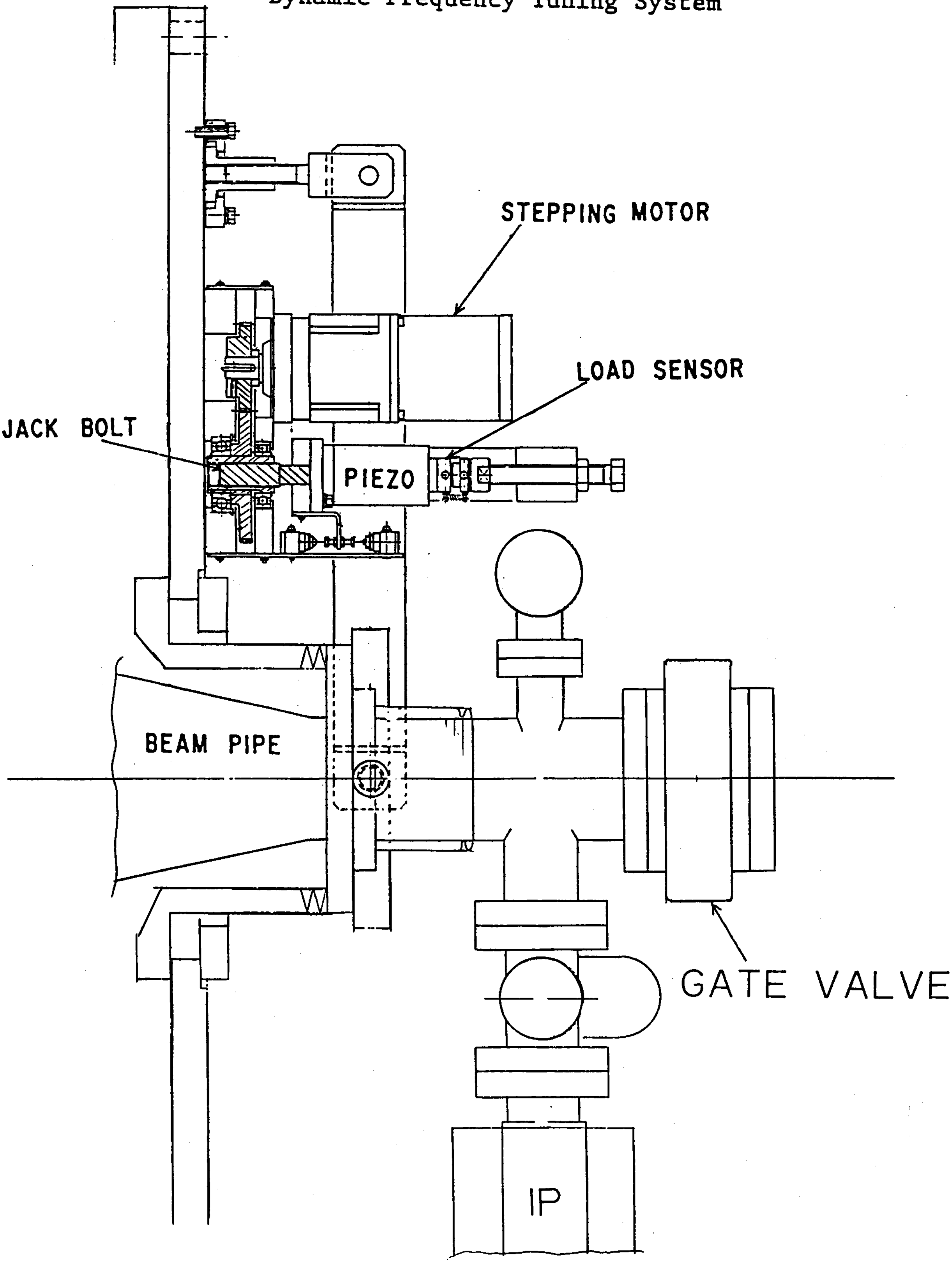


Fig. 2 Hydraulic balance of bellows

Fig. 3 Dynamic Frequency Tuning System



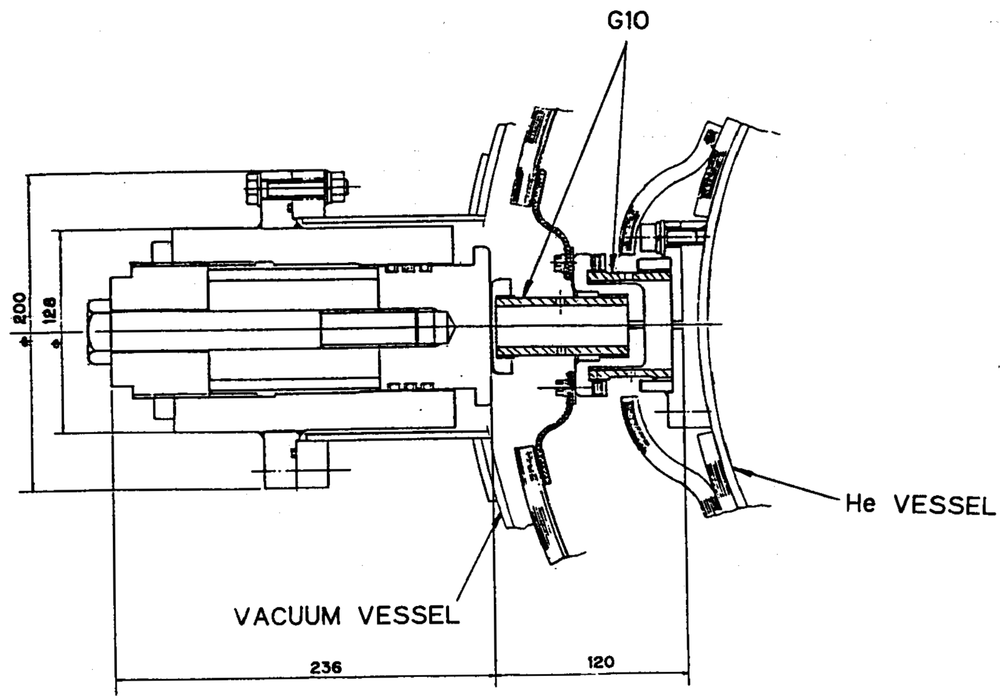


Fig. 4 He VESSEL SUPPORT

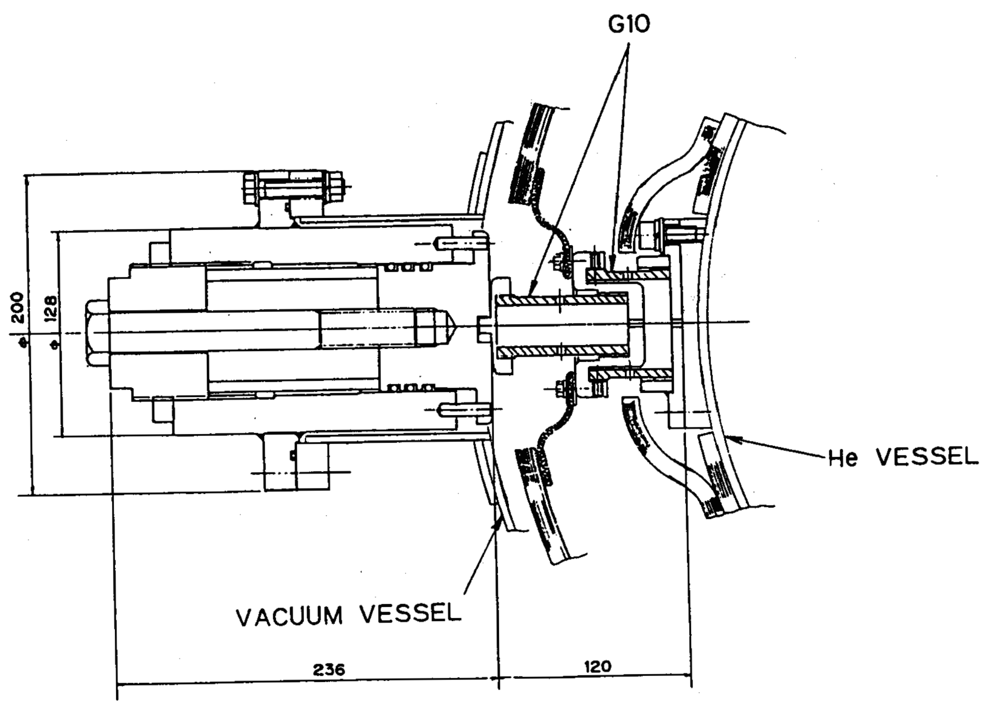
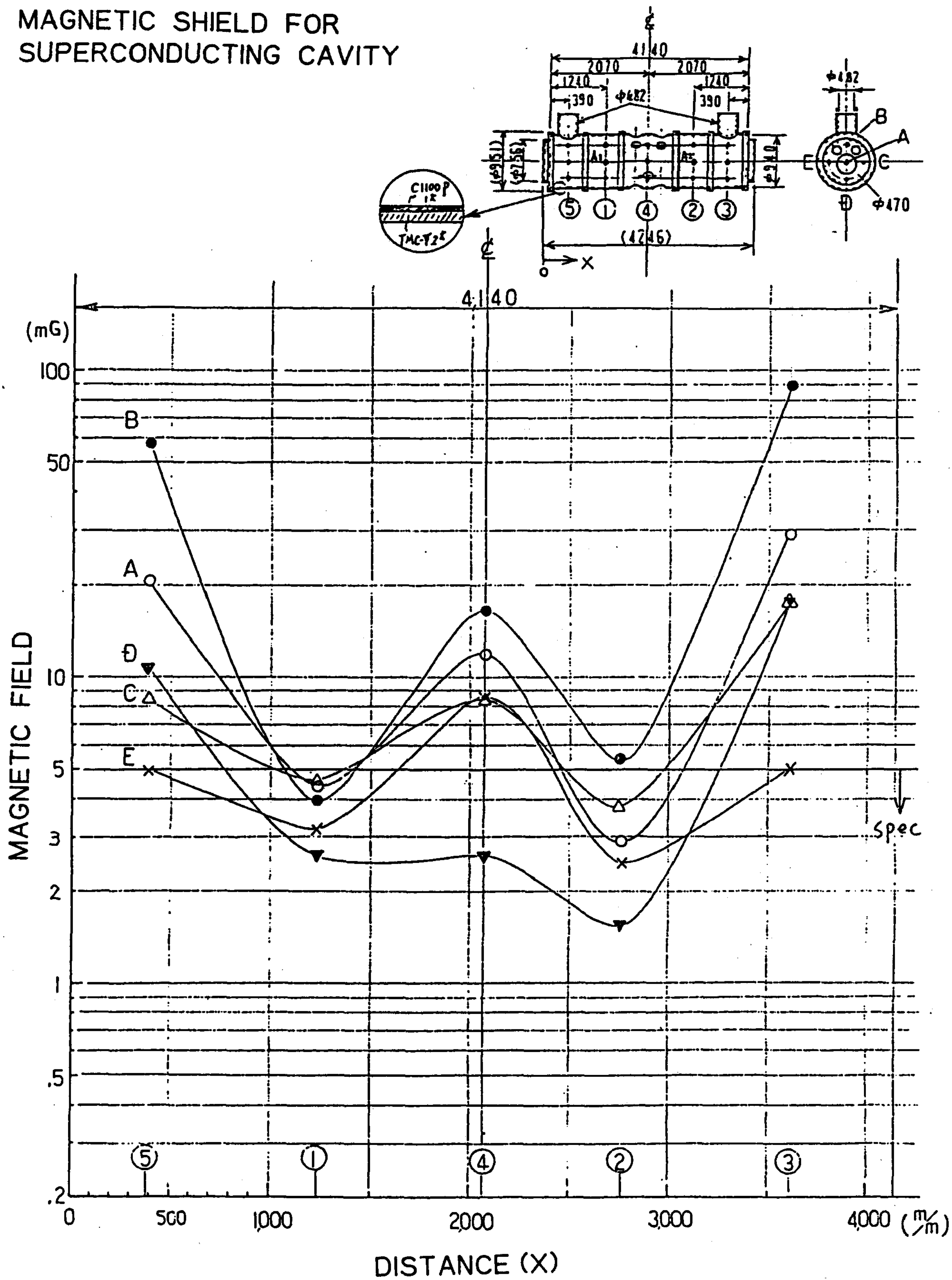


Fig. 5 He VESSEL SUPPORT
FIXING SUPPORT

Fig. 6

MAGNETIC SHIELD FOR SUPERCONDUCTING CAVITY



TEMPERATURE MONITORING FOR SUPERCONDUCTING CAVITIES

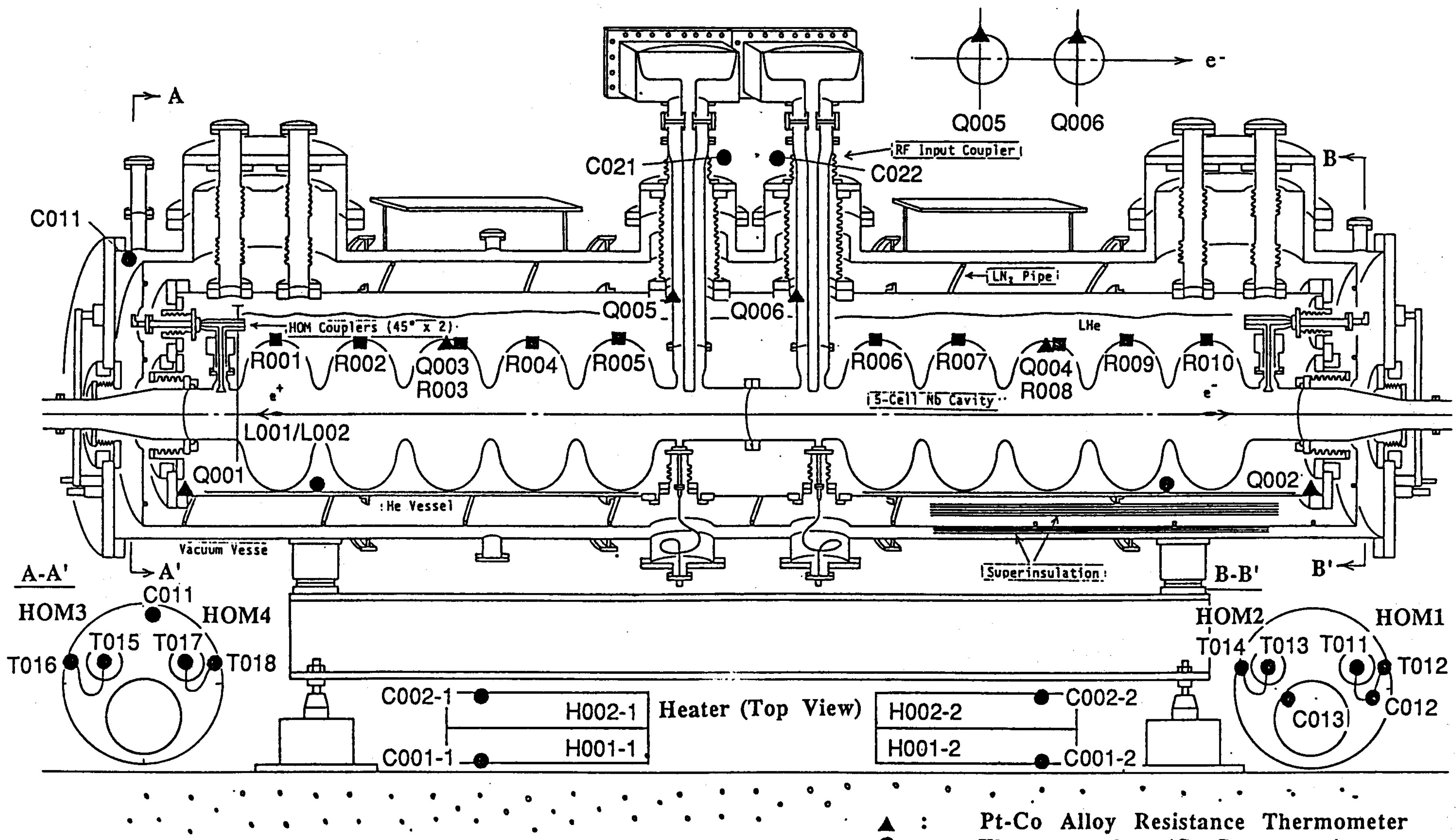


Fig.7

SAFETY VALVE FOR ULTRA-HIGH VACUUM

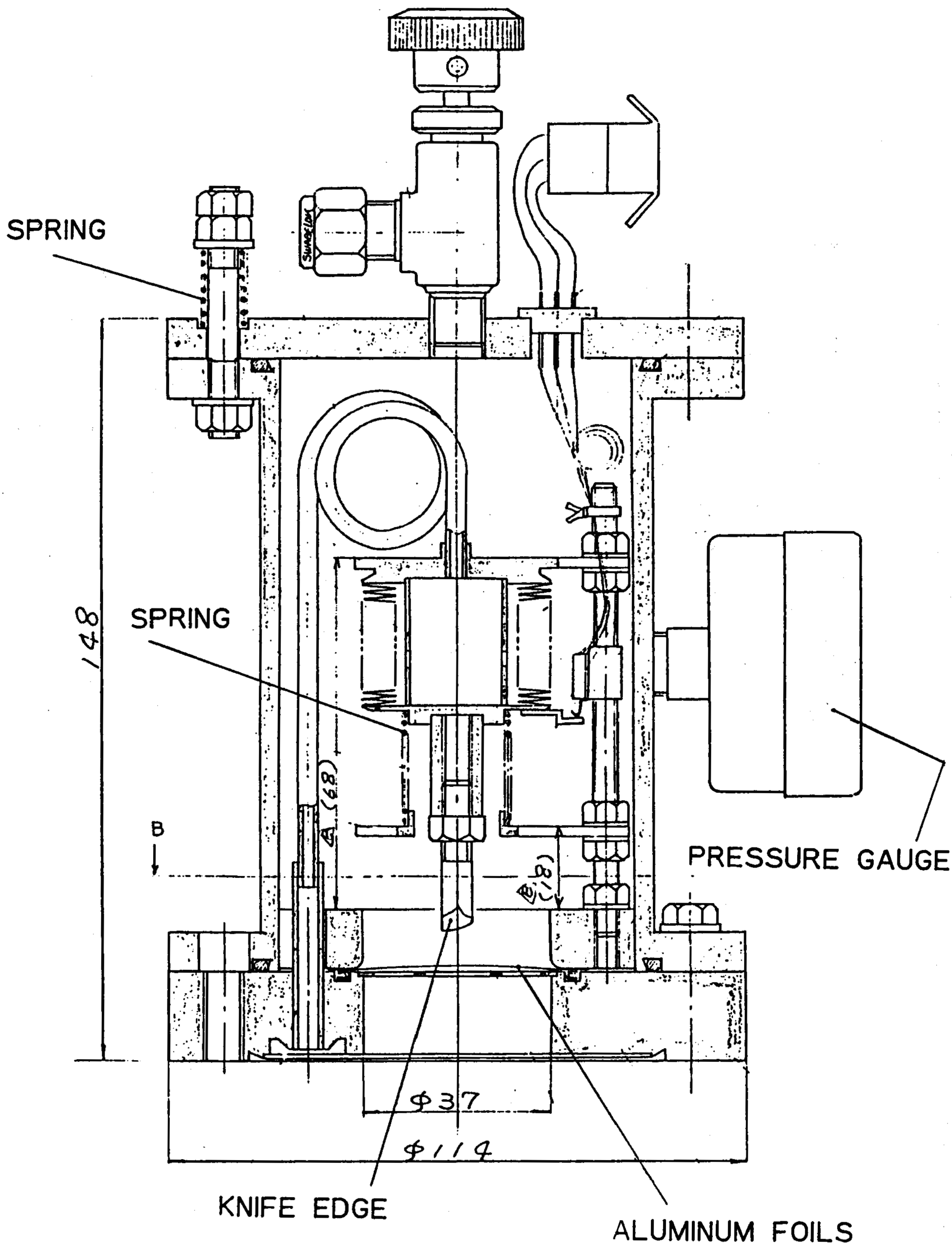
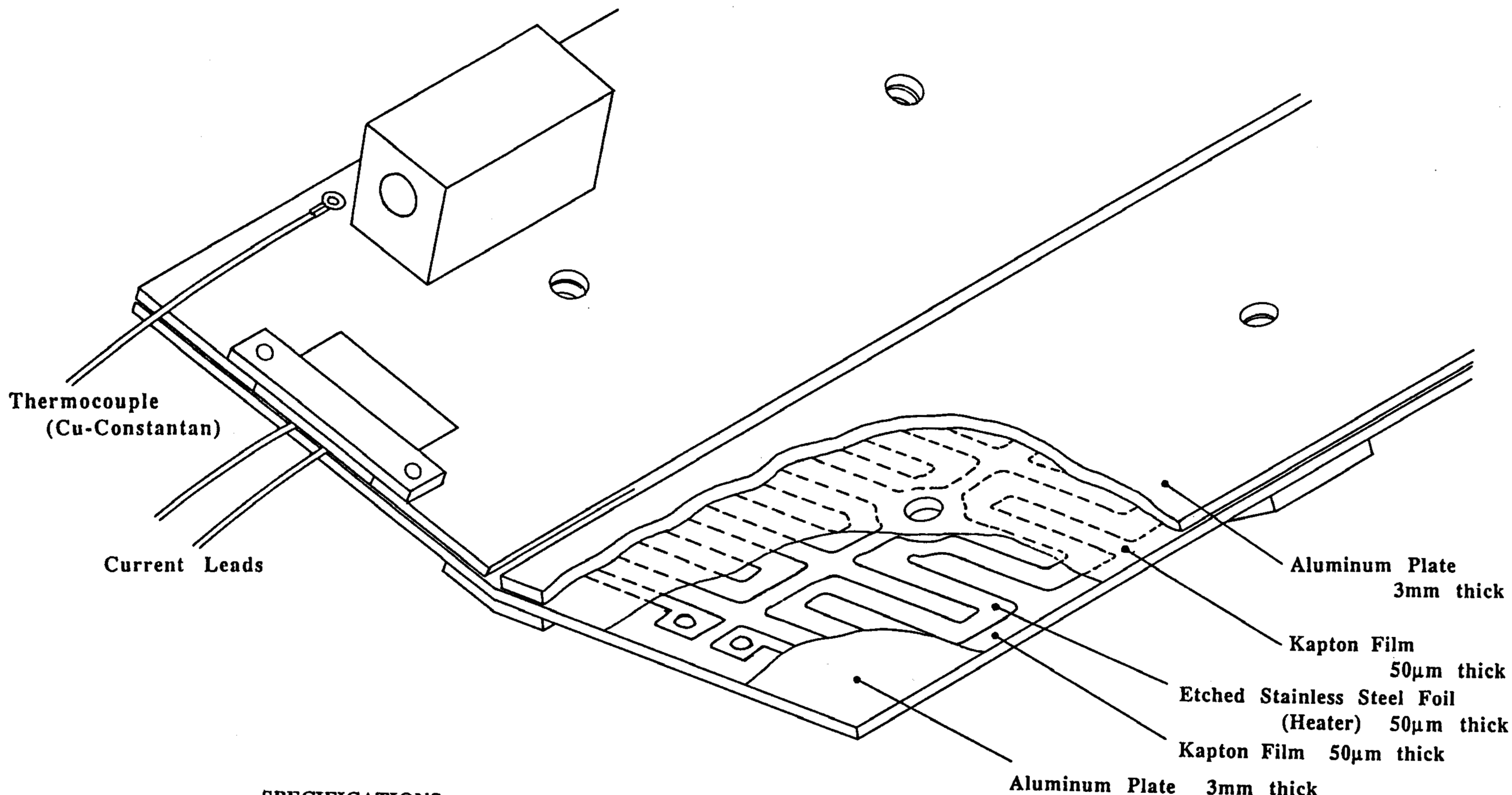


Fig. 8



SPECIFICATIONS

Wattage	:	250 W x 2
Voltage	:	100 V Max
Current	:	2.5 A Max
Dimensions	:	110 mm x 1450 mm
Surface Area	:	0.16 m^2 each

Fig. 9 ETCHED-FOIL FILM HEATER