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LONG, BELLOWS-FREE VERTICAL HELIUM TRANSFER LINES FOR THE LHC CRYOGENIC SYSTEM

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Abstract

The cryogenic system for the Large Hadron Collider (LHC) under construction at CERN will include four new vertical helium transfer lines connecting the new helium refrigerators to the underground areas. These four transfer lines will be installed between a refrigerator on the surface and an interconnection box located 80 m to 145 m underground. They consist of a vacuum jacket, a thermal screen and four internal helium pipes. Due to space and accessibility limitations, the lines have been specified without bellows or bends of any kind in the long vertical part; the thermal contractions must be compensated at the surface only. The displacement due to these contractions amounts to more than 35 cm in one case, and all four internal pipes, as well as the thermal screen, must be able to contract and expand independently. The lines will be built and installed by a consortium of Linde AG and Babcock Noell Nuclear GmbH. Their technical design choices are presented together with expected performance.

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INTRODUCTION

As part of the cryogenic infrastructure of the LHC [1,2] four 4.5 K helium refrigerators are currently being erected at CERN [3,4]. These refrigerators are being installed at surface level in four different points around the LHC ring. To supply and return the cold helium to and from the underground areas four vertical helium transfer lines are needed, one for each point. They will connect the new refrigerators to a cryogenic interconnection box (QUI) 80 m to 145 m underground and have a length between 90 m and 190 m. Each transfer line will consist of four internal pipes, hereafter referred to as headers. Their design data can be found in Table 1.

Table 1: Header data

		Header C (Supply)	Header D (Return)	Header E (Supply)	Header F (Return)
Nominal temperature	[K]	4.5	20	50	75
Nominal pressure	[bar]	3	1.3	19.5	19
Inner diameter	[mm]	100	150	80	80

The main part of each transfer line is a vertical straight segment between 75 and 125 metres long. Due to reasons of accessibility, no internal or external bellows or bends are accepted in this part. Hence, all the thermal contraction of this part must be taken in a thermal compensator specified to be on the surface.

During cool down and warm up of the LHC some of the headers will be warm while others are close to the nominal temperature given in Table 1.

DESIGN OF THE LINES

The four helium headers will be inside a common vacuum jacket and inside a common thermal shield, which is actively cooled at 75 K using header F to limit the heat load on the cold supply headers.

Figure 1 shows a cross section of the lines at a sliding point with all headers, the thermal shield, and the support structure.

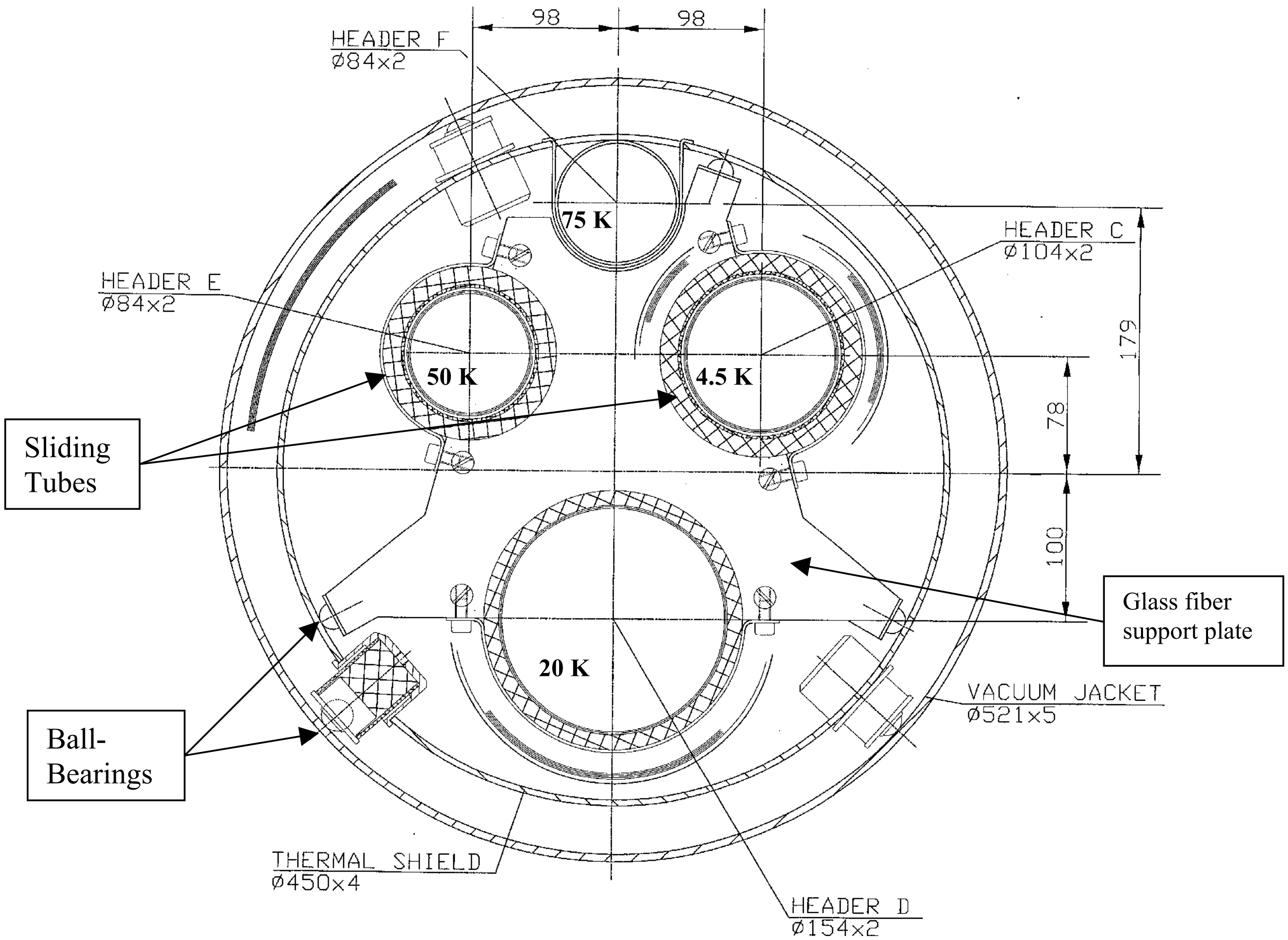

Figure 1: Sliding point cross-section.

Header D is fixed to a glass-fibre composite structure by means of a stainless steel clamp. To reduce the heat input to the header a special glass fibre intermediate layer is provided between the clamp and the headers. Headers C and E are mounted inside sliding tubes, which are also surrounded with glass fibre intermediate layers and fixed by stainless steel clamps to the glass fibre composite structure.

Inside the 75 K radiation shield the glass fibre composite structure is supported by ball bearings. Thus friction forces during movement of the inner parts are minimised. Further ball bearings support the 75 K shield. These ball bearings are carried in a glass-fibre composite tube to limit thermal conduction. During cool down of the system, each header and the shield will have different movements relative to each other and to the outer shell. This design allows the independent movements of all headers.

At straight sections, the support points are distributed at constant intervals inside the vacuum jacket. In the horizontal elbow sections at each end of the line, the distance between the supports will be adapted specifically.

THERMAL COMPENSATION

A thermal compensator installed directly above the long vertical part will compensate the movement during transient operation. For the longest line, the thermal compensator must take more than 35 cm of movement.

The design of the thermal compensator can be found in Figure 2.

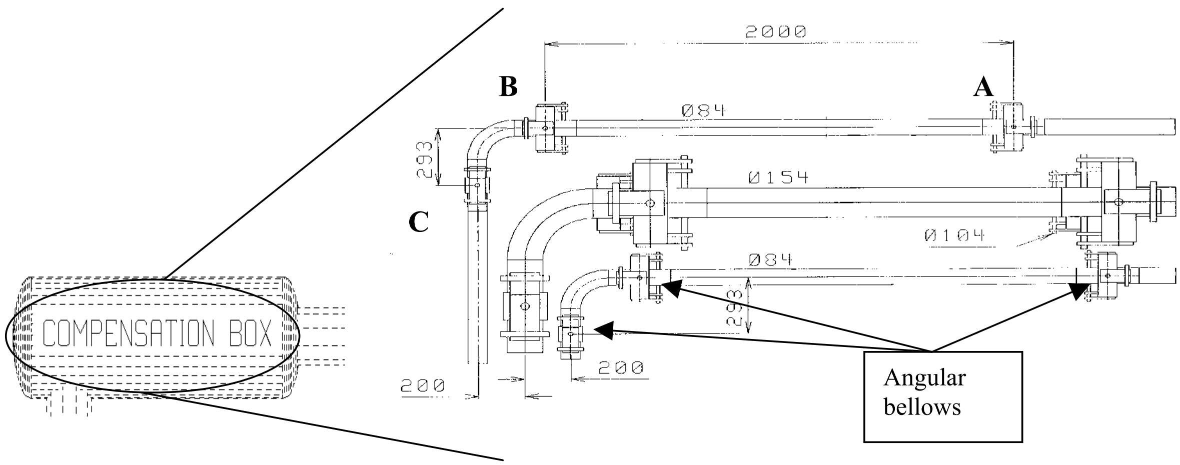

Figure 2: The thermal compensator, external view and internal configuration of the headers (enlarged).

Each header will be equipped with two angular bellows in the horizontal part (A and B in Figure 2) and one angular bellow in the vertical part (C). The vertical part has a sliding point directly below the compensator and a fixed point at the bottom up to 125 metres below. This means that bellows C will move vertically during cool down. As bellows A are fixed vertically, the header section between A and B will compensate the movement of C. The angular bellows allow this compensation, and the compensator can in addition adsorb the small contraction of the compensator itself and of the horizontal connection.

In warm conditions the header part between A and B is not perfectly horizontal, but is pre-stressed giving an angle of about 6 degrees above the horizontal plane. The compensation box has a diameter of 1600 mm and is equipped with a thermal shield of 1500 mm diameter.

The vacuum jacket has a fixed point at the top of the vertical part close to the thermal compensator. In case of an accidental breakdown of the vacuum, this jacket may also cool down and thereby contract. This contraction is taken by the horizontal connections at the top and bottom, and to allow the slight movement of these parts, they are supported by spring hangers and spring supports. With this solution, no bellows are needed for the vacuum jacket.

EXPECTED HEAT LOADS

To limit the heat loads into the cold helium, the lines will be equipped with a multi-layer insulation (MLI) system using a static vacuum better than 10^{-4} Pa (10^{-6} mbar) in cold conditions. Header E will have 10 layers of MLI, while all other headers, as well as the thermal shield, will have 30.

Table 2 shows the expected heat loads due to radiation and conduction through the support structure.

Table 2: Expected heat loads

Header		C	D	E	Shield
Radiation	[W/m^2]	0.05	0.05	0.03	0.65
	[W/m]	0.015	0.021	0.007	0.91
Sliding Point	[W/point]	0.105	0.117	0.042	1.1
Fixed Point	[W/point]	0.4	0.65	0.31	5

Taking into account that each line has between 20 to 40 sliding points, 1 to 2 fixed points, and some additional heat loads due to module connections and bends, the expected heat loads for the longest line (190 metres) can be found in Table 3.

Table 3: Expected heat load for 190-metre line.

Header		C	D	E	Shield
Heat Load	[W]	8	10	4	250

After installation the lines will be cooled down and the total heat load of each header will be tested using a dedicated test box connected at the end of the line. During and after this test the performance of the thermal compensator will also be verified.

CONCLUSIONS

Four vertical transfer lines have been specified by CERN and will be built by a consortium of LINDE AG and BABCOCK NOELL NUCLEAR GmbH. Their design has been finalised and the lines are currently under production. A dedicated thermal compensator will be installed at the top of the long vertical part, and the substantial thermal contraction of this part will be taken here. No compensation bellows or bends will be installed in this part.

The lines will be completely tested after installation and the heat load measured mid-2003.

ACKNOWLEDGMENTS

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