STATUS REPORT OF THE PETRA 18-CELL SUPERCONDUCTING CAVITY EXPERIMENT

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Abstract

A status report of the PETRA 18-cell superconducting cavity experiment is given.Technical descriptions and results of test measurements for individual components are reported.At the time of writing this report (July 1984) the complete system was being assembled and preparations for a PETRA beam test were on the way.

Introduction.

In 1981 the development and fabrication of a 1 GHz superconducting accelerating module was started in cooperation with the University of Wuppertal.This modul has an active length of 2.7m and consists of a 2*9 cell elliptically shaped structure.The general design ideas are described in/1/.The cryostat and many of the microwave components (input window,feed line absorber,HOM absorber etc.) were fabricated by the DESY workshop because these prototype components needed a fast design-test-redesign cycle.The niobium cavities and the niobium parts of the input and output couplers were fabricated by industrial firms/9,10,11/.Effort was made to develop a easy to handle,simplified final cleaning and preparation method which could readily be transfered to the industry.

Cryostat

The vacuum and the helium vessels are made of stainless steel and have a diameter(length)of 80cm(400cm) and 50cm(350cm) respectively.The radiation shield is made from aluminum and has two liquid N2 containers.The two large demountable end flanges of the helium vessel are sealed by grooved lead gasket.All cavity flanges are constructed in a way so that the beam pipe vacuum is sealed against the isolation vacuum.The only exception is the middle flange between both niobium structures.Here the Helicoflex ring /8/ seals against the liquid helium.The helium container is mounted with long stainless steel rods inside the vacuum vessel whereas the radiation shield fixed to the helium vessel by thinwalled pipes.For security reasons two pressure regulated and two burst valves are mounted at the helium dome to prevent an accidental pressure rise in the vacuum and helium room.
In several cooling down cycles the empty cryostate (without rf-structures) has been leak checked and tested.The steady-state losses for this condition are 7 watts.Details of the cryostat construction are shown in fig.2 to fig.6.

RF input line.

The rf power is coupled to the cavity by a rectangular waveguide which ends at the beam pipe of the resonator.The coupler is matched to a beam current of 4*4 ma and Eacc=3Mv/m (Qext=1.5*10↑5).To benefit from the strong coupling of the input coupler to some of the higher modes of the resonator a broad-band window and a feed line absorber had to be developed.The room temperature window uses a round ceramic disk which is matched by a tapered ridged waveguide section /2/.This design was high power tested at 50% overratings under matched (60 kw) and total reflected (35 kw) conditions/3/.The feed line absorber uses a broadband magic-tee which is connected at both side arms to reduced size rectangular waveguide sections with broadband absorbers/2/.After proper matching the insertion loss at the fundamentel frequency (1Gwz) was measured to be less than 1% wheras higher modes up to 3.0GHz were reasonably terminated/4/.

A counterflow pipe cooling system was integrated into the waveguide wall of the input coupler to minimize the heat load at 4.2 K by thermal conduction and rf-heating (fig.3).It consists of 30 transvers cooling channels of 1.5*8 mm cross section.The efficiency of the heat exchanger was tested by rf powering the waveguide section in a standing wave resonator mode.The temperature profile measurements along the waveguide for different amounts of cold He-gas flow gave approx. a predicted heat load of 2 watts for 50 Kw forward power.2 Nm↑3/h are required to cool the wave guide.
The additional rf losses at the normal- to superconducting joint at the input line were investigated by measuring the Q's of a rectangular Nb-resonator (fig.11) with differnt joints in the middle of the resonator(Indium,Lead,Al-Helicoflex/8/,Pb-plated Helicoflex/8/).As the best compromise between vacuum realibility and low rf losses we choose Al-Helicoflex(see tab.1).

sealing materials	losses at 60 Kw forward power
In wire	34 mW
Helicoflex,Al	95 mW
Helicoflex,Pb plated	381 mW
Pb foil, .3mm, oxidized	190 mW
Pb foil, .3mm, cleaned	114 mW

Tab.1:Measured rf-joint losses

Tuning

The field profile and the absolute frequency of the cavities were tuned by slight deformation of the individual cells /6/.Frequency tuning of the structure at 4.2 K is produced by lenghtening the whole structure.In the vertical test cryostat the tuning rate was measured to be 140KHz/9 cell/1 mm.A room temperature measurement showed only slight influence to the field profile for a total tuning range of 1.5 MHz.In the horizontal cryostat the tuning system uses three hydraulic power cylinders(at room temperature)which pull at the HOM coupler side of the structures with thin rods(see fig.2 and fig.6).The input coupler side is bolted to the helium vessel and provides the mechanical fixed point of the cavities.The tuning system is driven by standard PETRA tuning step motors and is designed for a tuning range of +- 250 KHz at a resolution of 50 Hz.

Cavity fabrication and measurements

Three nine cell cavities were fabricated,two by INTERATOM/10/and one by DORNIER/11/.A detailed fabrication and measurement history is given in /1/.All three resonators reached accelerating fields of Eacc=5-5.5 MV/m at 4.2 K after a treatment of tumbling/5/ and buffered chemical polishing (BCP)/5/.Following these measurements the end tubes of two resonators were cut off and the niobium input and output couplers were welded to the structures(LUFTHANSA/9/).The couplers were manufactered mainly by using electron beam welding.Stiffening bars and some geometricly difficult connections were TIG-welded.At the rectangular waveguide joint an explosive bonded NB-SS material was used for easy flange construction.Before mounting into the horizontal cryostat the cavities and couplers were tumbled and buffered chempolished again.

HOM-couplers and rf-probes

The HOM-coupler is welded to the outer side of the structures and is similar to the input coupler(fig.12).It is reduced in size to cut-off damp the fundamental mode propagation.To avoid the mechanical and electrical problems of two bellows in the rectangular waveguide (as originally forseen,fig.1) a broad band transition from rectanguler to coaxial waveguide is inserted befor the HOM line leaves the vacuum vessel.The HOM power is absorbed at room temperature by standard coaxial terminations.A funamental mode power of 80 watts is present at the coaxial end of the HOM coupler for a cavity field of 3 MV/m.This signal is used for rf field and phase control thus eliminating the need for an additional fundamental frequency probe.

Cryogenics

Fundamental and HOM couplers as well as beam pipe tubes are cooled by GHe counterflow (fig.2 and fig.3).The mass flow is individually adjusted slightly above the value needed.Temperature measurements at the output of each cooling line are used to regulate an electric heating system for controlling equilibrium conditions.
For cooling down and operating at 4.2 K a 150 W refrigerator is used.In case of breakdown the resonator will be cooled at 100K by a closed GHe system with LN2 heat exchangers.

T-mapping

A total of 900 resistors are mounted to the cavities and couplers (fig.17).The read out system uses 18 multipexer moduls at 4.2K and a computer controlled digital voltmeter.In addition, a fast real time observation by a chopped oscillograph display is possible.Ac-current sources and 210-ohm resistors are used to increase the sensitivity at 4.2K/7/.

Controls and interlocks.

Temperature and pressure sensors in the cryostat as well as status signals from the refrigerator and high power klystron are combined to give the logical information required for the PETRA beam interlock.The philosophy of this system/12/ is compatible with the computerized PETRA controls.

Conclusions

All individual components have been tested successfully.The present activities concentrate on the check of the complete system before its installation in the PETRA storage ring.

Acknowledgement

The support of the technical groups at DESY during the fabrication is greatfully acknowledged.The engaged participation of members of the rf-group and the enthusiastic help provided by the F21-group during the installation and testing of the many components is greatly appreciated.
We would also like to thank all laboratories and companies who have contributed to the developement and fabrication.

Figure captions

Fig.1 :Main layout of the 18-cells 1GHz superconducting PETRA experiment.The HOM output line is changed according to fig.2.

Fig.2 :Sectional view of the HOM side of the cavity.

Fig.3 :Sectional view of the rf input side of the cavity.

Fig.4 :Cross section of the cryostat at the input coupler.

Fig.5 :Cross section of the cryostat at the HOM output coupler.

Fig.6 :Front view of the cryostat.

Fig.7 :Schematic drawing of the input window.

Fig.8 :Parts of the input window before high power test.

Fig.9 :HOM output line.

Fig.10 :Inside of the HOM line showing the ridge section for the waveguide to coax line transformation.

Fig.11 :Test cavity for flange loss investigations.

Fig.12 :Complete 9-cell structure.The HOM waveguide coupler is in front of the picture.

Fig.13 :Mounting rig for welding the coupler to the structure.

Fig.14 :First cooldown of the empty cryostat.

Fig.15 :Complete input-cavity-output assembly during rf test measurements.

Fig.16 :Test assembly of the 18-cell module.

Fig.17 :Mounting the resistors (900 in total) and cold multiplexers to the cavity.The resistors are attached to thin TEFLON mounting strips.

References

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8 CEFILAC,90,Rue de la Roche du Geai,42029 Saint-Etienne Cedex,France

9 Lufthansa-Werft,Postfach 300,2000 Hamburg 63,W.Germany

10 Interatom, 5060 Bergisch Gladbach 1,W.-Germany

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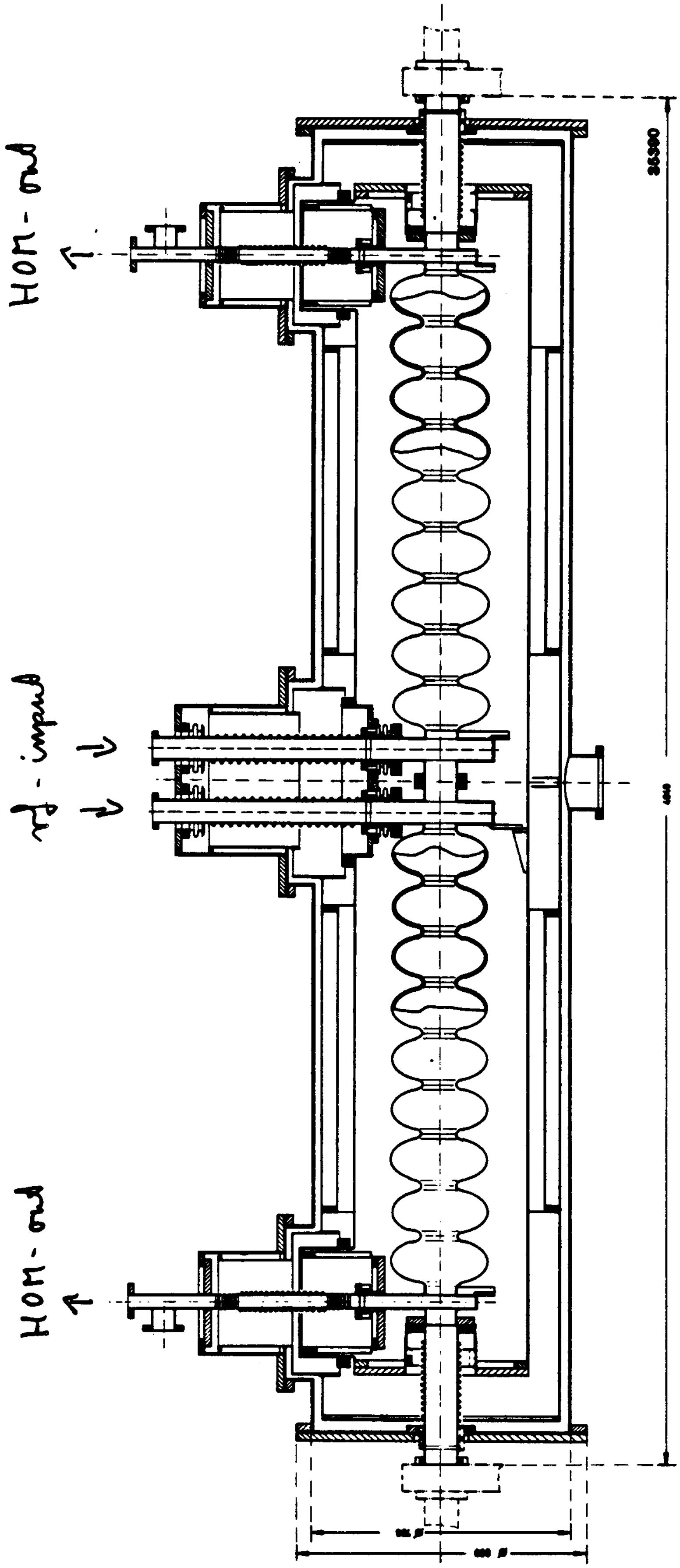

Fig.: 1

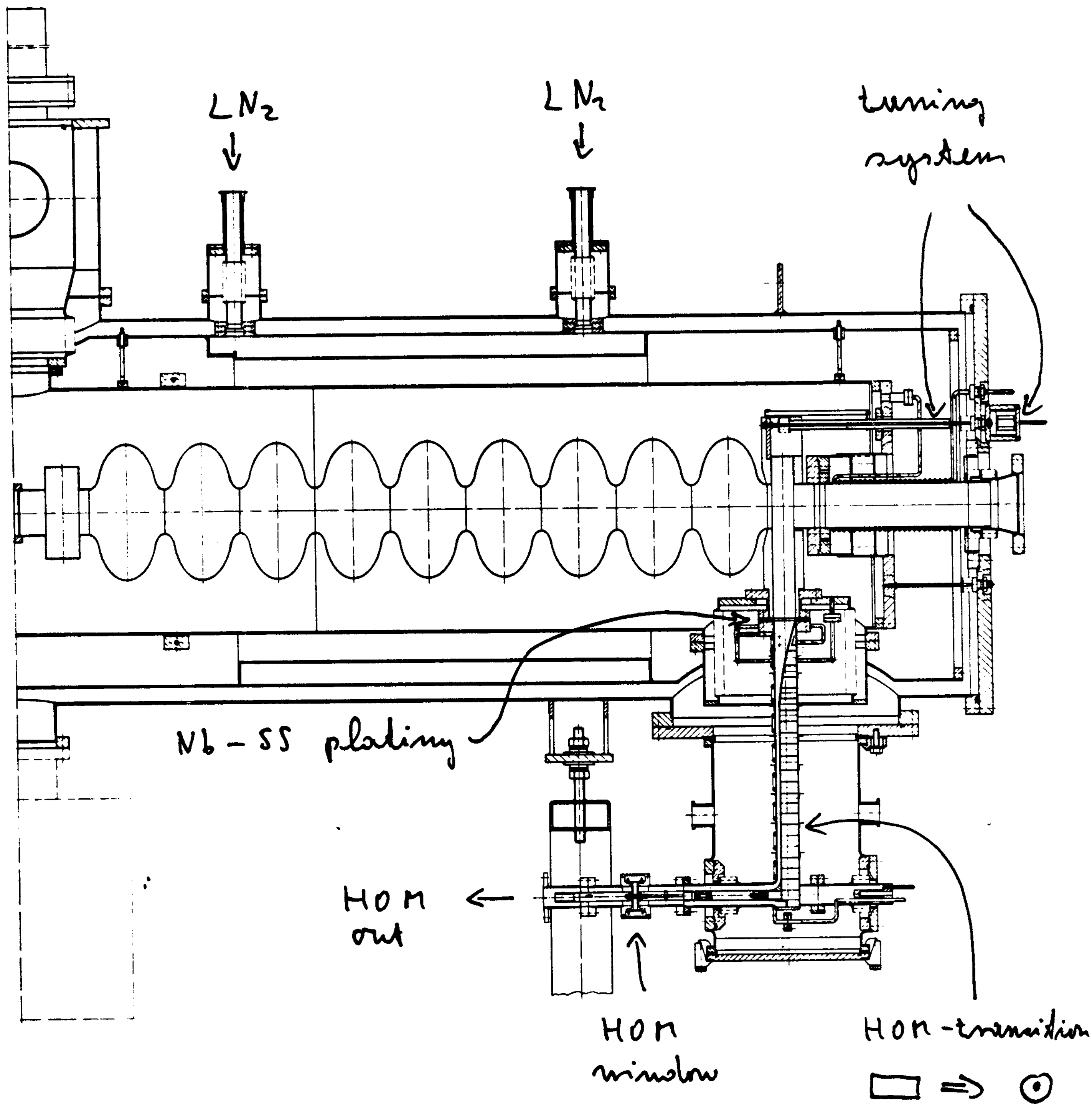
LN2
LN2
tuning system
Nb – SS plating
HOM out
HOM window
HOM-transition

Fig. : 2

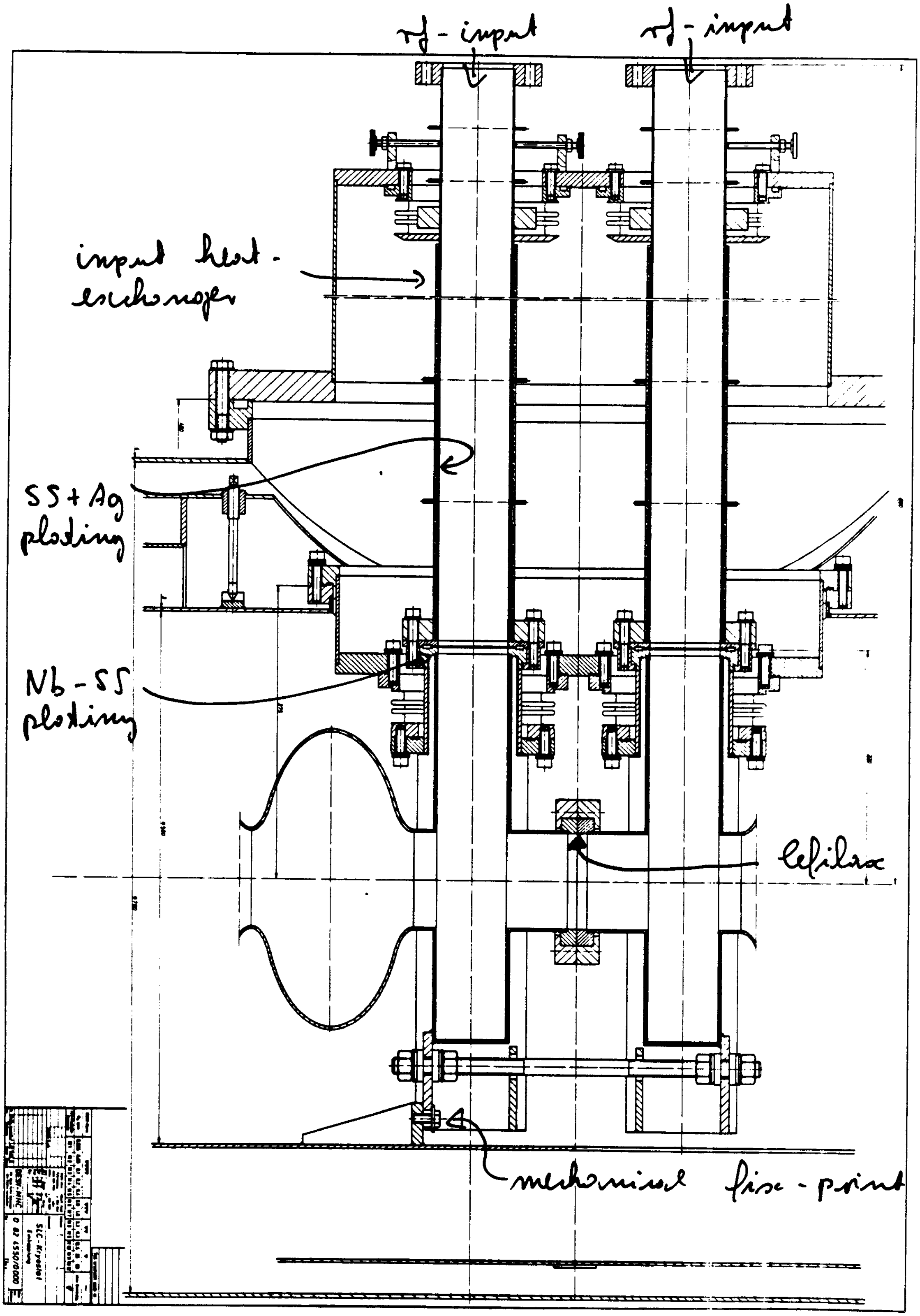
rf - input
rf - input
input heat-exchanger
SS + Ag plating
Nb - SS plating
mechanical fix-point

Fig.: 3

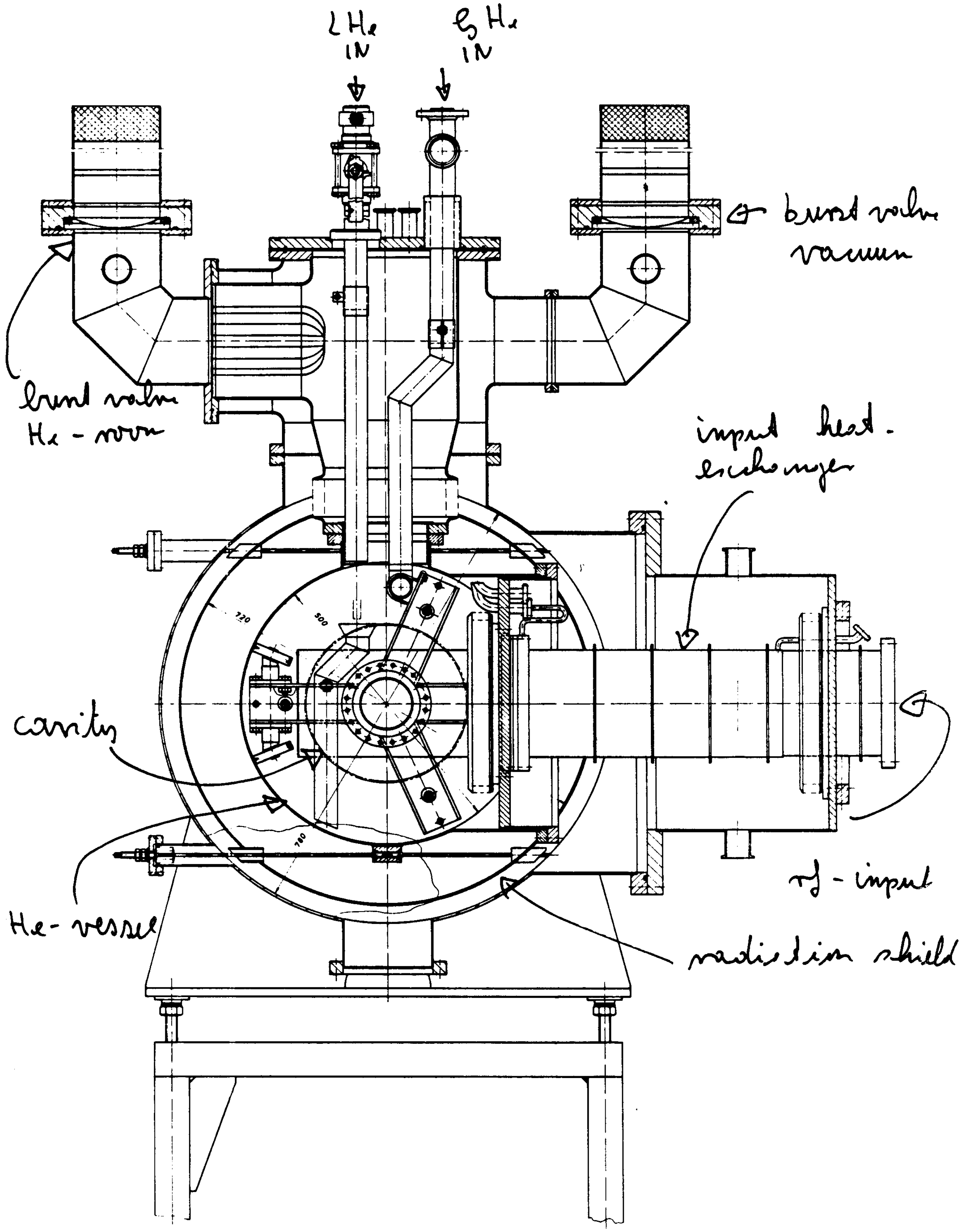
LHe IN
GHe IN
burst valve vacuum
burst valve He-room
input heat-exchanger
720
500
780
cavity
rf-input
He-vessel
radiation shield

Fig.: 4

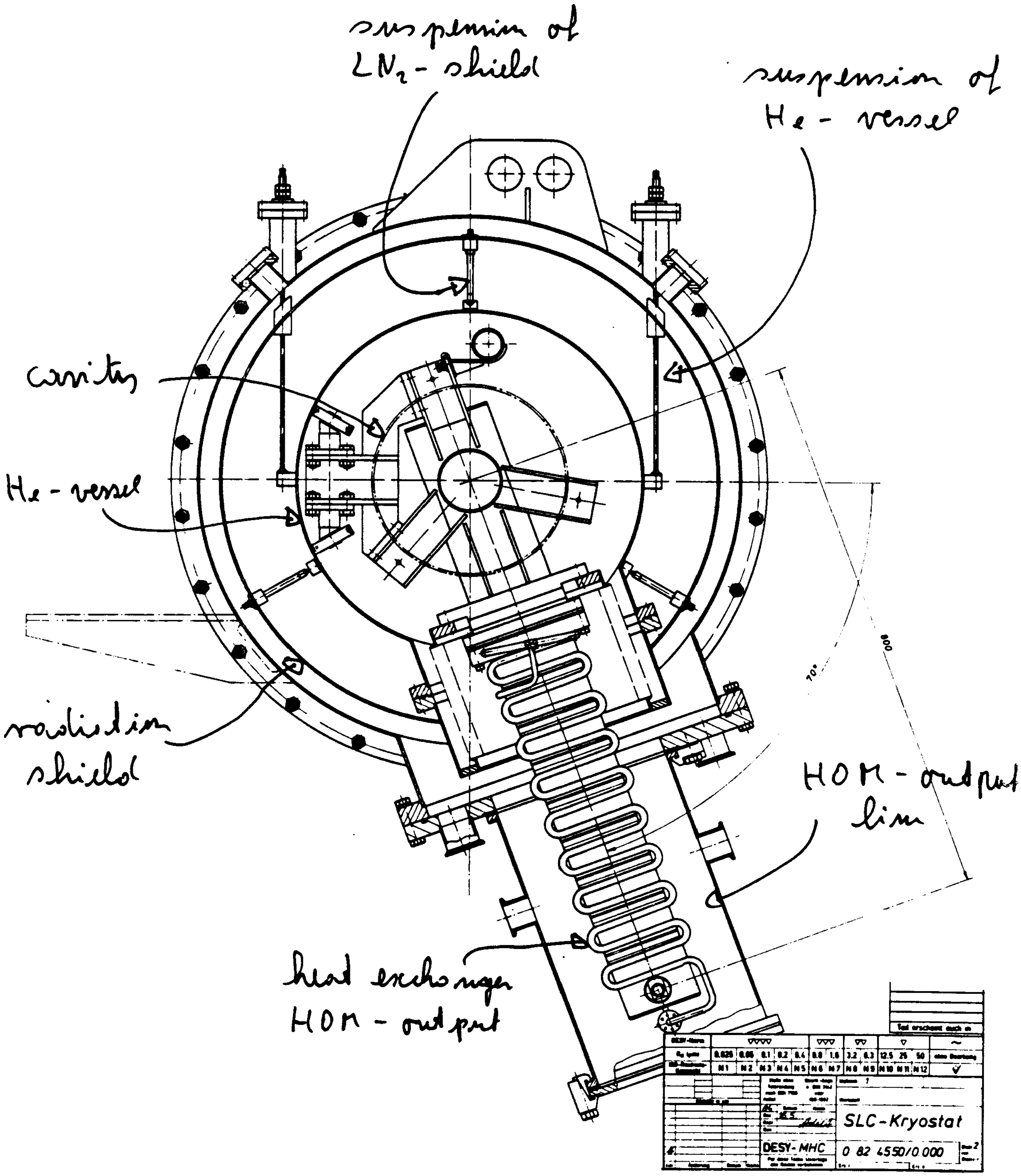
suspension of
LN2 - shield
suspension of
He - vessel
cavity
He - vessel
radiation
shield
HOM - output
line
heat exchanger
HOM - output
70°
800
SLC-Kryostat
DESY-MHC
0 82 4550/0.000

Fig.: 5

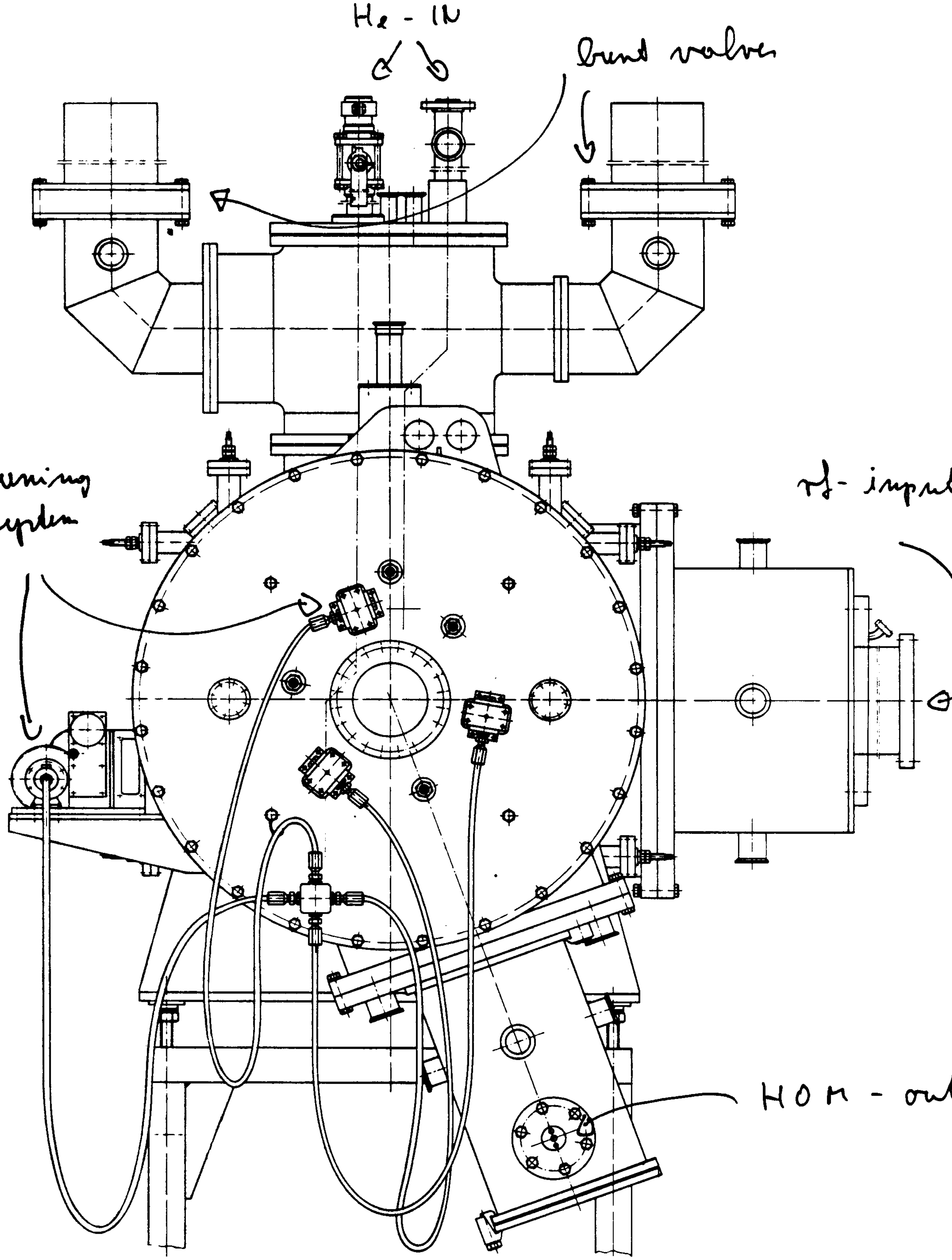

Fig.: 6

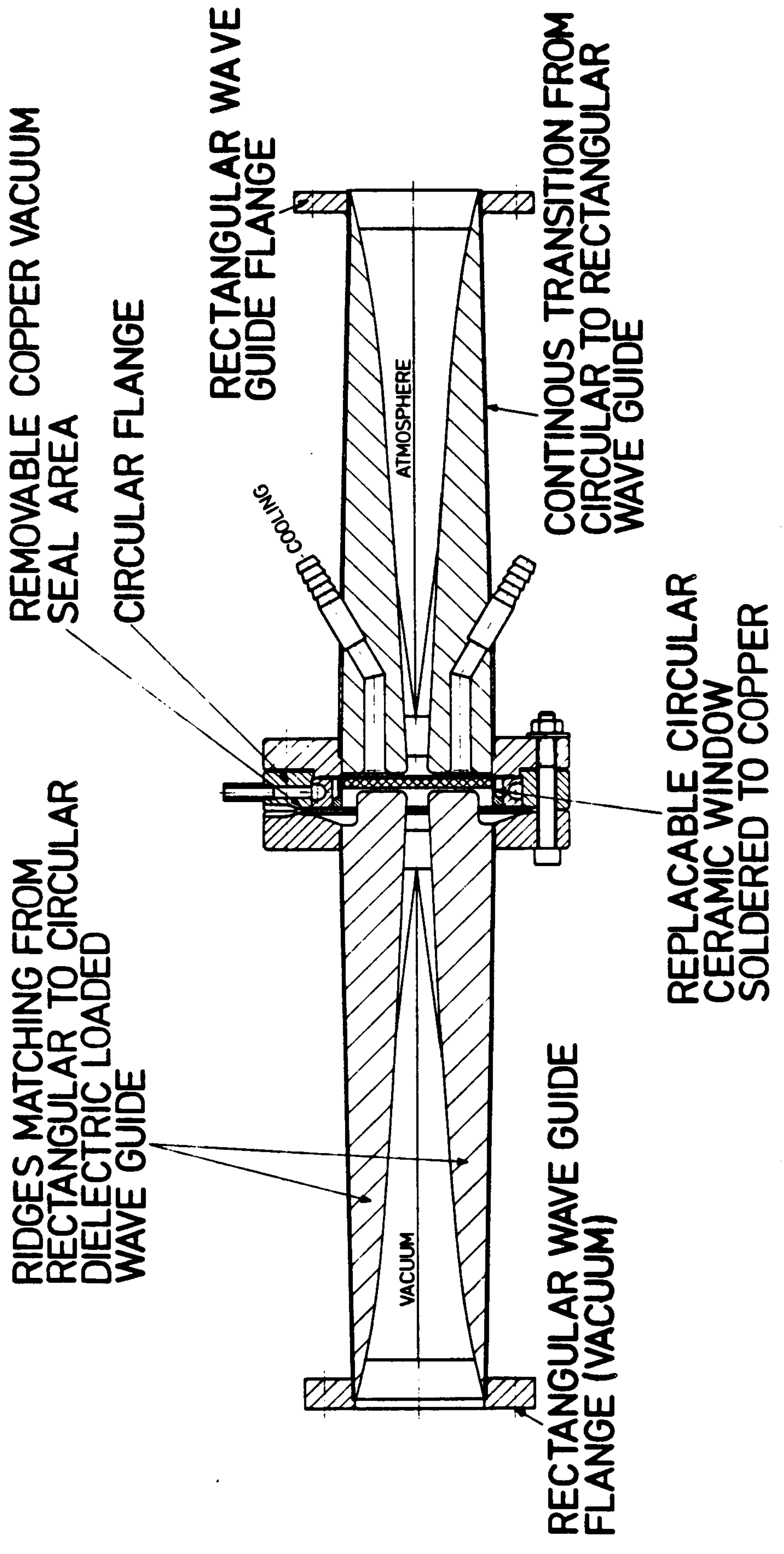

FIG.7 BROADBAND WAVE GUIDE R.F. POWER FEED WINDOW

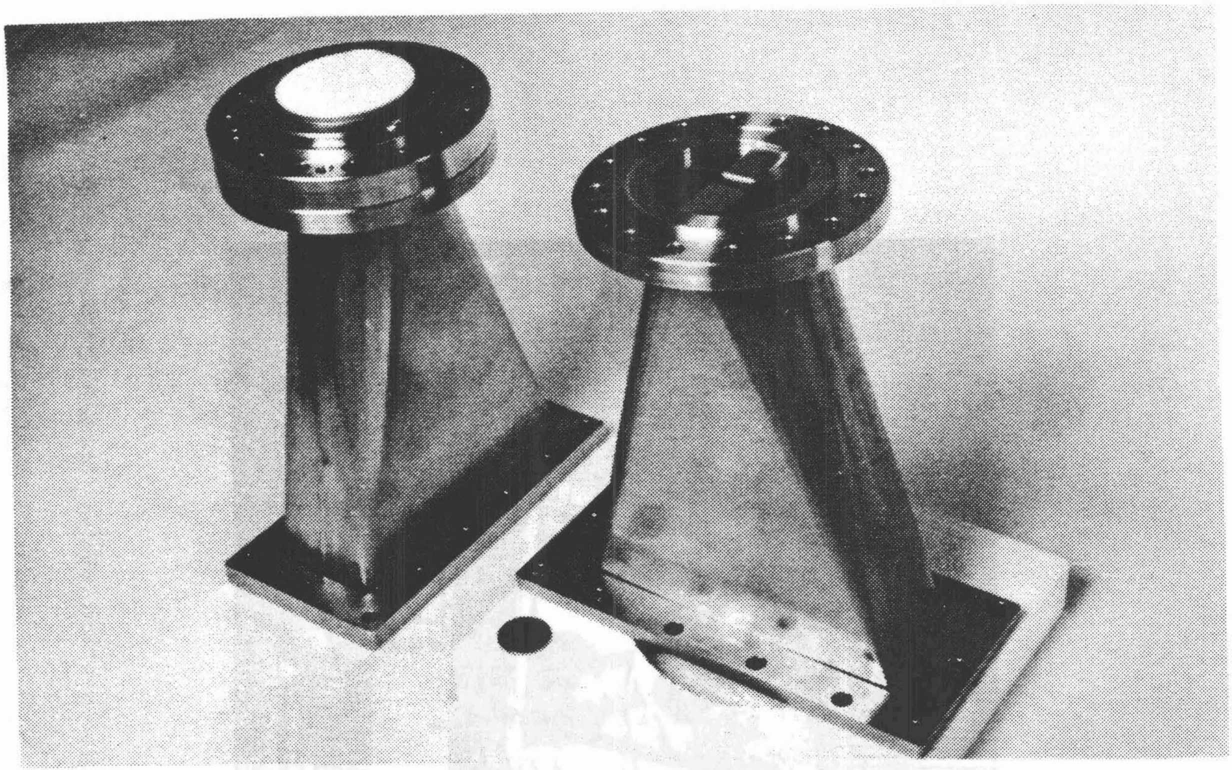

Fig. 8

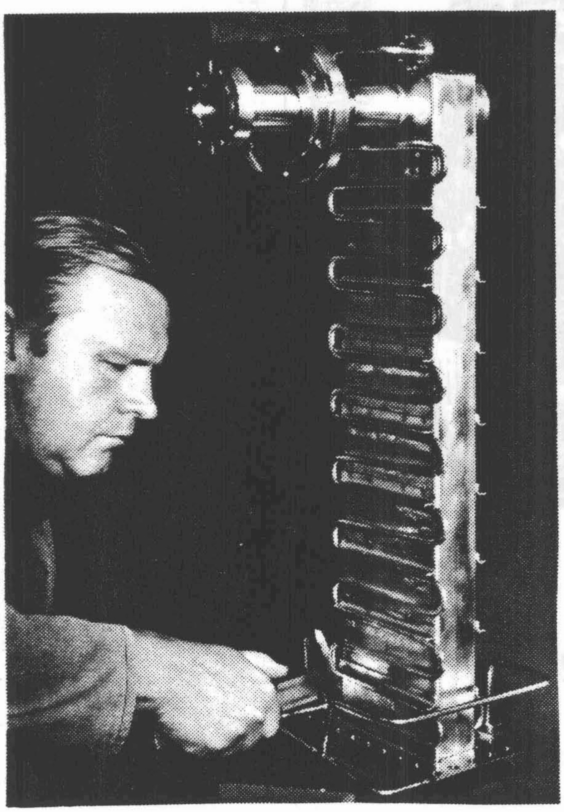

Fig. 9

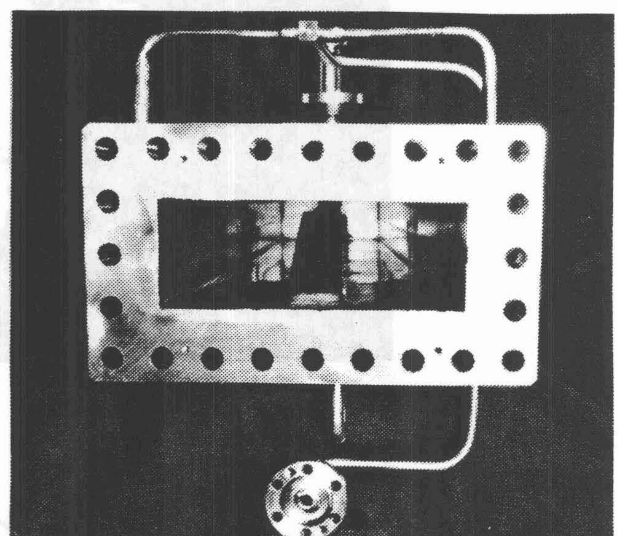

Fig. 10

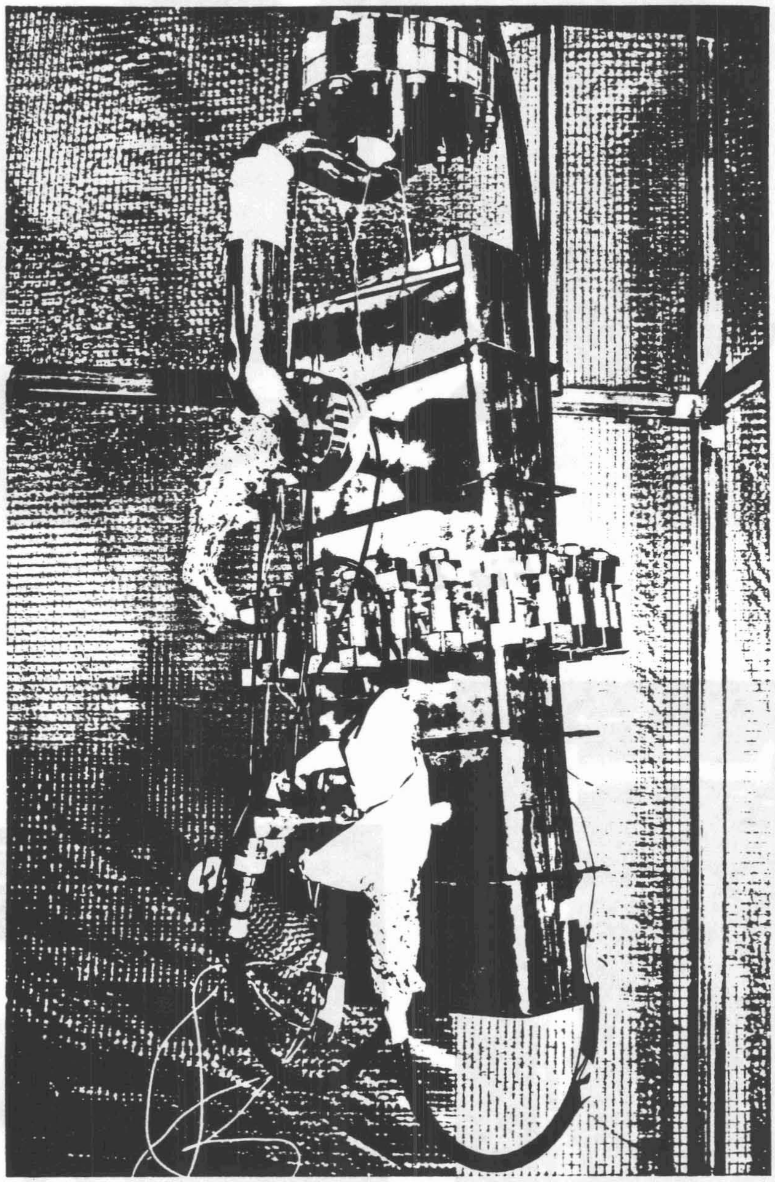

Fig.: 11

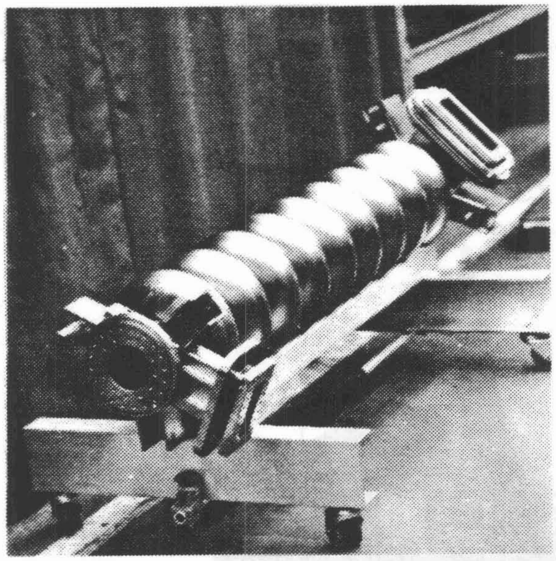

Fig.: 12

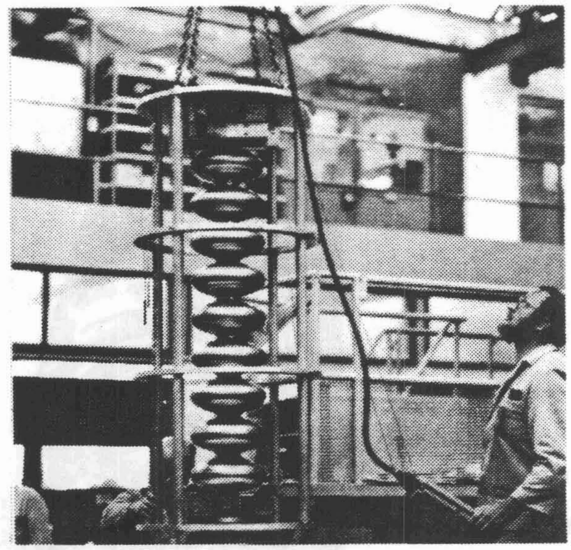

Fig.: 13

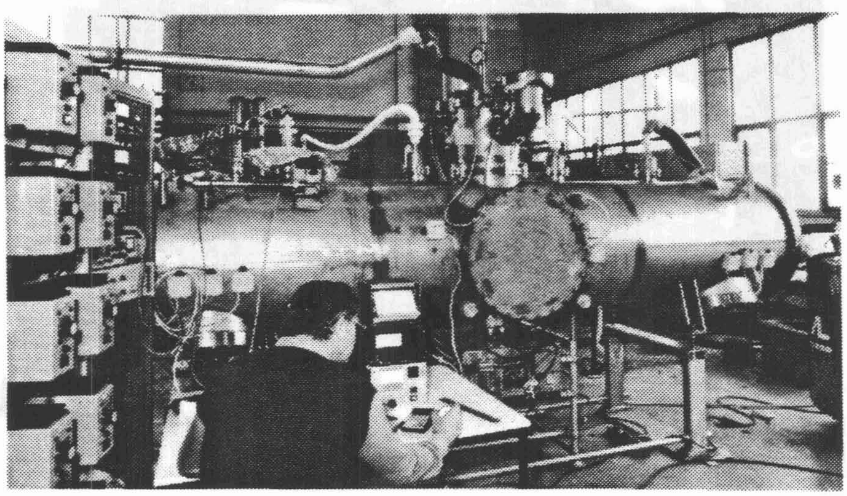

Fig.: 14

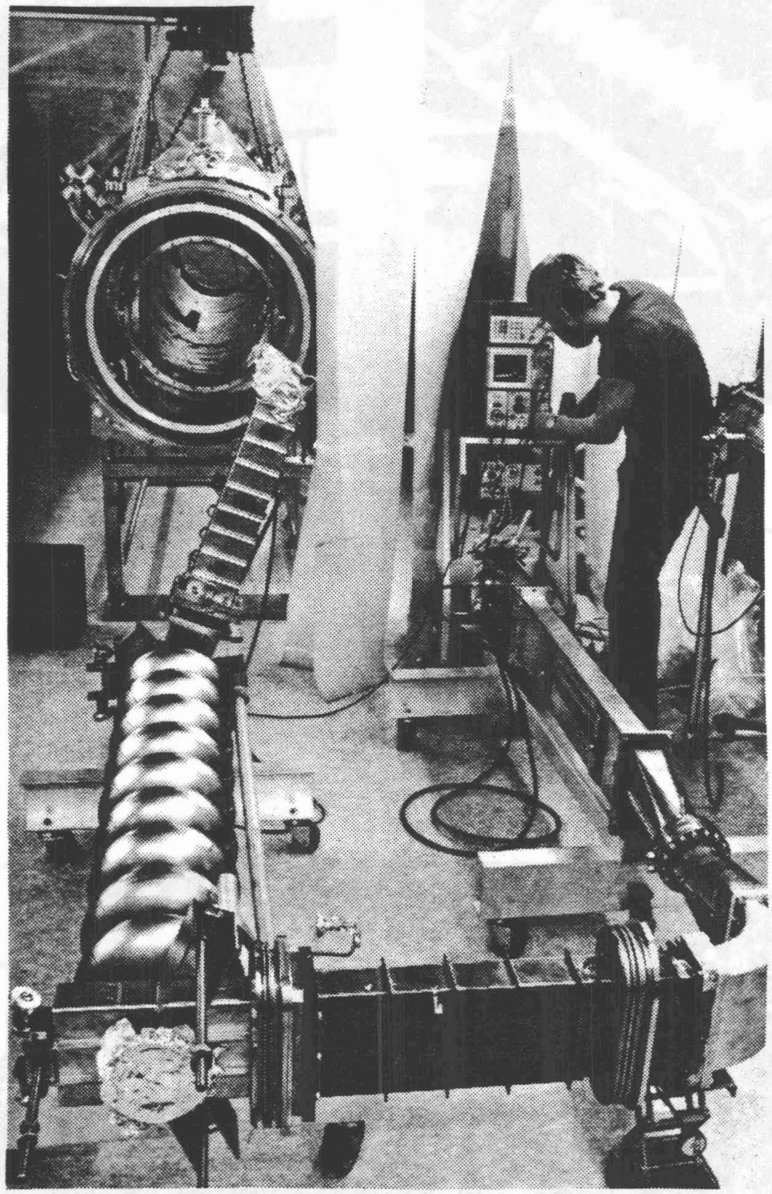

Fig.: 15

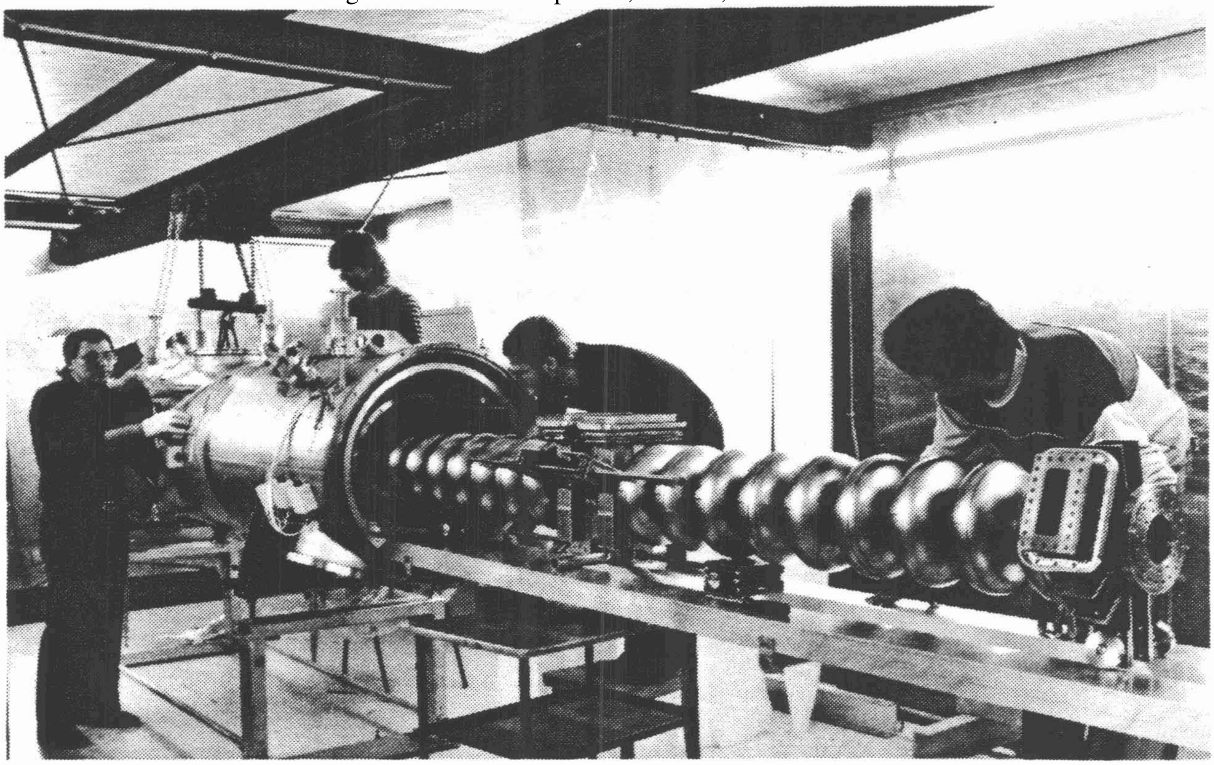

Fig.: 16

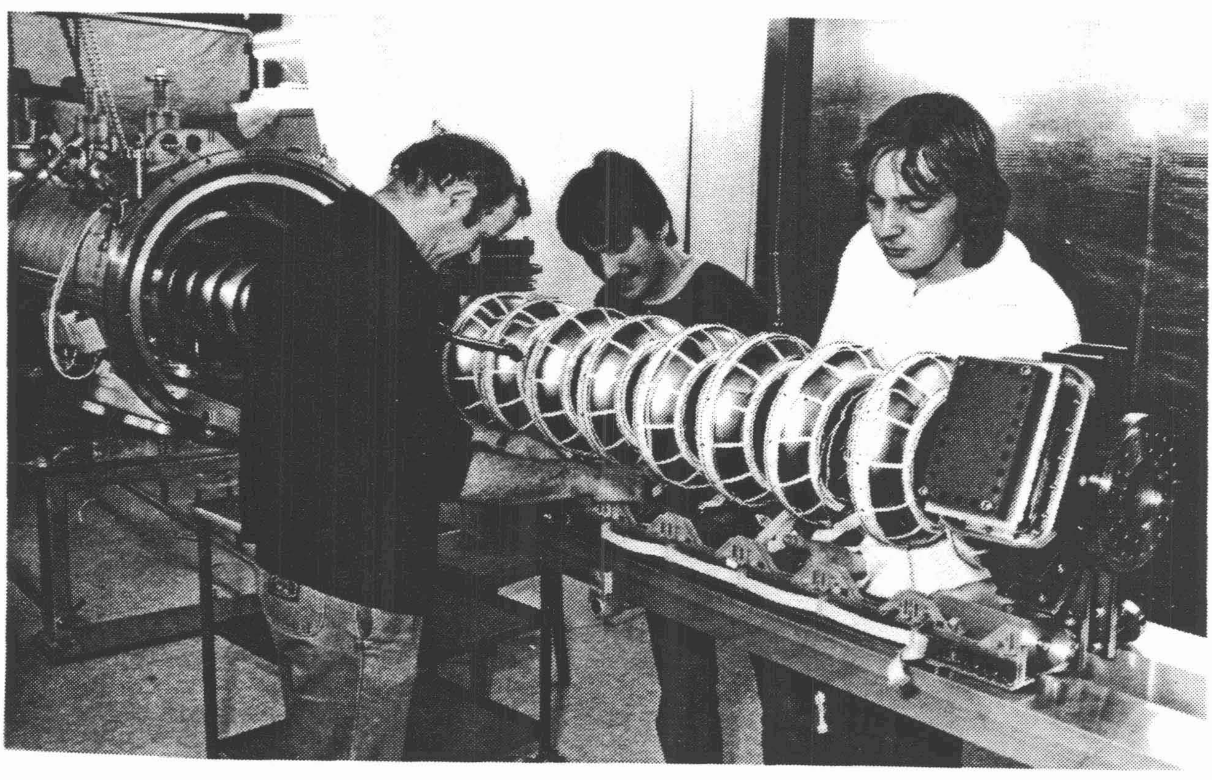

Fig.: 17