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TEST RESULTS OF A 1.2 kg/s CENTRIFUGAL LIQUID HELIUM PUMP FOR THE ATLAS SUPERCONDUCTING TOROID MAGNET SYSTEM

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The toroid superconducting magnet of ATLAS-LHC experiment at CERN will be indirectly cooled by means of forced flow of liquid helium at about 4.5 K. A centrifugal pump will be used, providing a mass flow of 1.2 kg/s and a differential pressure of 40 kPa (ca. 400 mbar) at about 4300 rpm. Two pumps are foreseen, one for redundancy, in order to feed in parallel the cooling circuits of the Barrel and the two End-Caps toroid magnets. The paper describes the tests carried out at CERN to measure the characteristic curves, i.e. the head versus the mass flow at different rotational speeds, as well as the pump total efficiency. The pump is of the "fullemission" type, i.e. with curved blades and it is equipped with an exchangeable inducer. A dedicated pump test facility has been constructed at CERN, which includes a Coriolis-type liquid helium mass flow meter. This facility is connected to the helium refrigerator used for the tests at CERN of the racetrack magnets of the Barrel and of the End-Cap toroids.

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Test results of a 1.2 kg/s centrifugal liquid helium pump for the ATLAS superconducting Toroid Magnet System

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INTRODUCTION

A detailed description of the liquid helium cooling scheme of ATLAS magnets can be found in [1]. The high mass flow and head, which are necessary to cool the toroidal magnets of ATLAS is provided by a 1.2 kg/s centrifugal pump, which has to be qualified before the installation at the ATLAS experimental site. The liquid helium pump is required to produce a differential pressure of about 400 mbar (40 kPa) at a nominal mass flow of 1.2 kg/s. In order to measure both the characteristic curves and the pump efficiency, a dedicated test facility has been designed and constructed at CERN.

Figure 1. Photo of the test facility

TEST FACILITY DESCRIPTION

A picture of the pump test facility designed and constructed at CERN can be seen in Figure 1 and the corresponding flow scheme in Figure 2. The 600 litre vertical dewar is connected to a 1.2 kW @ 4.5 K refrigerator, which can maintain the liquid helium at constant level. The dewar and all the interconnecting cryogenic transfer lines are with superinsulation (MLI) and no active thermal shield. Liquid helium is withdrawn from the bottom of the dewar, maintained around 1.25 bar, and is directed to the inlet of the pump. In the pump cryostat a by-pass pipe, with an on-off electro-pneumatic cryogenic valve, allows for the cooling of the downstream part of the installation. The pressure head, provided by the pump, is measured by means of a differential pressure transducer placed between its inlet and outlet port. Each circuit connected to the pressure transducer is provided with an additional small volume in order to prevent any thermo-acoustic-oscillation. The liquid helium mass flow is measured by means of both a cryogenic Coriolis [2] mass flow meter and a Venturi mass flow meter installed in series. The latter was installed since it was not known whether the vibrations introduced by the centrifugal pump could somehow interfere with the resonant oscillating system used in the Coriolis mass flow meter. No mutual interference was detected during the extensive measurements and the output signal was always prompt and very stable. The required variable hydraulic impedance of the circuit was achieved by throttling a cryogenic electro-pneumatic valve, installed downstream of the Venturi flow meter and just before the return line towards the vertical dewar. In order to measure the heat load of the complete system with the pump at rest, and in particular from the dewar and back to it through the pump, including the above mentioned measuring devices, a resistive heater (max. 500 W), was installed to initiate and maintain a thermosyphon-driven circulation of the liquid helium. Another resistive heater (max. 1500 W), was also immersed in the liquid helium at the bottom of the dewar in order to calibrate the Venturi gas flow meter installed on the return line from the dewar to the refrigerator. The calibration was carried out at several values of injected electric power. Calibrated temperature sensors (Cernox™, Lakeshore) were installed as can be seen in the schematic diagram of the test facility. The complete test facility is remotely controlled and supervised via a microprocessor-based control system.

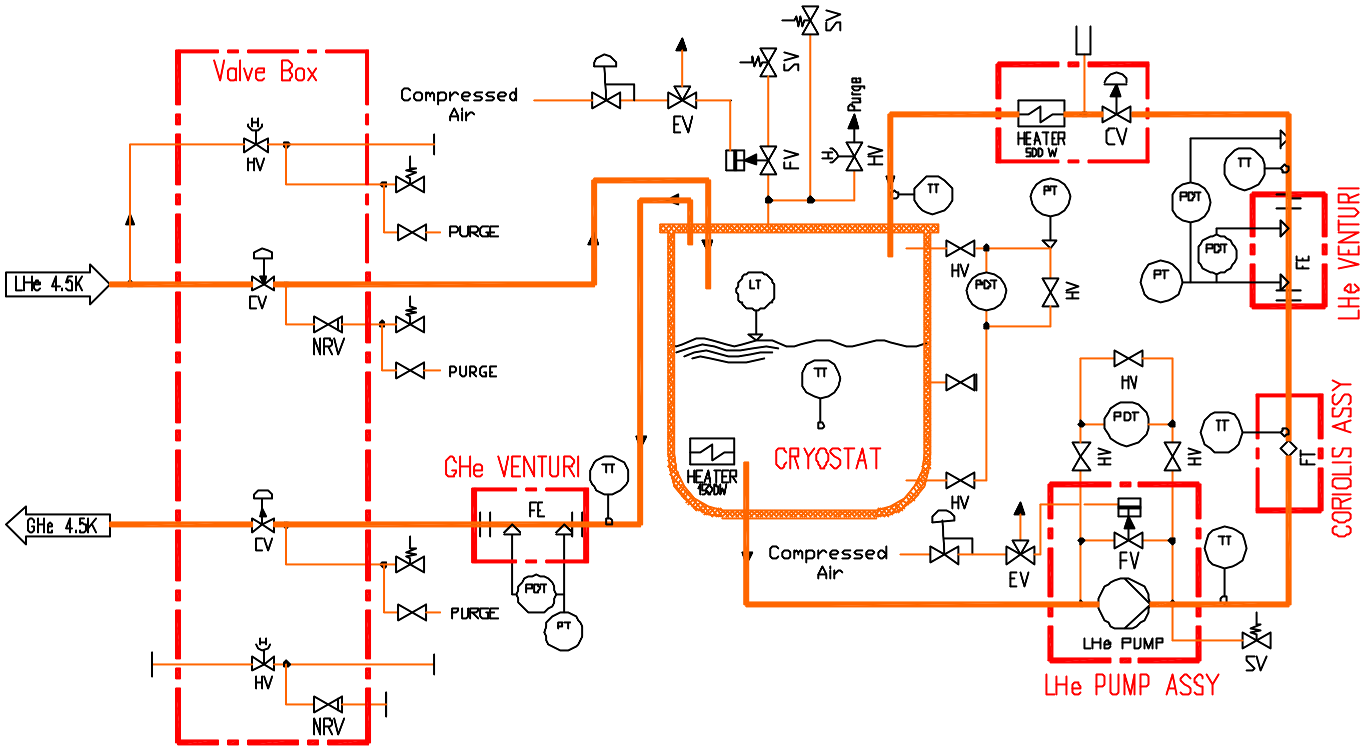

Figure 2. Flow scheme of the test facility

TEST DESCRIPTION AND RESULTS

The centrifugal liquid helium pump is constructed by Barbers & Nichols [3], according to the specification prepared by CERN.

Two impellers with slightly different diameters (112.55 mm and 105.1 mm) were tested, both equipped with the same inducer. The pump is of a full emission type [3], i.e. with curved blades. One of the two impellers (the bigger one) has straight radial discharge vanes on its rear side, whilst the second has curved ones. The pump is designed in such a way that its shaft has only two ball bearings working at ambient temperature. The motor shaft has an extension to the impeller about 200 mm long and no centering bearing.

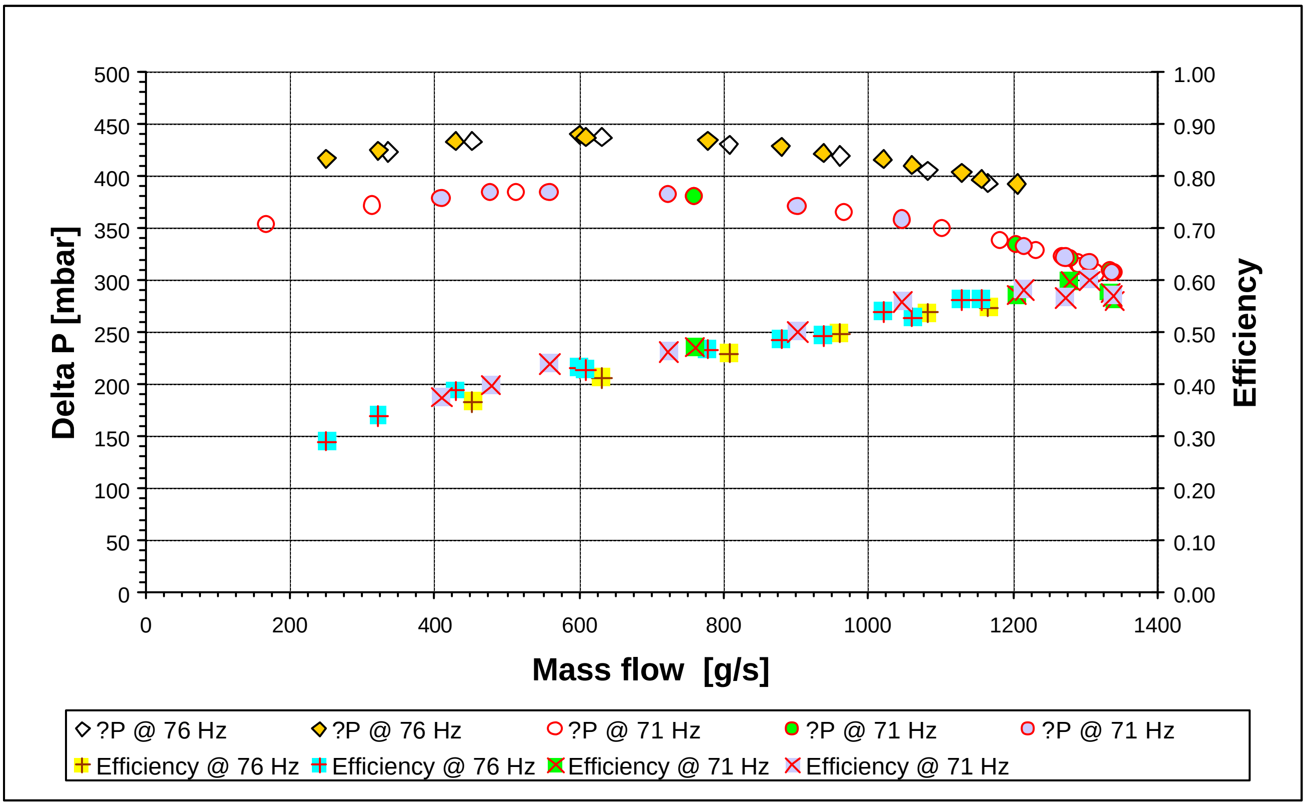

Figure 3. Characteristic curves and efficiencies of the pump with the impeller diameter 112.5 mm.

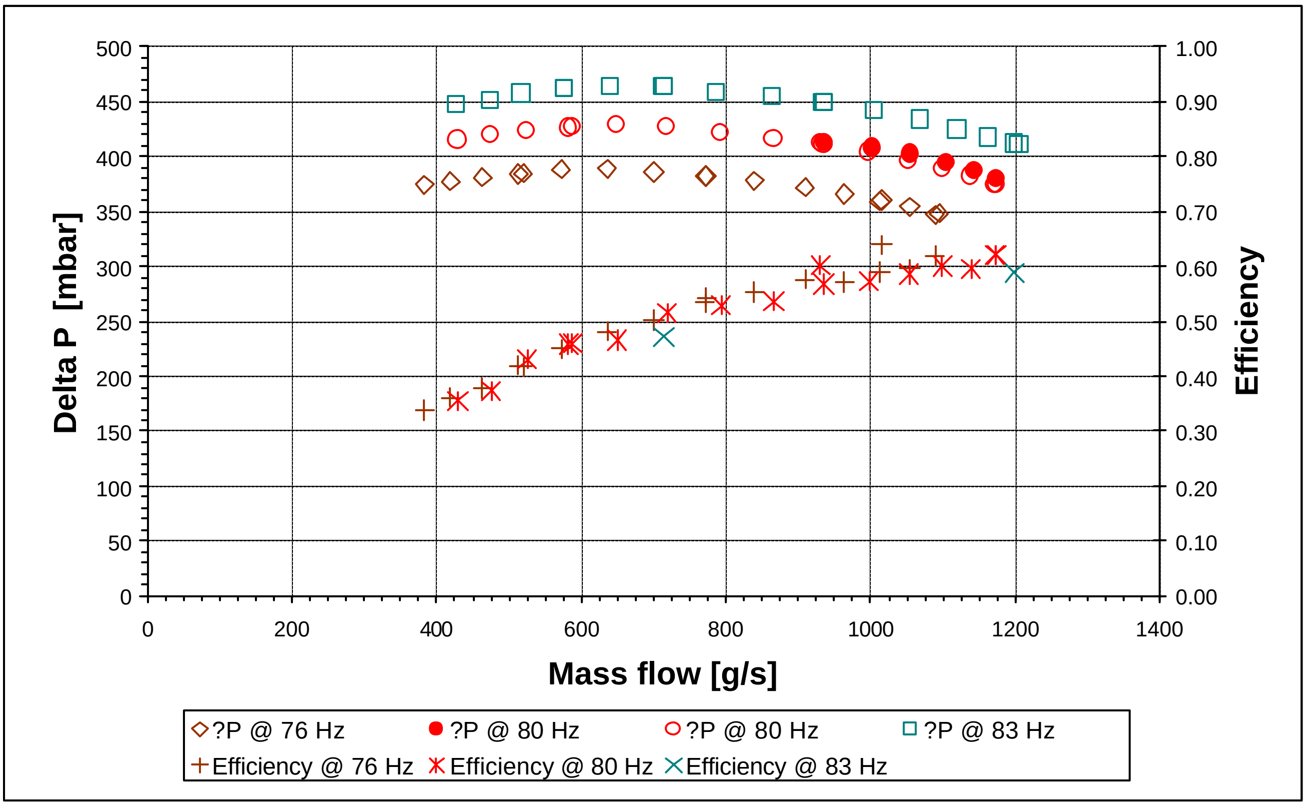

Figure 4. Characteristic curves and efficiencies of the pump with impeller diameter 105.1 mm.

A few insulated thermal shields, in the volume around the pump shaft, provide the necessary temperature stratification of the helium vapor from 4.5 K to ambient temperature. The pump has been designed and tested for a pressure of 2 MPa (ca. 20 bar). The motor has been designed and tested to operate in helium atmosphere.

The measurements were carried out as follows. At first the Venturi gas flow meter was calibrated, by changing the electric power injected into the dewar. In order to measure the heat load of the complete system a thermosyphon circulation was induced injecting about 200 W downstream the throttling valve, with the valve fully open, the pump at rest and its by-pass open. In those conditions, with the level and the pressure constant in the dewar, the heat load of the test facility, including the static load of the pump (around 20 W), can be obtained by subtracting the heating power from the total load, evaluated from the helium vapor flow.

Several characteristic curves were measured with the two impellers and at different rotational speeds around the nominal one of 71 Hz (ca. 4300 rpm). The reliability of the test facility can be seen from the good reproducibility of the data. Given a certain rotational speed, the larger the impeller the higher the mass flow. Around the specified values of differential pressure (ca. 400 mbar) and mass flow (ca. 1.2 kg/s) the power dissipated by the pump is 670 W, which corresponds to an efficiency of about 60%. The efficiency in the graphs is the ratio between the hydraulic power and the total power dissipated by the pump. The latter was measured by subtracting the heat load of the test facility from the total heat load measured for a given value of mass flow and differential pressure. It was not possible to measure the actual speed of the motor, then the frequency quoted in the graphs is that given by the variable frequency drive, which does not necessarily correspond to the actual rotational speed: a small difference might occur due to a possible "slip factor". More tests were carried out in order to compare the characteristic curves, and the corresponding efficiency, with and without the inducer in place. In can be seen in Figure 5 that, for a given rotational speed, the presence of the inducer on one end helps in increasing the head at lower mass flow, whilst it causes a decrease in efficiency at higher mass flow.

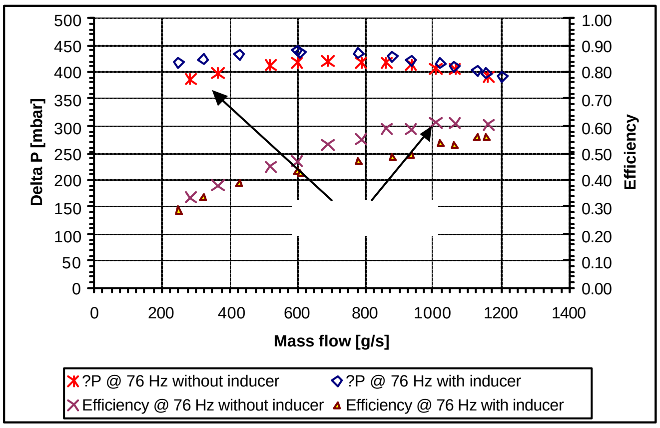

Figure 5 Characteristic curves with and without the inducer

CONCLUSIONS

Extensive and detailed measurements have been carried out at CERN, using the test facility described and built on purpose, in order to measure the characteristic curves of the 1.2 kg/s liquid helium pump for the magnets of the ATLAS experiment. The efficiency of the pump, as a function of the liquid helium mass flow, was also measured. The pump has shown to meet the hydraulic performances required for cooling the magnets, i.e. 400 mbar at 1.2 kg/s, with a total efficiency of about 60 % around the nominal rotational speed of 4300 rpm.

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