CRYHOLAB, A HORIZONTAL CAVITY TEST FACILITY: NEW RESULTS AND DEVELOPMENT

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Abstract

In the framework of super conducting RF cavity R&D for high intensity proton LINAC (XADS, EURISOL …) the IPN Orsay CEA-Saclay collaboration is developing five-cell (700 MHz, β = 0.65) cavity for the high energy section of the LINAC. A first prototype, previously tested in vertical cryostat, has been equipped with a stainless steel 316 L helium vessel and tested in the horizontal facility « CRYHOLAB » at 2K. The cryogenic installation of « CRYHOLAB » is now fully integrated and the cryostat is directly feed from a 120 l/h helium liquefier. After a short overview of the cavity horizontal tests results the cryogenic installation developments and performances will be presented .

INTRODUCTION

The different operations on the 5-cell cavity (chemical etching, field flatness adjustment and heat treatment against Q-disease) were performed and an accelerating gradient of 16 MV/m was reached in vertical cryostat test for the cavity without its helium tank. After this first stage the cavity was equipped with its helium vessel and tested in vertical and horizontal cryostats. These experiments validate the cavity RF design [1] and technological manufacturing choices. It also permit to stand the cryogenic performances and operations modes of “CRYHOLAB” in its final configuration.

CAVITY MEASUREMENTS

RF Measurements

After the field flatness tuning and the various chemical treatment operations the cavity was first tested in vertical cryostat . A slow cooling test showed the Q-disease effect limiting the Q0 to around 8 108 A heat treatment at 650° C was then performed and proved to be efficient with a measured Q0 of around 4 10^{10} for both slow and fast cooling tests.
The different measurements in vertical and horizontal cryostat are summarised in figure 1. All the tests shows, as it was already seen with the A 105 mono-cell prototype, a multipacting barrier around 10 MV/m.
A not yet understood phenomenon [2] was observed during all the different tests in vertical and horizontal cryostat. During the tests a reflection of a part of the incident power at the entrance of the cavity and a limitation of the accelerating field was observed and was not connected to known limitation causes.
This effect takes place at 15 MV/m in vertical cryostat tests and 8 MV/m in horizontal cryostat.

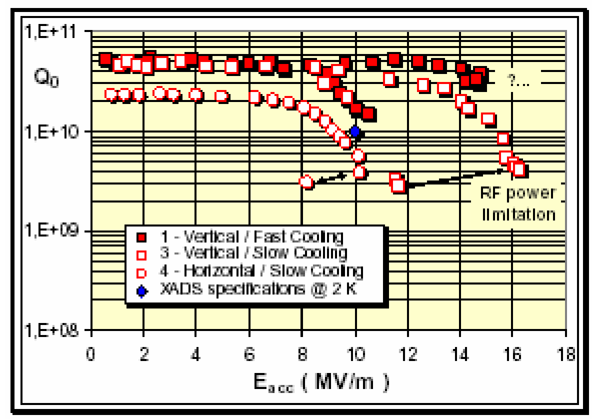

Figure 1: RF Characteristics.

A way to bias this phenomenon was to switch off the RF for a rather important amount of time, around two minutes depending on the accelerating field, between two data points. It was then possible to measure in vertical cryostat (curve 3) an accelerating field of 16 MV/m with a RF power limitation due to electron emission. In horizontal cryostat it was not possible after various RF processing to pass the multipacting barrier (curve 4).
Investigation on this limiting phenomenon is under progress

Technological Choices

Technological choices on the type of the cavity flanges and the material of the vessel tank were made.
The use of Conflat flanges for the beam tubes and pick -up apertures was motivated to prevent risk of leak on helicoflex / Niobium flanges jointing assembly [3]. The knives must be machined on forged 316 LN rough-machined flange after being brazed with copper on niobium sleeve tubes.
The flange on our 5-cells cavity are tight but the draw back is that copper is attacked by acid during the chemical operations which implies a very accurate protection of the brazed joint to avoid leaks formation.

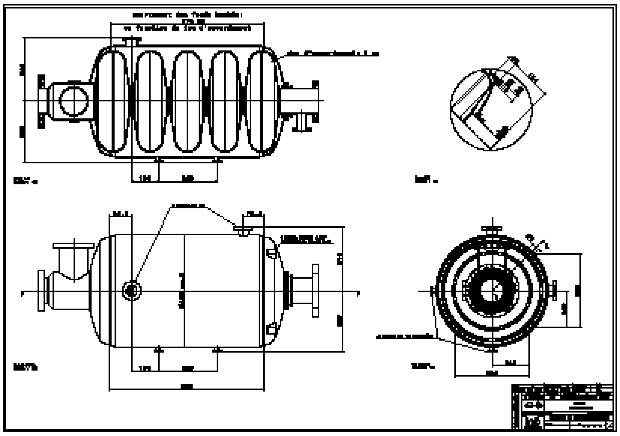

Figure 2: Helium vessel design.

The use of stainless steel brazed on Niobium with copper instead of EB welding titanium for the helium tank was also chosen to reduce the cost (total price below 10 keuros) and increase the mechanical stiffness of the cavity/helium vessel structure. 316 L stainless steel was used and the effects of ferromagnetic transitions during TIG welding were not observed during the test in vertical cryostat (with and without the cylindrical part of the vessel) for a Q0 value of 4.5 10^{10}.

CRYHOLAB PERFORMANCES

General Cryogenic Layout

The main improvement of the CRYHOLAB installation [4] is the connection to the former MACSE accelerator liquefier. The main features of the cryostat and its associated equipment are described figure 2.
The cryostat and the 20 m long helium feeding line (3) are shielded at 80 K with liquid nitrogen supplied from a 5000 litres LN2 container. Two buffers, 200 litres and 80 litres, outside (4) and inside (7) the cryostat, acts as phase separator and prevent from over pressure inside the cryostat LN2 circuit during the transitory feeding operations. The helium feeding line (3) shielding temperature and the LN2 buffers level are regulated by mean of a set of cold stop valves.

A 80 litres liquid helium buffer (10) is feed from a 2000 litres dewar (1) connected to the liquefier cold box (2). This buffer feeds the different helium circuit of the cryostat : the power coupler cooling loop (5), the support table cooling circuit (8), the cavity loop for the cooling down operation (6) and the cavity feeding buffer (11) for the 4 K and 2K stationary operations.
To reduce the flash losses in 2 K operations a sub cooling heat exchanger (9) cools the helium I to around 2.3 K before the JT pressure reduction valves (12).

The cryostat buffer level is regulated with a regulation valve (13) to reduce the flash losses during helium feeding. Two JT valves (12) (20 W and 70 W at 2K) regulate the cavity buffer level. In 2 K operation the bath pressure is regulated by controlling the speed of the pumping group (14) with a pressure stability better than +/- 1 mbar. A finer regulation is performed by mean of a heater situated in the cavity buffer (11).
In 4 K operations the helium return gas is directly sent to the clean helium capacities (15).

In 2K operations the gas coming from the cavity cooling volume is routed from the pumping group exhaust to the helium storage

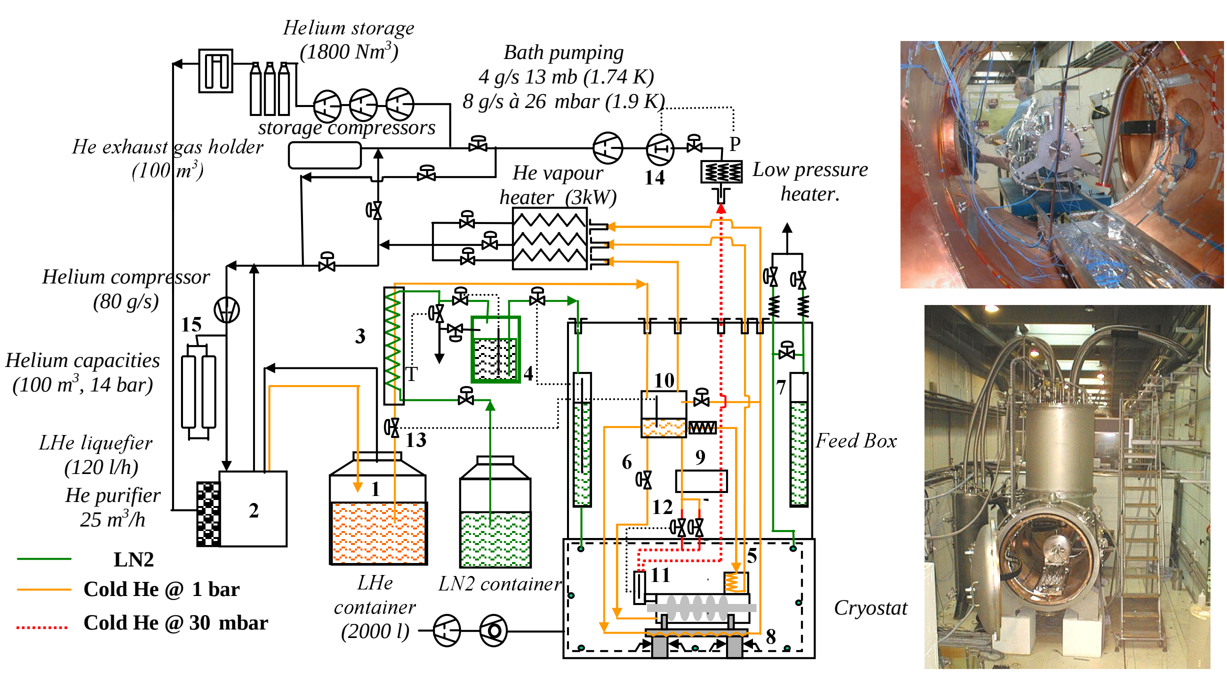

Figure 3: Cryogenic Installation.

Operation Modes

Operation with 500 litres dewar is possible but causes exploitation difficulties (the process is not fully computer aided) during the week end days-off as the total consumption in static operation (without RF power) is around 14 l/h .

Two experiments in liquefier modes were performed, one for 2 weeks and the second for 3 weeks. After the first experiment the liquefier was stopped with the 2000 litres dewar filled to keep the cold box in a clean helium gas atmosphere. After 2 weeks the liquefier was rerun without problem for the second experiment.

The cryogenic installation, initially designed to feed the MACSE accelerator, is able to handle at least the 80 W @ 2 K power required for the cavities tests.

Important leaks in the pumping group causes pollution and lead to operate the installation in an hybrid configuration where the helium gas coming from the pumped bath is not routed to the cycle gas loop. The installation cryogenic power is then limited, for long term operation at 2K, by the He purifier initially designed to compensate small leaks. A three weeks long experiment, with several intermittent operations at 2K, showed that the 2000 litres liquid helium container used as liquid buffer and the helium gas buffer capacities were enough to handle the unbalance between small clean helium gas production and peak losses (RF on) during 2 K operations.

The liquefier production, in static operation (RF off), was reduced to around 80 l/h but remains higher than the cryostat and feeding lines losses (~ 30 l/h). Balancing the liquefier production and the cryostat consumption can be performed by regulating the 2000 litres LHe container level with a heater situated inside the cryostat buffer .

The cavity bath pressure at 4 K is around +/- 20 mbar when routing the gas toward the pure gas capacity and +/- 1 mbar when returning the gas to the exhaust gaz holder. A pressure regulation valve is for seen to allow cavity tests at 4 K with closed loop operation.

At the level of the liquefier cold box the O2 and H2O analysers were not sufficient to control the cycle gas purity. A N2 mass spectrometer was added and revealed to be mandatory for our specific installation.

Cryostat Operation Times

After the cavity installation inside the cryostat, the helium tubing rinsing and the pumping of the cryostat insulation vacuum was done during one working day.

The LN2 parts of the cryostat were cooled during two days (week end days-off) leading to a shield temperature of 80 K and cryostat cold parts and cavity temperature of around 200 K. From this stage 200 litres liquid helium were used during 2 hours to start feeding the main liquid helium buffer with liquid.

A quasi stationary state was obtained after 12 hours.

At the end of the experiment the warming up of the cryostat was achieved after 4 days.

Cryogenic Performances

The power consumption of the different parts of the cryogenic installation established using level measurements and gas meters are presented in table 1.

Table 1: Measured static losses.

	Liquefier mode	500 l dewar mode
80 K loops		
Feed Box (T=4K) Main buffer + coupler loop + support table loop	<8 W/11.5 l/h	<5 W /6.6 l/h
Cavity + cavity buffer	<4 W/5.7 l/h	<2 W/2.8 l/h
Feeding losses	<10 W/14 l/h	<3 W/4 l/h
Total	<22 W/31 l/h	<10W/14 l/h

CONCLUSIONS

These first experimental results show good RF performances, above the XADS specifications. They validated the several intermediate preparation procedures (field flatness tuning, chemical etching, high pressure rinsing, thermal treatment at 650 °C against Q-disease) and the horizontal test facility “CRYHOLAB”. The use of stainless steel for the helium tank is reinforced but further studies can be done about the Niobium/SS brazing solution leading to an improvement of the protection of the copper brazed joint or the use of gold instead of copper to prevent risks of leak formation during chemical preparation.

Further analysis is to be done to understand the unknown phenomenon limiting the accelerating gradient.

The next steps will be to test the cavity equipped with its Cold Tuning System and its power coupler into “CRYHOLAB”.

REFERENCES

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