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CRYOGENIC AND ELECTRICAL TEST CRYOSTAT FOR INSTRUMENTED SUPERCONDUCTIVE RF CAVITIES (CHECHIA)

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ABSTRACT

This facility has been designed to carry out cryogenic RF quality factor (Q_{RF}) measurements, cold tuner tests, high order modes coupler tests, main coupler tests and full RF tests of superconducting cavities under real accelerator conditions (pulse mode, feedback loops, etc). The cryostat is built to receive one horizontally positioned cavity equipped with its helium vessel, its tuner and various RF couplers. The maximum heat load is ≈ 58 W (2.5 g/s) at 2 K for high power peak processing and ≈ 6 W (0.25 g/s) under normal conditions. Q_{RF} will be obtained from heat load measurements by LHe level variation and gas flow measurement at known temperature and pressure. The calibration is given by a DC electrical heater. The paper describes the design and the preliminary results of cryogenic performance tests of the cryostat itself.

INTRODUCTION

The cryostat is built to receive a 9 cell cavity fully equipped with its welded helium vessel, main coupler, HOM couplers and cold tuner before final assembly of 8 cavities together in the TTF (Tesla Test Facilities) cryomodule.

It will allow measurement of cavity performances, tuning range, accuracy and speed of the cold tuner, depending on bath pressure variations and Lorentz forces action in the cavity.

It may also allow a more detailed study of RF electron trajectories and X ray production, due to surface emitters.

In this simplified layout the quench behaviour of cavities at high fields can be studied and first tests on the handling of quenches and adequate protection systems can be performed, involving not only RF signals, but also the bath pressure and cavity vacuum.

MAIN FEATURES OF THE CRYOSTAT

The vacuum vessel made of mild steel is equipped with a large hinged cover, giving full access for the cavity assembly. All connections are placed close to the cover (input coupler, helium supply vacuum pipe and cabling).

Two thick aluminum shields, one cooled at 77 K with liquid nitrogen, the second at 4.5 K with liquid helium insure the thermal insulation of the cavity (fig 1).

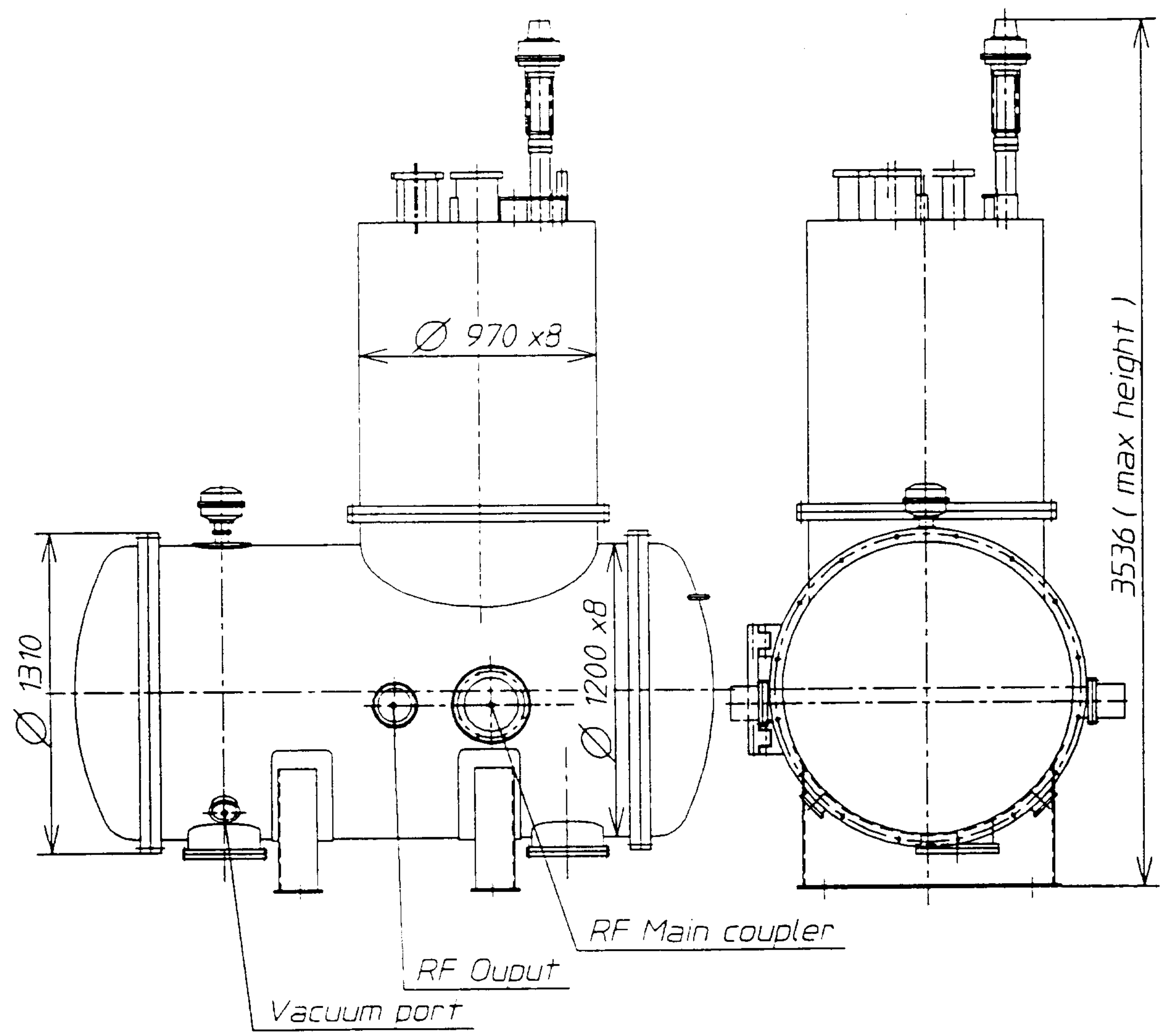

Figure 1. Outside view of the cryostat

The cavity is fixed on a bench supported by two insulating posts. Each post has two intercepts one at 4.5 K and one at 77 K.

The cryogenic equipment is placed in a vertical turret . All components are easily accessible by lifting the vacuum turret sleeve (fig 2 & 3).

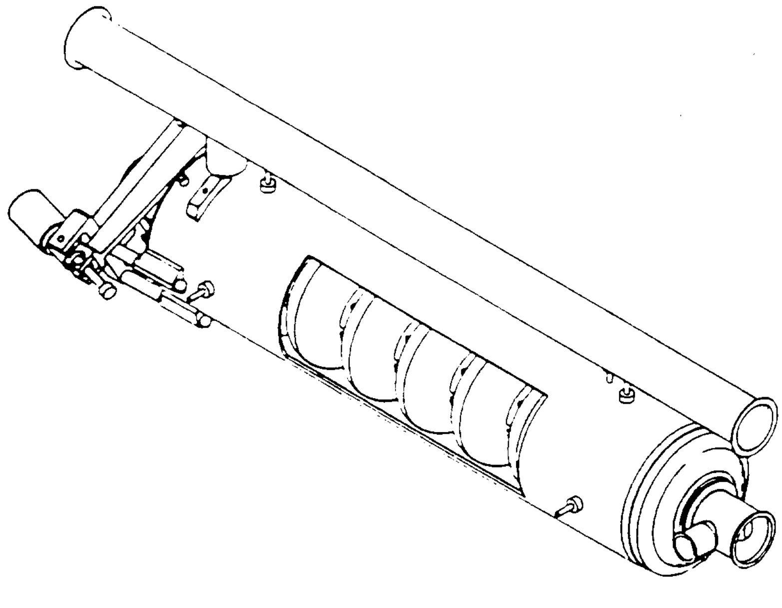

Figure 2. Dressed RF cavity, with cold tuning system.

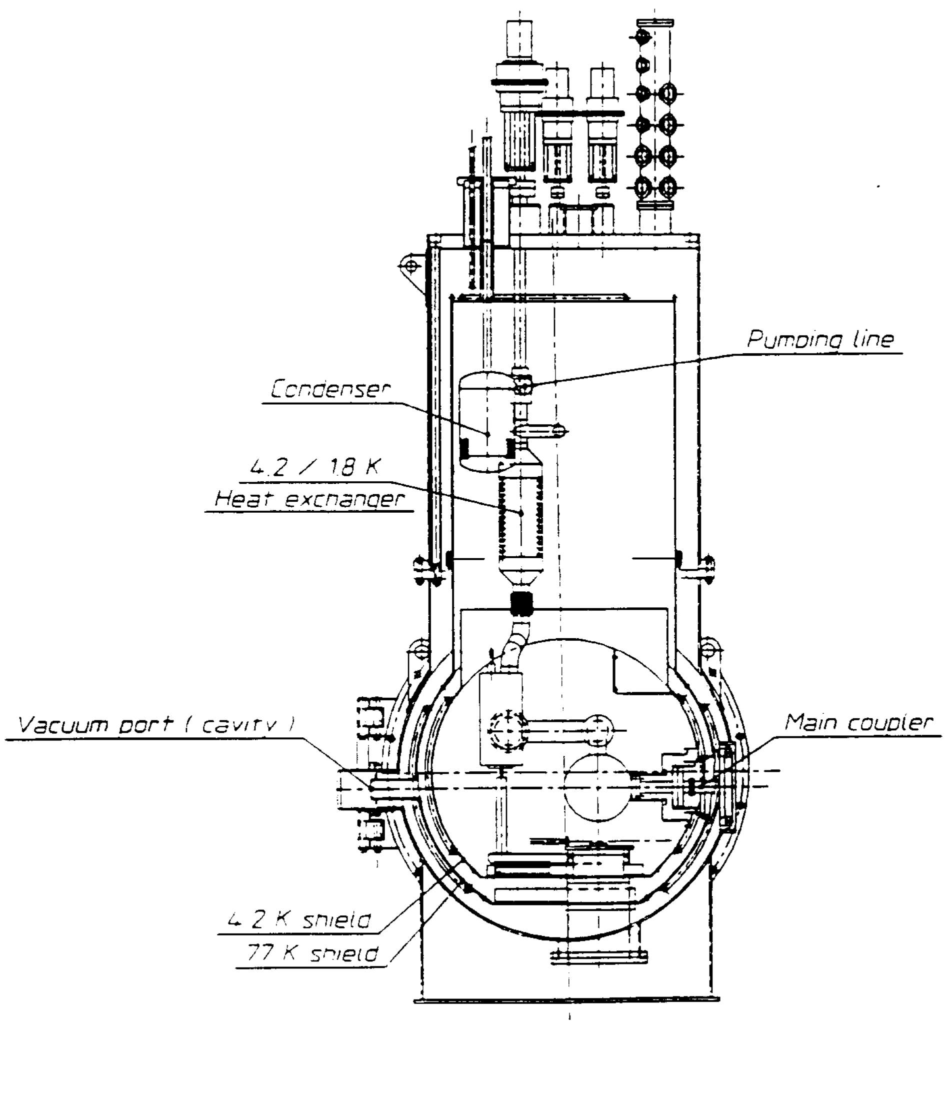

Figure 3. Cross section of the turret.

Table 1. Main characteristics of Chechia

Item	Unit	Value
Length	mm	2 612
Height	mm	3 536
4.5 K shield dimensions	mm	Ø 954 x 1850
Design pressure		
1.8 K section	bar abs	2
4.5 K section	bar abs	3
77 K section	bar abs	3
Heat consumptions		
1.8 K section	g/s	0.012
	W	0.28
	l/h	0.29
4.5 K section	g/s	0.49
(including transfert line)	W	9.9
	l/h	14.25
4.5 K shield temperatures		
Temperature inlet	K	≈ 4.5 K
Temperature outlet	K	≈ 6.5 K

CRYOGENIC FLOW CHART

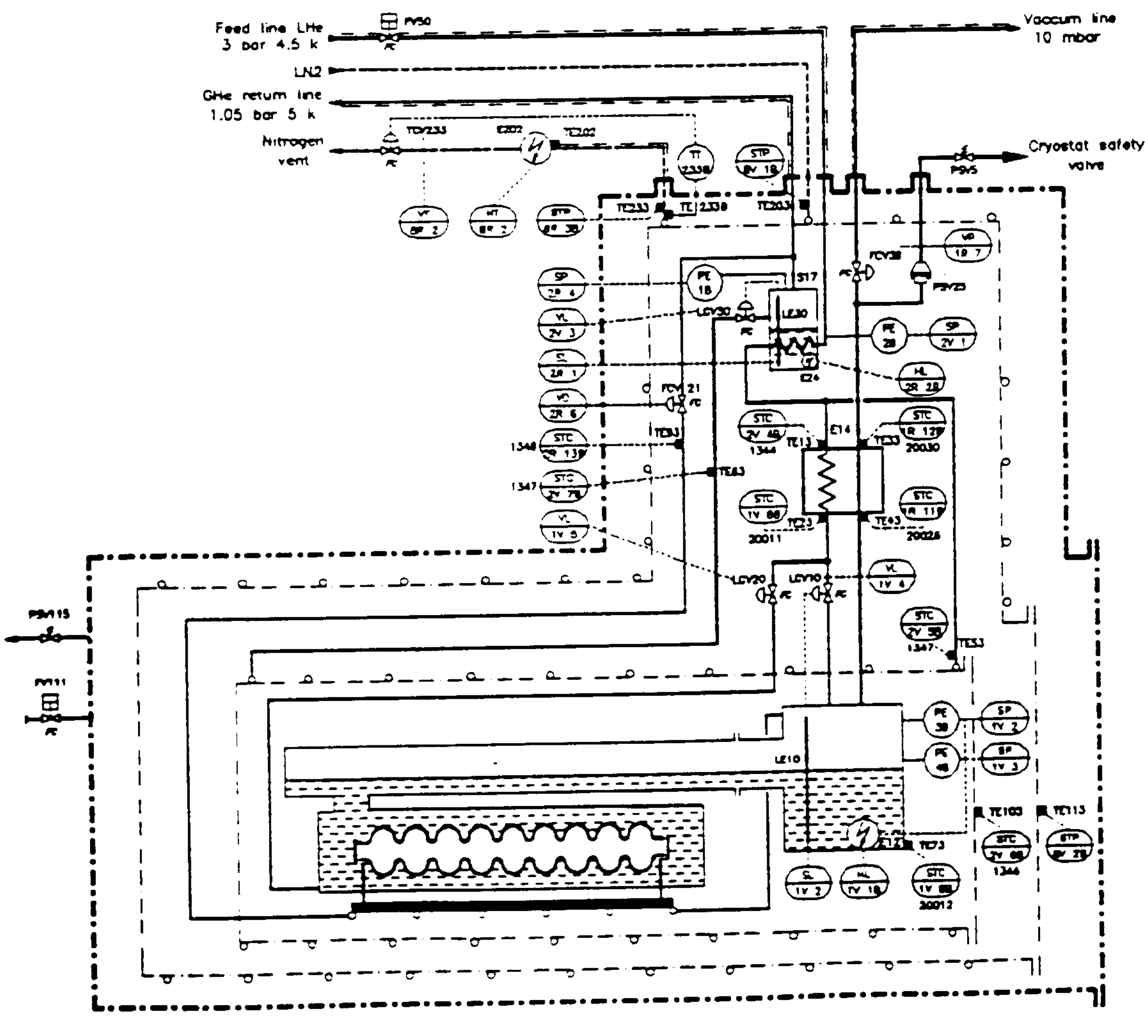

Figure 4. General flow chart of CHECHIA.

The flow schematic for CHECHIA is shown in fig. 4.

The helium is supplied by a 4.4 K/900 W refrigerator at a pressure of about 3 bars and a temperature of 4.4 K.

Before being expanded into the two phase volume, the mass flow is passed through the 5 K heat shield. After having absorbed the heat load of the shield, the helium returns at about 5K to the condenser inlet and expands through the valve LCV 30. The vapor is returned to the refrigerator or to the helium recovery circuit (fig. 4).

From the liquid phase of the condenser a flow of about 2.5 g/s is forced into the heat exchanger where it is subcooled to about 2.2 K by means of the 2 K vapor return flow from the cavity helium vessel.

The final pressure in the cavity will be 16 mb at 1.8 K, after expansion through the Joule-Thomson valves LCV 10 and 20.

Table 2. Instrumentation

Sensors	Quantity	Type
Thermometers		
HOM	2x2	Carbon sensor RIVA®
Main coupler	2	»
Spare	5	»
He vessel		
Shields		
J.T. valves	1	Carbon sensor RIVA®
Pumping line	1	»
Cold tuner	2	»
Heater (2 K circuit)	1	»
Level sensors		
2 K sump	1	SC wire sensor
2 K sump	1	»
Pressure sensors		
1.8 K circuit	1 + 1	WIKA® MKS®
4.5 K circuit	2	WIKA®

UTILIZATION OF THE CRYOSTAT

Cavity performance measurement.

The aim is to measure a few points of the curve Q_{RF} versus accelerating field. As the input coupler will not have the right coupling coefficient, cryogenic measurements have to be done to determine the heat load at 2 K with and without RF.

The Q_{RF} input power is simulated by an electrical heater placed in the 2K sump.

The goal is to reach an accuracy of ≈ 0.4 W which means that the static heat load has to be at most about 4 W.

Two methods will be used:

1. For a steady liquid level, one measures the flow rate out of the cryostat. A good accuracy is expected in measuring the pumped helium gas flow, with mass flow meters, provided the measurement is made during sufficiently long time.

2. With no helium flow in, one measures the liquid helium level change. To increase the accuracy, the level probe is installed in the 2 K sump. This container is placed higher than the cavity vessel which can be kept full of helium during the measurement. The cross section of the sump is small enough to amplify the level variations.

High peak processing treatment.

The HPP technique offers the possibility of cleaning up residual emission. Controlled exposures that test the survival of the benefits of HPP will be carried out to establish a protocol for the assembly of cavities. The helium consumption at 2 K will then be much higher than under normal RF processing. A compromise has been set at 2.5 g/s for the maximum helium flow at 2 K, corresponding to 58 watts.

RESULTS

Determination of Q_{RF} with the flow meters.

Two mass flow meters are used, one covering the range of 0 - 1 g/s and the second the range of 0 - 20 g/s.
Equivalent Q_{RF} input is computed from the voltage on the heater. The flow was measured for various values of Q_H input power. The steady flow is obtained after 1 hour stabilization. For 1 watt after integration of the flow-meter signal during 1 hour, the precision is better than ≈ ±0,2 W in the range of 20 to 40 watts of input power.

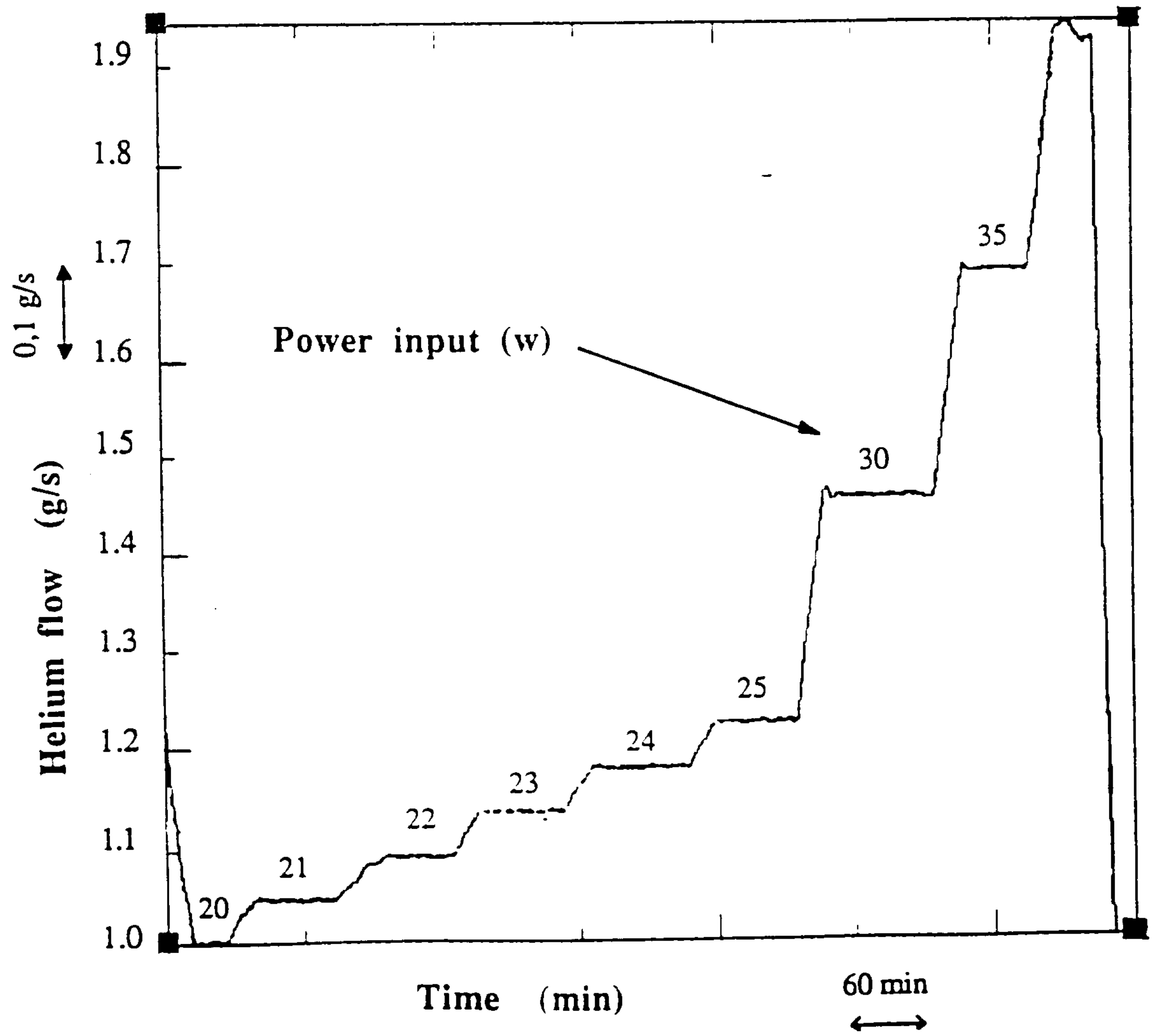

Figure 4. Flow measurements function of Q_H input (computed), with mass flow method

If a calibration is made before the test of the cavity, an accuracy of ≈ ±0.1w can be reached.

Determination of Q_{RF} with level difference

The level is measured with a superconducting sensor in the sump, the internal diameter is 150 mm.

The precision of level measurement is ≈ 1 mm over a height of about 80 mm, which gives an accuracy better than ≈ ±0.2 w (over 4 mn). This measurement requires no additional calibration.

Table 3 - Measurement of Q by level difference at 1.8 K

Q input (w)	0	1	2	18	34
Total evaporated He flow (g/s)	0,012 (1)	0,053	0,095	0,82	1,48
Corrected flow (g/s)		0,042	0,084	0,81	1,47
Q measured (w)		0,97	1,95	18,2	34,2

(1) Static losses

The precision of this method is altered by the decrease of heat losses coming from the piping when the input power increases.

CONCLUSION

Both mass flow and level difference measurements can reliably be used to determine the Q_{RF} values. The accuracy of mass flow measurements depends on the calibration before the tests. The level difference method gives a better accuracy in the low range values (0 - 10 watts).

REFERENCES

1. A proposal to Construct and Test Prototype Superconducting R.F. Structures for Linear Collider, DESY/Hamburg, April 1992.
2. Tesla Test Facility Linac - Design Report, March 1995, TESLA 95-01.