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A CRYOGENIC TEST STATION FOR SUBCOOLING HELIUM HEAT EXCHANGERS FOR LHC

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Abstract

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1 INTRODUCTION

The superconducting magnets of the LHC [1] under construction at CERN will be cooled at 1.9K by distributed cooling loops working with saturated two-phase helium, and supplied with cold supercritical helium. In order to minimise the vapour fraction produced in the final expansion, counter-flow heat exchangers will be needed.

These 250 subcooling heat exchangers will be integrated in the cryogenic distribution lines [2] so that a high reliability as well as good efficiency are expected. Prototypes of different technologies have been selected. Their qualification for the series production is depending on the results of cryogenic tests at their nominal and low-flow operating conditions carried out in CEA-Grenoble where a dedicated test station was set up, in the frame of collaboration between CEA and CERN for the construction of LHC. This papers describes this test facility and gives first results.

2 LHC SPECIFICATION

To fulfil CERN specifications, the heat exchangers must comply with constraints on dimensions, thermal efficiency, and pressure drop in the very low pressure stream.

2.1 Thermodynamics.

The heat exchanger has to operate at full capacity in nominal operation mode, as well as at low capacity in reduced operation mode. In steady-state operation, with the inlet conditions specified, the heat exchanger has to fulfil the functional requirements [3] listed in Table1.

2.2 Pressure drops.

For any operation modes, on the VLP stream, the pressure drop must remain below 100Pa. This restrictive specification is imposed by the pumping facility and is the obliged condition to guarantee the temperature of 1.9K [4] in the LHC magnets. Concerning the HP stream, the maximum pressure drop in any operation modes must not overtake 20kPa.

Table 1 Steady-state operation modes

Process Interface			Operation mode	
Location	Condition		Nominal	Reduced
Supercritical inlet	Pressure	[kPa]	240 to 360	240 to 360
	Temperature	[K]	4.9	4.9
	Flow	[g/s]	4.5	1.5 to 4.5
Very low pressure inlet	Pressure	[kPa]	1.64	1.64
	Temperature	[K]	1.8	1.8
	Flow	[g/s]	4.5	1.5 to 4.5
Supercritical outlet	Temperature	[K]	≤ 2.20	≤ 2.20
Very low pressure outlet	Temperature	[K]	≥ 3.38	≥ 3.38

3 THE TEST STATION

3.1 Description

The design of the test station must permit to check all these operation modes. Figure 1 shows the process flow diagram of the test station composed of a cryostat, pumps and screw compressor. In order to test the subcooling heat exchangers at their nominal and reduced operating conditions, supercritical helium at 0.36MPa and 4.9K is produced in the high pressure (HP) stream by passing through counter flow perforated plates heat exchangers HX1 and HX2 [5]. Cooling down of this HP stream is also improved by exchange in a nitrogen bath at 80K and in the 4.5K helium bath. At the outlet of this helium bath the temperature is adjusted with an electrical heater in order to control a temperature of 4.9K at the inlet of the subcooling heat exchanger. At the outlet of the heat exchanger, the HP stream is expanded in a Joule Thomson control valve which regulates the level of 1.8K superfluid helium bath. A by-pass is needed on the HP side to perform cool-down of this heat exchanger.

The very low pressure cold gas from 1.8K helium bath is pumped through the subcooling heat exchanger and a 15kW heater by a roots pump in series with an oil ring pump. This heater was developed by CERN and produces very low pressure drop (less than 100Pa for a 20g/s mass flow at 1.8K).

The low pressure circuit starts from the 5000l helium tank which fills in the 4.5K helium bath in the cryostat allowing the cooling of the supercritical flow thanks to a coiled heat exchanger; then the vaporised gas is returning to the inlet of the screw compressor, exchanging enthalpy with the HP circuit in heat exchangers HX1 and HX2.

The mass flow varying between 1.5 and 4.5g/s is created by an electrical heater located in the 1.8K helium bath. The standard operation of this test station consists in remaining this heating power constant, while the level regulation of the 1.8K helium bath is performed by the Joule Thomson control valve. In order to reduce heat losses, the 4.5K ring shaped bath and the 1.8K bath are concentric.

The 80K thermal shields are actively cooled by liquid nitrogen. This nitrogen cooling loop ensures a fast cool-down.

The heat exchangers are tested one by one, but the design of the cryostat allows easy access to the heat exchanger to be tested so that only one day is necessary before next exchanger can be tested.

The heat exchanger is connected with Kenol flanges. The instrumentation is linked to the cryostat and therefore, the same sensors are used for all the tests.

3.2 Instrumentation.

Temperature: At each end of the heat exchanger to be tested two temperatures measurements are installed. The first one measures the temperature of the pipe, the second one the temperature of the fluid. The accuracy is about +/- 0.05K .

Pressure: on the supercritical side at the inlet of the heat exchanger pressure is monitored thanks to a pressure transmitter working at very low temperature.

Differential Pressure: measurement is done at room temperature with the help of a pressure transmitter whose accuracy is 0.1%.

Mass flow is monitored via a thermal flow metre on the HP stream. In order to be sure that flows is identical in each stream of the heat exchanger to be tested, the level of the 1.8K bath is kept constant.

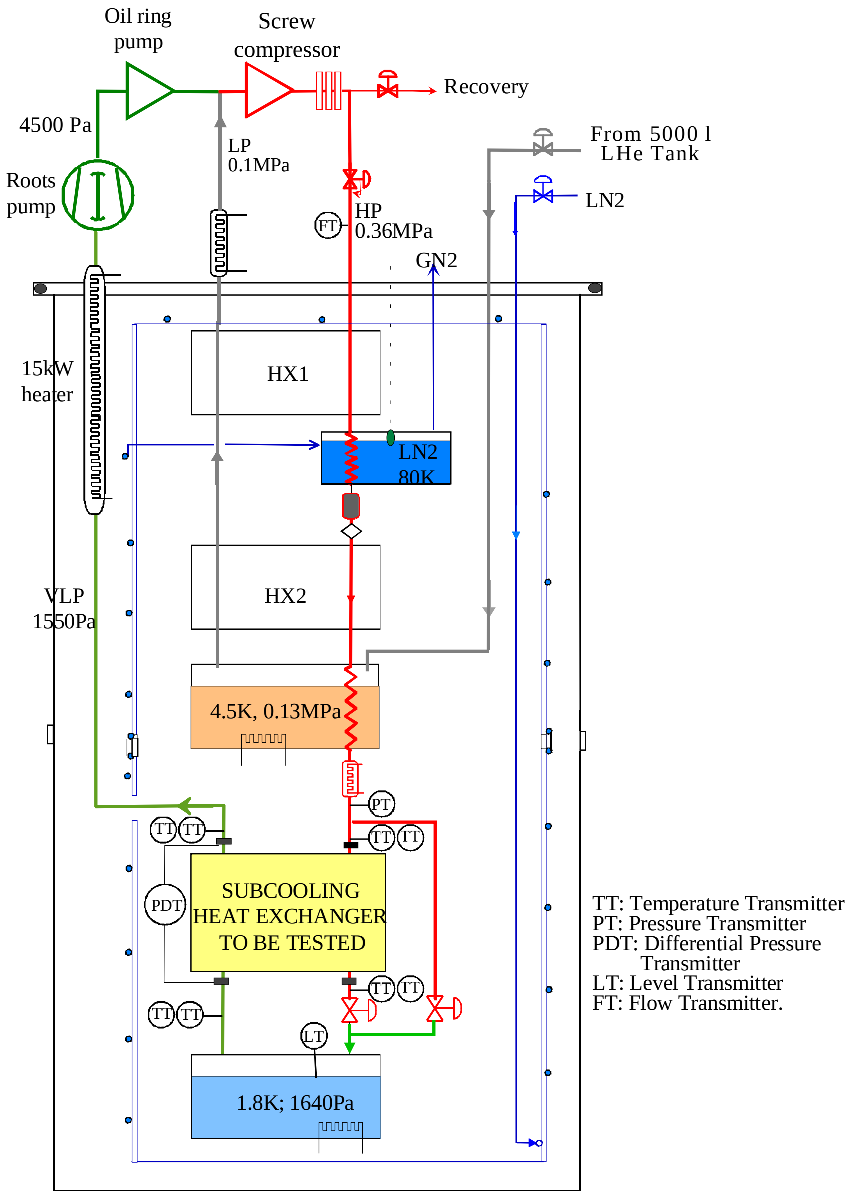

Figure 1 Process flow scheme of the test station

3.3 Uncertainty.

Taking into account the accuracy of measurement sensors, we have performed calculations of its influence on the performances of the subcooling heat exchanger.

For instance, concerning thermometers, a difference of +/- 1% which corresponds to +/-0.05K on the inlet of heat exchanger on the HP side, would involve a mistake of +/- 1.1% on the calculation of the heat exchanger efficiency. Consequently, it seems that the accuracy of temperature measurements allows an acceptable estimation of the performances of the subcooling heat exchangers.

The stability of the liquid helium bath at 1.8K must be carefully monitored. Indeed, this parameter ensures that heat exchanger to be tested is perfectly balanced, with identical flows in each stream, HP and VLP. Taking into account the geometry of the 1.8K vessel, and the superconducting level gauge indications, we know that a level variation of 0.5% per minute represents a mass flow unbalance in the heat exchanger of 0.13g/s which is 3% of the nominal flow.

4 PUMPING FACILITY

4.1 Roots pump skid.

The characteristics of the Roots pump are as follows: for nominal operation mode: mass flow 4.5g/s, inlet pressure 1250 Pa, outlet pressure 4300Pa. For ultimate performance: 18g/s, inlet pressure 5700Pa, outlet pressure 15,5kPa. This roots pump is equipped with a variable speed drive unit which regulates the temperature of the 1.8K helium bath.

4.2 Oil Ring Pump.

This pump can deal with a 4.5g/s mass flow at 4000Pa inlet pressure and recover it at atmospheric pressure. This oil ring pump has been under operation in CEA-grenoble for several years. Its integration in the cryogenic test facility has requested the set up of a new process control system.

5 FIRST RESULTS

Four suppliers were selected by CERN and asked to provide two identical prototypes subcooling heat exchangers, to be tested at their nominal working point in the test station. Indeed, CERN's requirement was to verify the reproducibility of production as well as the technical specification in view of a series. Several technologies were proposed and some have already been tested in the cryogenic test station.

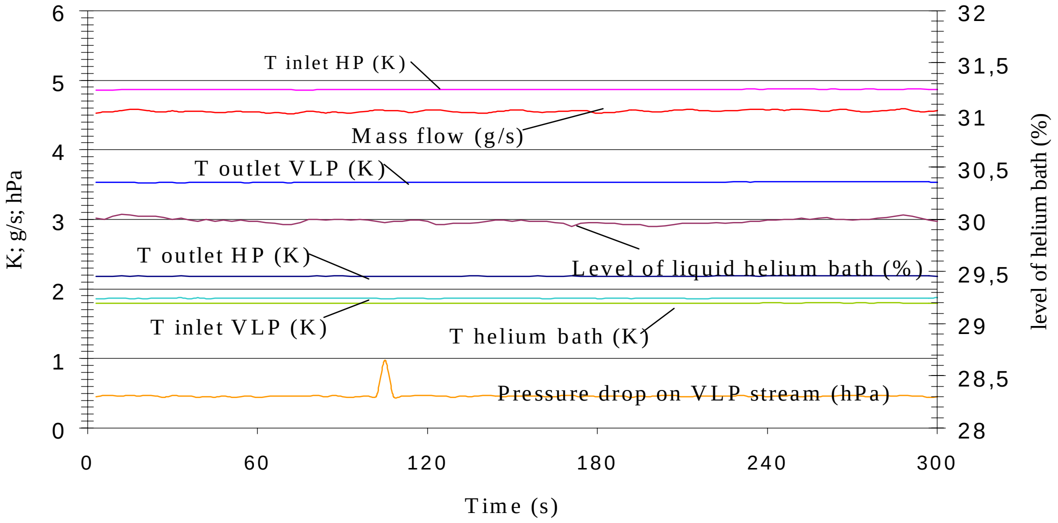

Figure2 Measurements during tests of prototype heat exchanger

6 CONCLUSION

These first results have demonstrated the capacity of this test station to perform tests at nominal and low-flow condition. Several prototypes of heat exchangers have already been tested in 1999. Other tests will continue in 2000. This test facility is dedicated to test one heat exchanger over ten of the 250 subcooling heat exchangers needed for LHC.

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