RECENT RESULTS ON SUPERCONDUCTING CAVITIES AT KEK

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1. Introduction

Since 1979 our efforts have been devoted to the development of superconducting 500 MHz cavities to study the feasibility of using them for the TRISTAN [1),2)] electron ring. It is anticipated to build the superconducting rf system in the TRISTAN for upgrading the energy of e^+e^- and also for saving the electricity.

Three single cavities [3),4)] and a three-cell structure were built and tested up to now. The results of these cavities and some of the associated experimental work are reported here.

2. Fabrication of the cavities

2-1. Niobium material

Typical properties of the material we are using now are listed in Table I.

We plan to build the next single cavity with high thermal conductivity material from Heraeus.

Table I. Properties of Niobium material.

Impurities	(ppm)
C	20 ∿ 50
H	3 ∿ 10
N	20 ∿ 30
O	40 ∿ 100
Fe	10
Zr	100
Si	10
W	< 50
Ta	620 ∿ 900
Ti	10
Mo	< 50
Niobium	99.85 %
R.R.R.	22 ∿ 37

2-2. Forming

Up to the present, 500 MHz cavities were made by spinning starting from 2.5 mm niobium sheet.

Other forming techniques as deep drawing to make half cell or bulging from tubing to make single cell are now under developing. Fig. 1 shows the model copper cavity of 1 GHz made by bulging.

2-3. Surface treatments

Electropolishing is the main process of the surface treatments in our case. Half cell is electropolished removing about 130 μm from the surface, then after electron beam welded, the cavity is annealed at 900 °C and again electropolished for about 30 μm, oxipolished twice at 80 volts and rinsed by pure water and methanol.

For the electropolishing, our experimental research to find the optimum paramenters has shown the followings:

a) Current density is the most important parameter, 30 ∿ 100 mA/cm^2 at 25 ± 5 °C is essential to obtain the mirror like surface, also about 200 mA/cm^2 could be adopted for macro polishing.

For example, a combination of polishing at 200 mA/cm^2 to remove 100 μm and then polishing at 50 mA/cm^2 to remove another 30 μm is effective.

b) Optimum concentration of HF is 60 ∿ 90 cc/liter (46 % HF). This corresponds to 8 ∿ 15 volt to get the current density of 50 mA/cm^2.

c) Polishing solution could be cured by adding appropriate amount of HSO_3F and H_2O, so quite long term storage and use of the solution is possible.

d) By moving the solution or cavity at the relative speed of $\lesssim$ 10 mm/sec, not intermittent but continuous polishing is possible.

e) Before and after electropolishing impurties as H, N, O, C in the niobium do not change within the accuracy of measurements.

3. Performance of the Cavities

Typical results of the single cavity is shown in Table II.

Table II. Typical results of the single cavity.

	4.2K	1.8K
Q_0 at low field	4.1×10^9	4.8×10^{10}
E_{acc}^{Max}	6.5 MV/m	7.0 MV/m
Q_0 at E_{acc}^{Max}	2×10^9	3.6×10^9
Electron loading threshold(E_{acc})	5.2 MV/m	
β	500	
Residual resistance	4.5 nΩ	

Cavity performance is generally improved by locally grinding of the defect and re-treatment of the surface as shown in Table III. Break down is mostly observed at the welding seam.

Table III. Improvement of E_{acc}^{Max}(MV/m) by successive treatments.

Cavity No.	1st	2nd	3rd
S-1	4.1	5.7	6.5
S-2	4.2	6.5	
3-L	4.5	5.7	
3-C	4.1	4.8	> 5.2
3-R	4.6	5.6	

4. Three-cell structure for the beam test

4-1. Structure

Three single cavities (3-L, 3-C, 3-R, in the Table III) were welded together to make a three-cell structure for the beam test.

Fig. 2 and 3 show the three-cell structure. Each cell has two HOM ports and a small pickup port. The center cell has an additional input coupler port.

Field flattness of a few percents was obtained by modified dimension of two end cells and also by giving the permanent deformation of the cell length of each cell.

The structure was at first tested in a vertical cryostat without all couplers and obtained the field gradient of 5.2 MV/m without break down. More higher field level was not measured due to the shortage of rf power and rather low Q_0 value.

In a horizontal cryostat Q_0 and E_{acc} were measured by helium consumption. Fig. 4 shows the results of these measurements. Maximum field gradient at beam test was limited to 4.3 MV/m by helium boil up, it seems to be due to the heating of the input coupler.

4-2. Tuner

A mechanical tuner as shown in Fig. 5 was built. Total length of the sturcture could be changed ± 1.7 mm corresponding to the frequency change of ± 250 KHz with smallest tuning step of 7 Hz. But the system had backlash of 500 Hz to 2 KHz depending to the tuning position, so two additional piezo tuners were equipped at both ends of the cryostat as shown in Fig. 6. The piezo tuners also change the total length of the structure and control the frequency with a range of ± 1 KHz. The piezo tuners worked well with a feed back system and compensate the frequency change of the structure due to the pressure change of He bath for example.

4-3. Cryostat and refrigeration system

Fig. 6 shows the horizontal cryostat for the three-cell structure. The design was especially restricted by the limited height of the ceiling of the tunnel.

Static loss of the cryostat is 12 watts and the loss of the three-cell structure is for example 40 watts at E_{acc} = 4 MV/m, so the total refrigeration power of about 65 watts is needed, including the heat loss of helium transport system.

Fig. 7 shows the sketch of the cryogenic system. Cool down from the room temperature to the helium temperature is done by the refrigeration mode in which the refrigerator is directly connected to the cryostat, it takes ∿ 36 hours. During the beam test, liquid helium is transfered from a 1000 liter reservoir.

4-4. Input and HOM couplers

An input coupler as shown in Fig. 8 was used, inner and outer conductors are made out of copper and copper plated stainless steel and cooled by helium gas flow. It was found the rf power which could be transfered to the beam was limited to 4 KW due to the heating of the input coupler.

A loop type HOM coupler and two antenna type HOM couplers were used, they are shown in Fig. 9 and 10. The loop coupler has a quarter wave length filter for the fundamental frequency. These are made of niobium.

4-5. Beam test

The results of the beam test are only briefly reported here, more detailed report will be given during the workshop.

a) Maximum accelerating field was 4.3 MV/m.

b) With the SC structure alone 10 mA in single bunch at 2.5 GeV were stored. The beam current was not limited by the SC structure but limited by the heating of two gate valves at both ends of the cryostat.

c) Maximum power given to the beam was 4 KW at 4 GeV and 4 mA beam.

d) The results of the power measurement of longitudinal higher order modes roughly agreed with the calculation.

e) A transverse beam oscillation due to TE_{111} - π mode was observed without beam loss.

5. Future plan

Two or three units of five-cell sturcture will be built for the TRISTAN accumulation ring, an input coupler on the beam tube is being studied. Development of the high power input coupler is the most urgent problem.

References

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3) T. Furuya, S. Hiramatsu, T. Nakazato, T. Kato, P. Kneisel, Y. Kojima and T. Takagi, IEEE Trans. Nucl. Sci. NS-28, No. 3, (1981), 3255.

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Fig. 1 A model copper cavity of 1 GHz made by bulging.

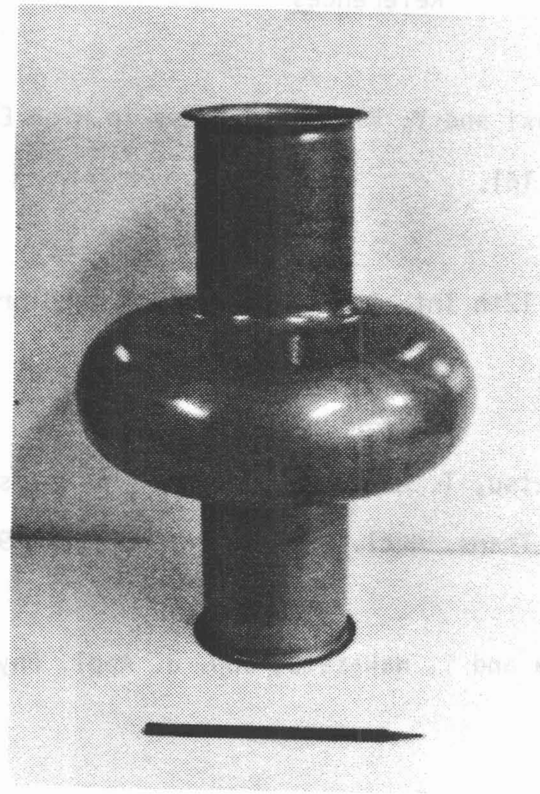
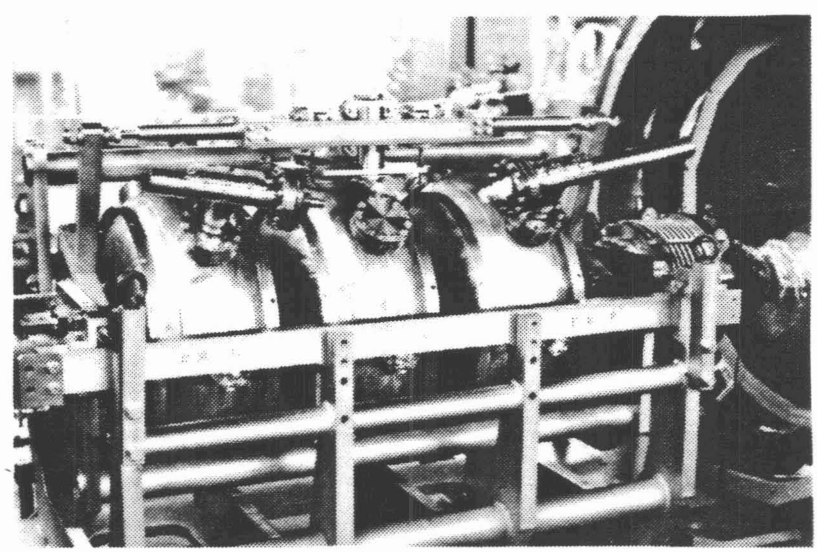


Fig. 2 A three-cell structure.



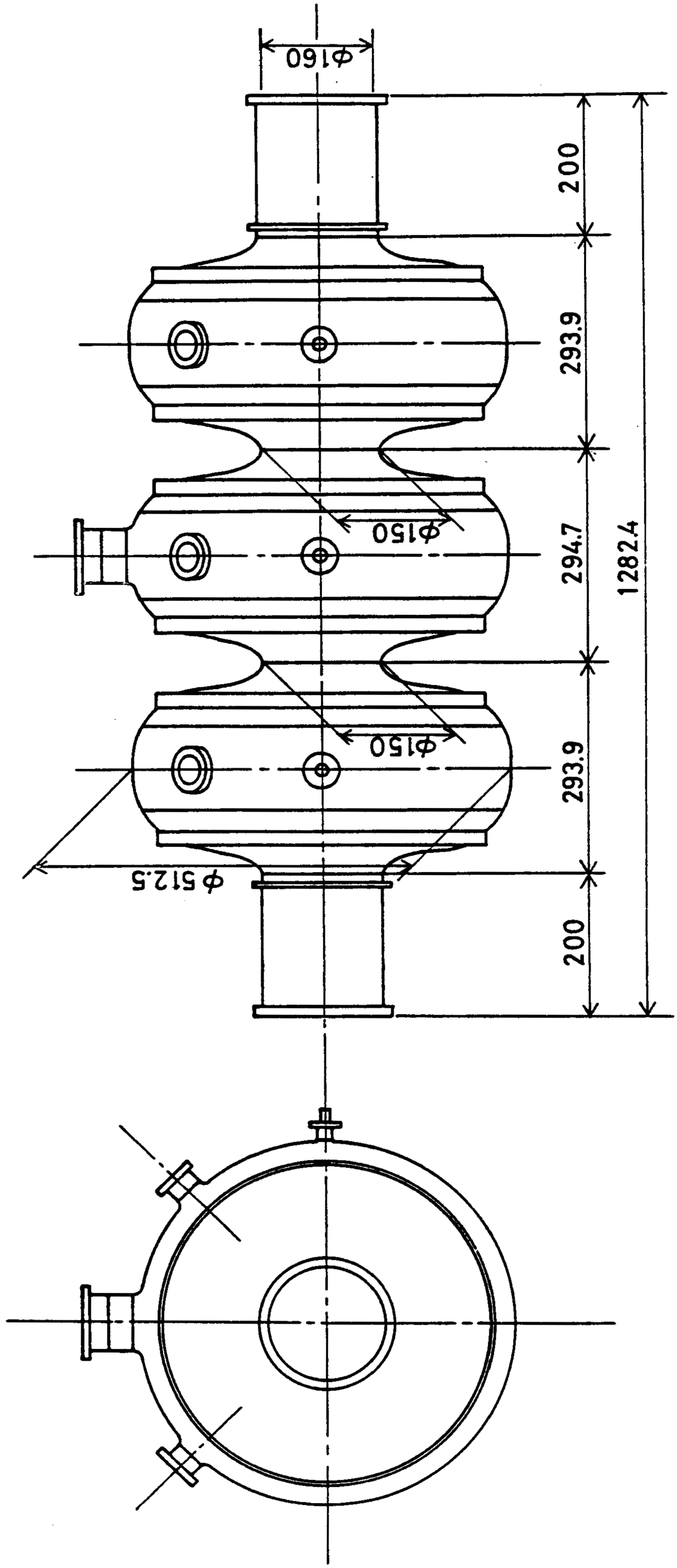


Fig. 3 A three-cell structure.

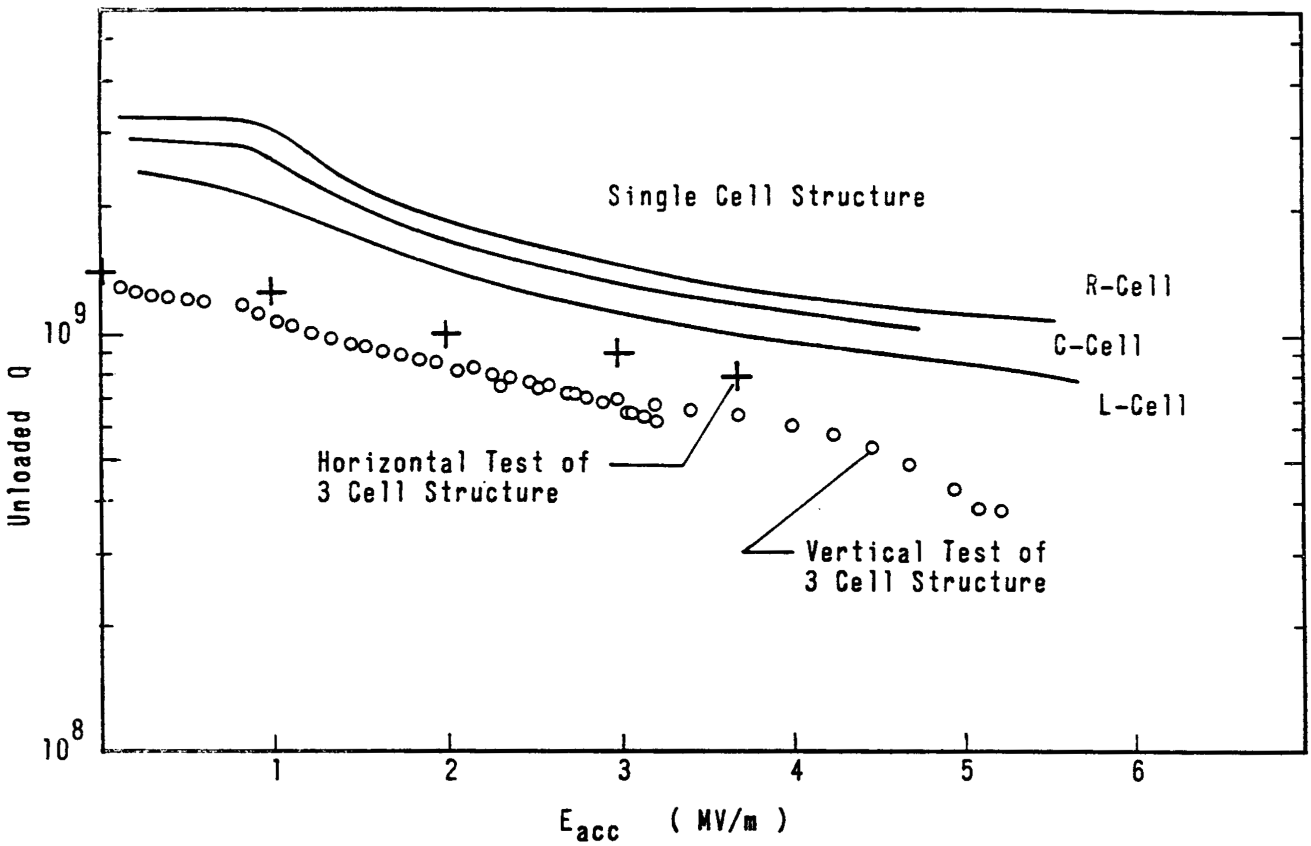


Fig. 4 Q_0 and E_{acc} of the three-cell structure.

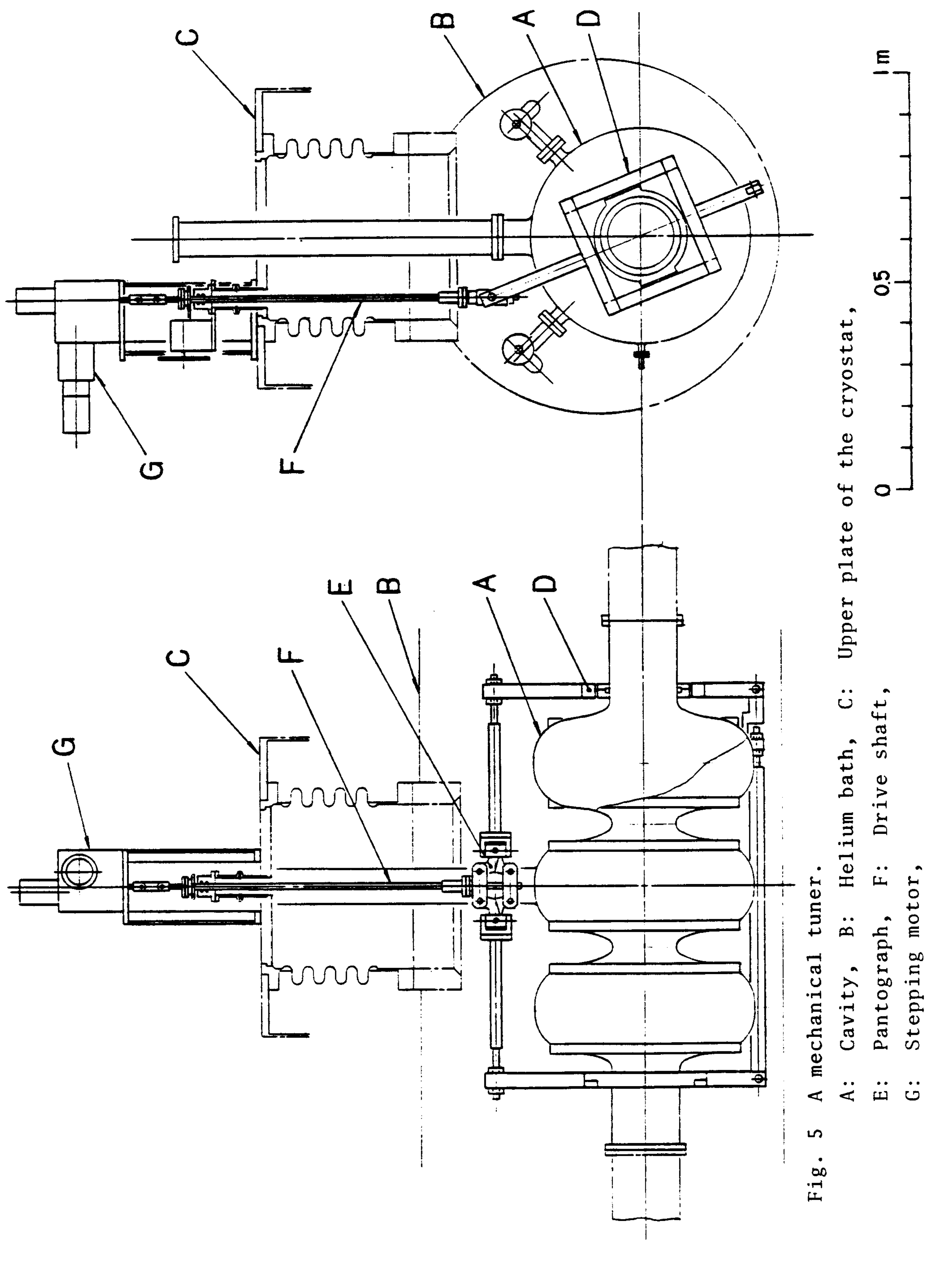


Fig. 5 A mechanical tuner.
A: Cavity, B: Helium bath, C: Upper plate of the cryostat,
E: Pantograph, F: Drive shaft,
G: Stepping motor,

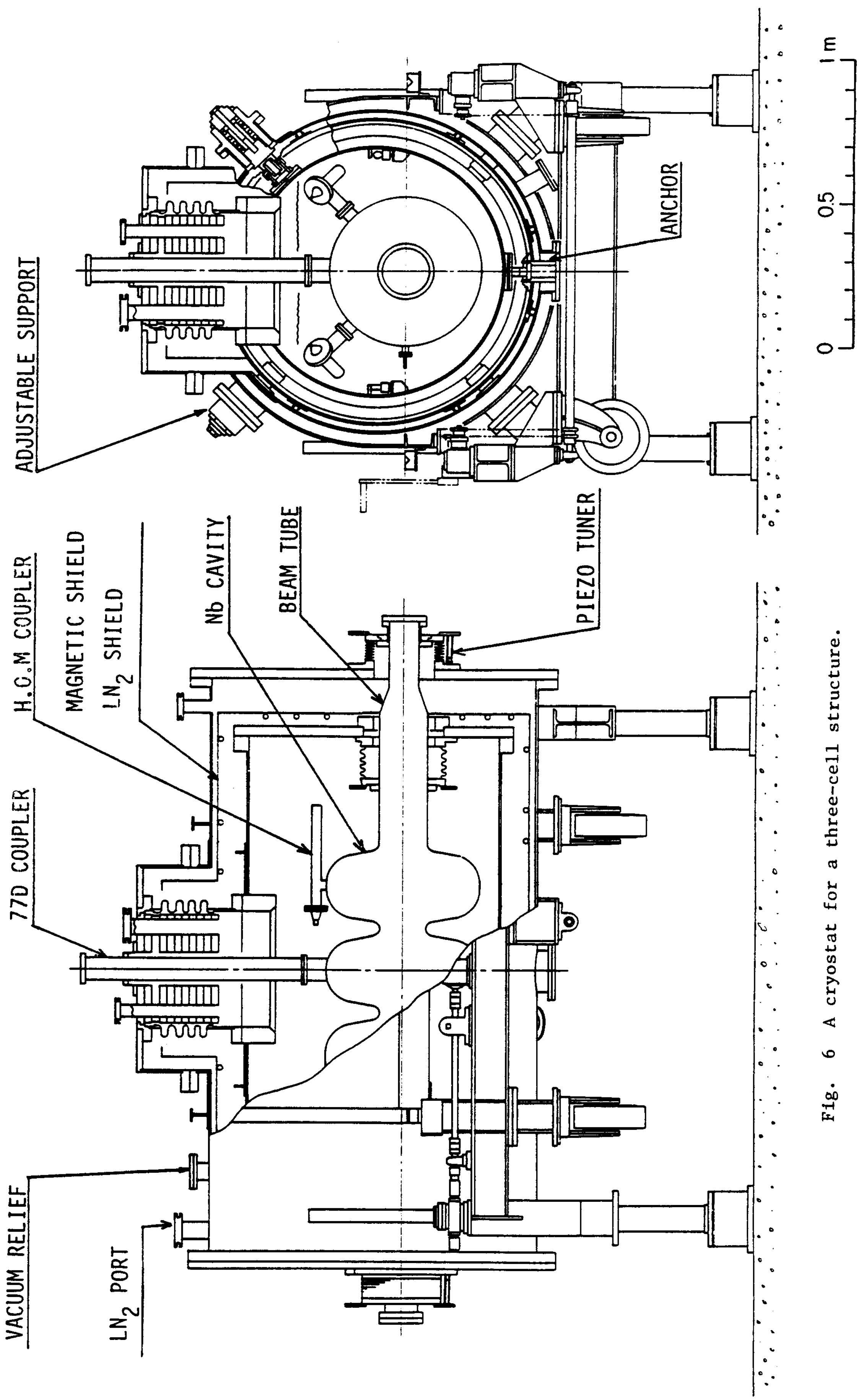


Fig. 6 A cryostat for a three-cell structure.

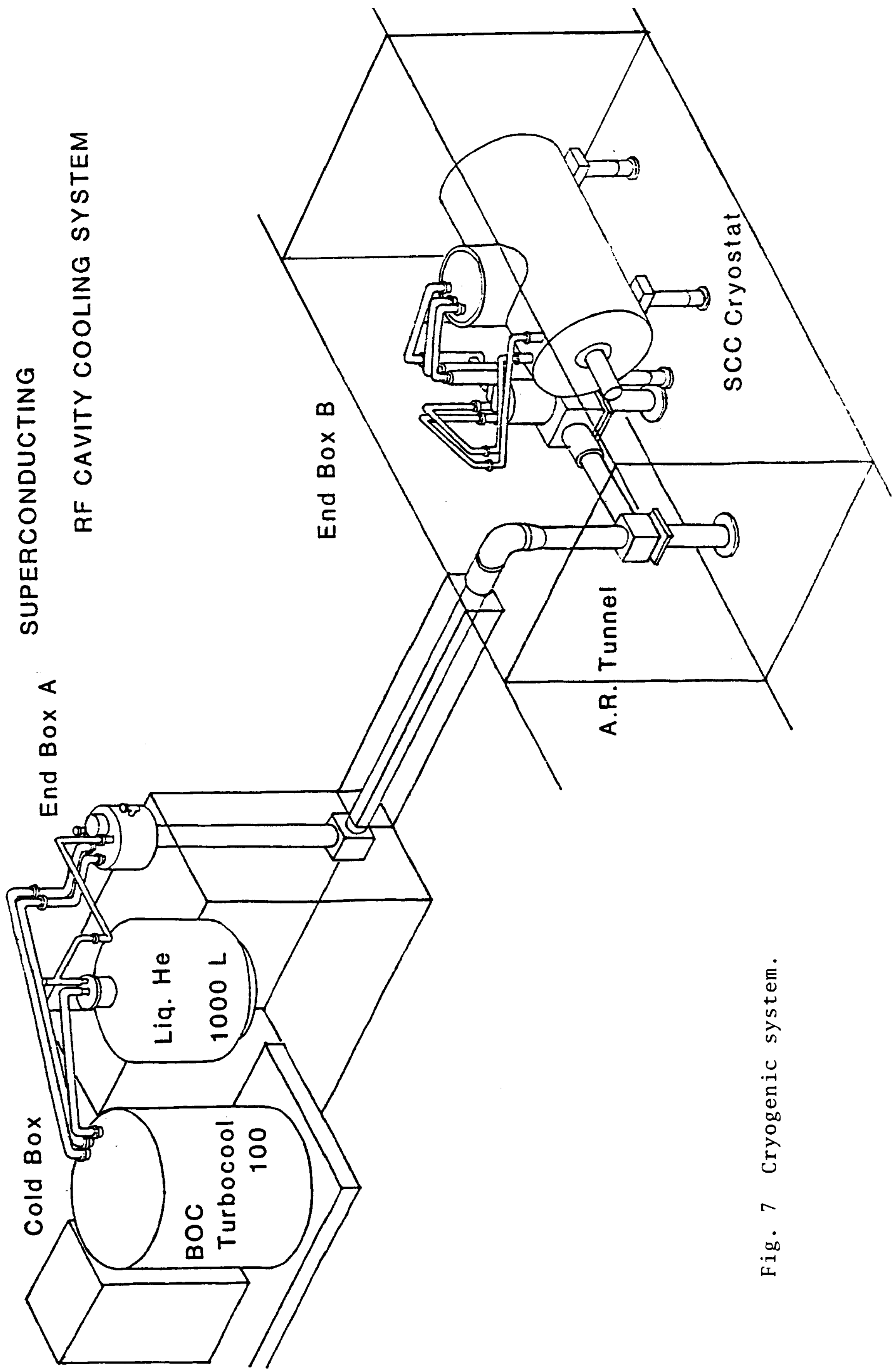


Fig. 7 Cryogenic system.

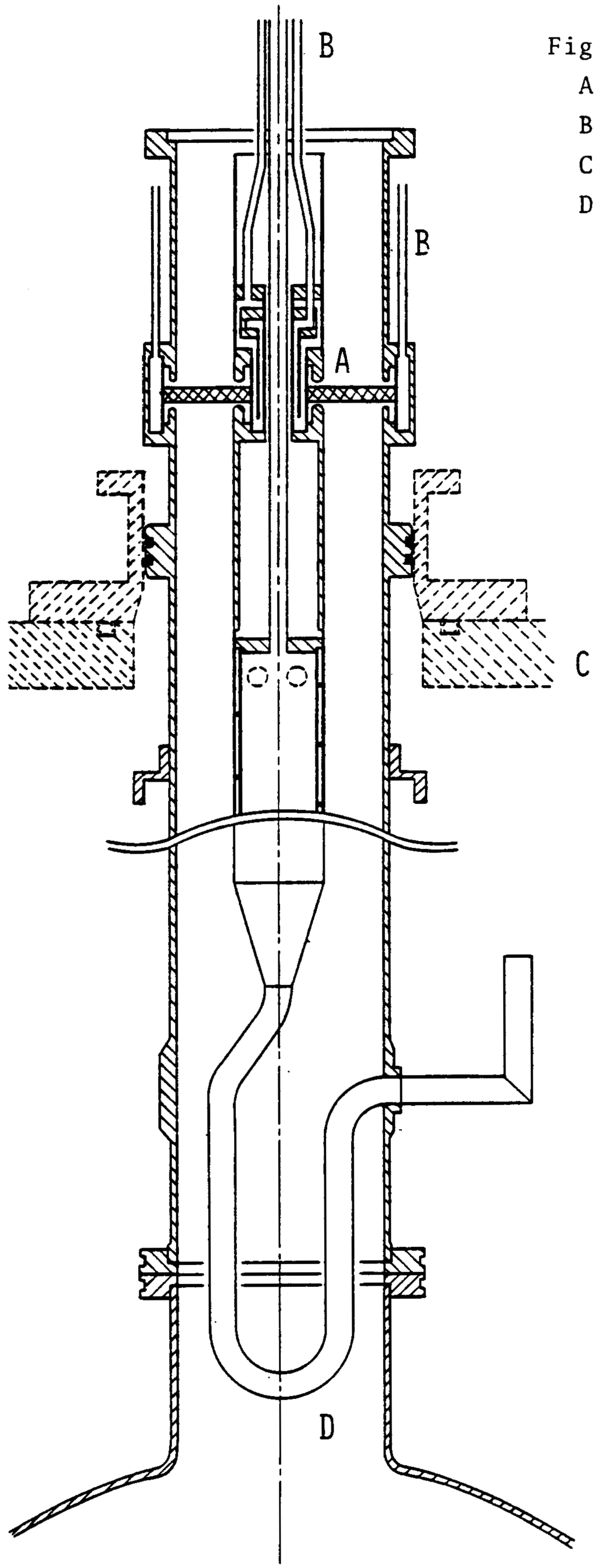


Fig. 8 Input Coupler.
A: Ceramic window
B: N_2 gas cooling pipe
C: Upper plate of cryostat
D: He gas cooled coupling loop

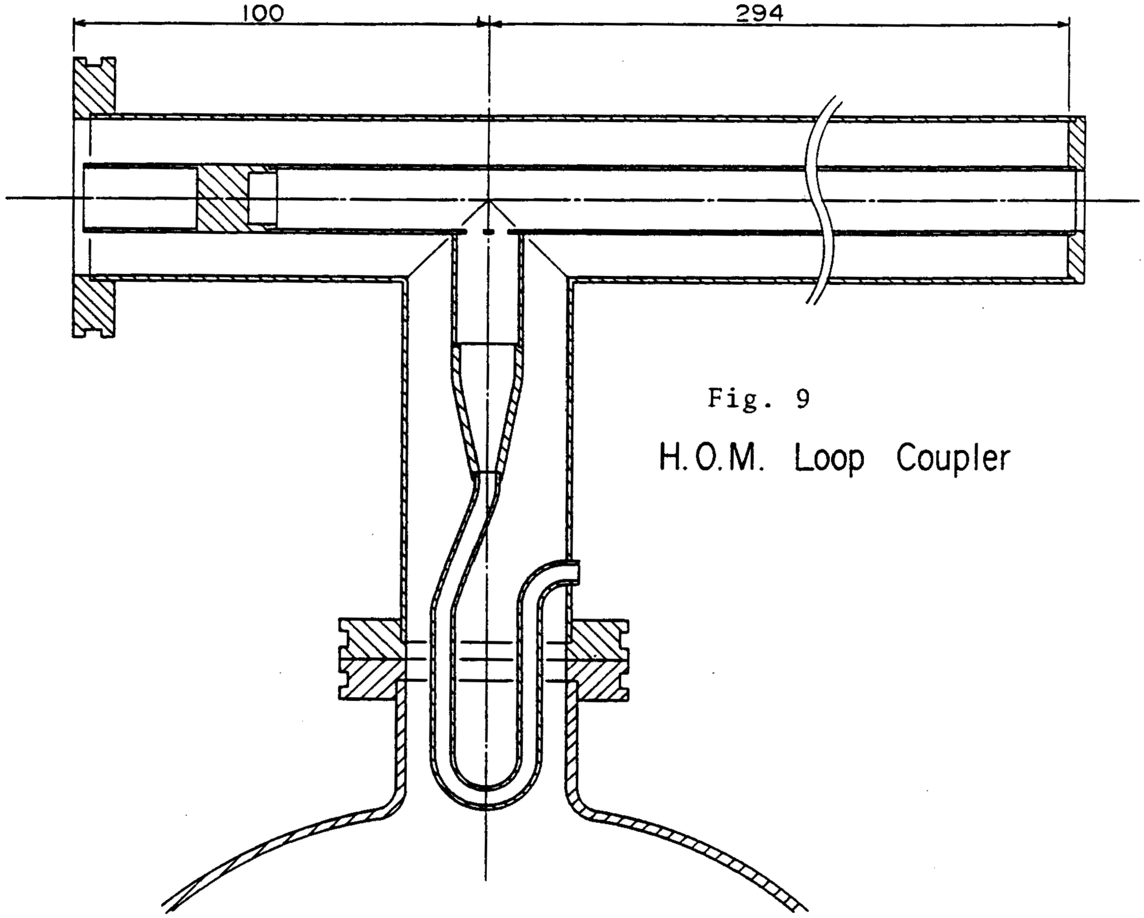


Fig. 9
H.O.M. Loop Coupler

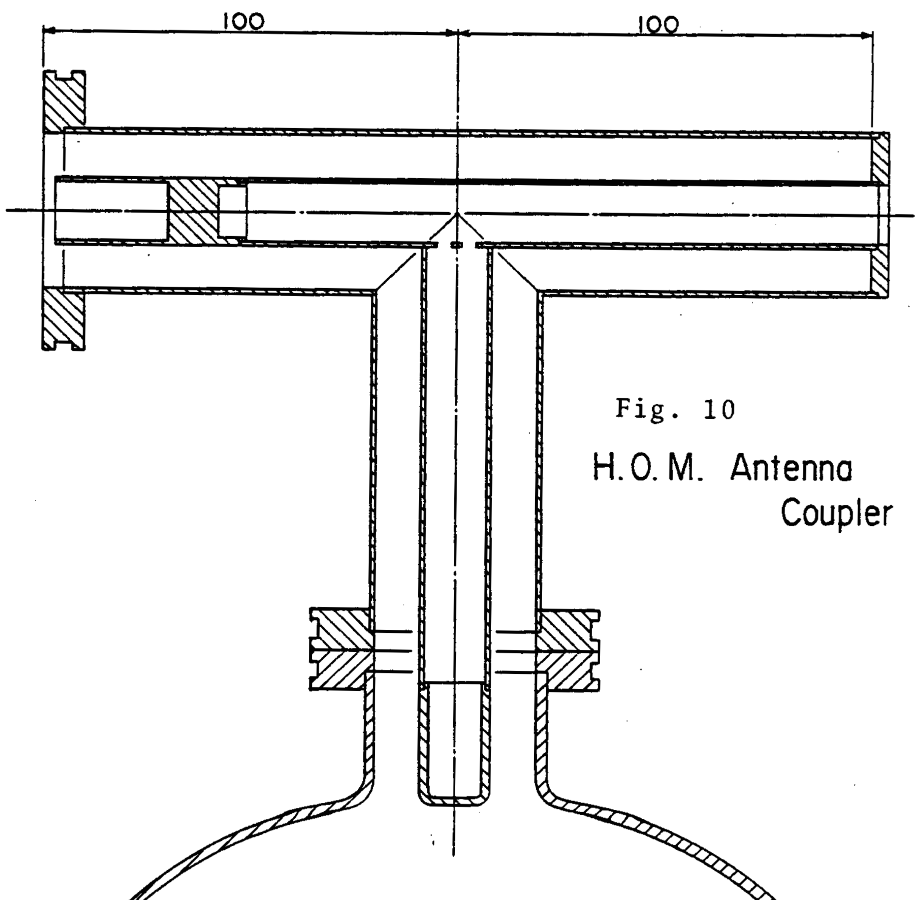


Fig. 10
H.O.M. Antenna Coupler