LARP IR Cryogenics: Design Temperature Profile for an LHC Upgraded IR

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Introduction

The temperature profile resulting from increasing the heat load to the 1.9 K helium in the current LHC interaction regions (IR's) has been documented [1]. A number of thermal limitations in the design were identified. Based on these limitations and the expected IR heat load increase accompanying a ten-fold increase in machine luminosity, a design temperature profile for the upgraded IR's is presented. This design temperature profile will provide guidance in designing the upgraded IR cryogenics system.

Design Temperature Profile

Table 1 presents the design temperature profile for the cryogenics system of an upgraded IR. This temperature profile is very similar to that proposed by CERN for Next European Dipole (NED) and IR upgrades [2, 3].

Table 1 Temperatures in an upgraded IR.

Segment	Temperature range [K]	ΔT [mK]
Magnet bore annular space to heat exchanger crossover pipe	2.150-2.050	100
Heat exchanger crossover pipe	2.050-1.950	100
Heat exchanger crossover pipe to heat exchanger (saturated side)	1.950-1.826	124
Pressure drop along the inner triplet heat exchanger	1.826-1.816	10
Pressure drop through the J-T heat exchanger shell	1.816-1.791	25
Pressure drop through piping to the first stage cold compressor	1.791-1.716	75

Pressure-induced, equivalent temperature drops in the subatmospheric He system account for about 25% of the total available temperature budget. These are not actual temperature drops and do not assist in heat transfer; therefore they should be kept to a minimum. These equivalent temperatures are shown in Figure 1.

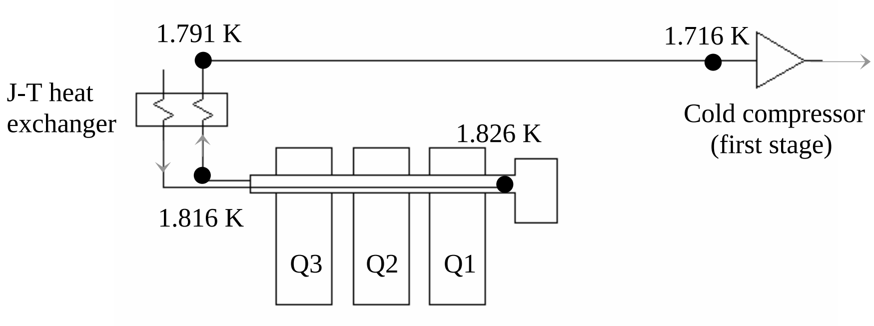

Figure 1 Equivalent temperatures in the subatmospheric He system.

A saturation temperature of 1.716 K assumes that the first stage cold compressors are moved closer to the interaction regions and that they are upgraded to reach 12 mbar instead of the current 15 mbar [4]. Moving the cold compressors means the associated piping could be appropriately sized to keep the temperature drop due to pressure and elevation changes at 75 mK.

Heat load scaling indicates that the existing J-T heat exchanger design will have a significantly higher temperature drop than 25 mK at 1.2 kW per inner triplet. However, moving cold compressors means that modifications to some QRL (compound cryogenic distribution line) service modules would be required to accommodate the piping changes. An upgraded J-T heat exchanger could be integrated at the same time.

Three-quarters of the temperature budget is allocated to the pressurized He II system and the magnet heat exchanger wall. Nearly one-quarter of the temperature budget is allocated to He II conduction through the crossover pipe to the heat exchanger. This portion of the heat path has the highest heat flux, and the temperature gradient therefore grows quickly. It is important to note that the piping configuration of Figure 2 is different than that of the existing inner triplet. An upgraded inner triplet will likely have twice as many crossover pipes (one at each end of every cold mass), and these crossover pipes will connect to the cold mass end domes rather than the interconnect piping. These changes will minimize the heat flux and length per crossover pipe. The distributed heat paths within the cold mass and the heat exchanger annulus are somewhat easier to handle. Temperatures in the pressurized He II system are shown in Figures 2 and 3.

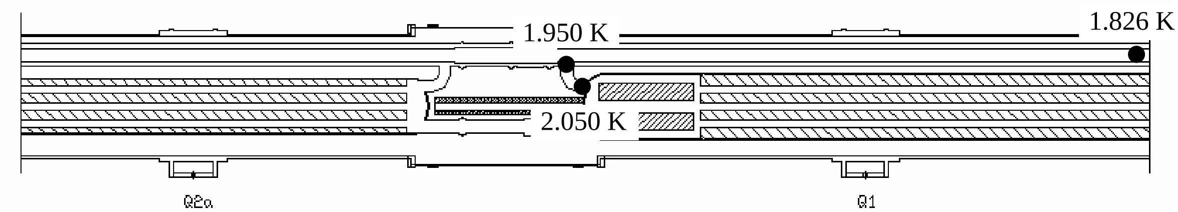

Figure 2 Pressurized He II temperatures in the Q1 and Q2a magnets.

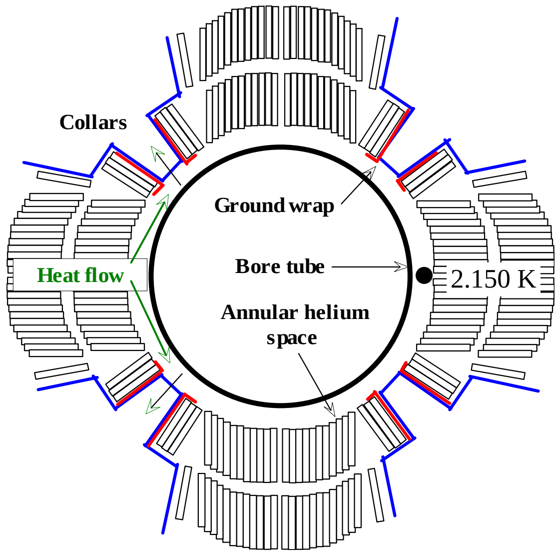

Figure 3 Pressurized He II temperature at a representative magnet cross-section.

Conclusions

A design temperature profile for an upgraded IR has been presented. Three-quarters of the temperature budget has been allocated to the pressurized He II system with the remaining one-quarter allocated to the subatmospheric He system.

As the cryogenics system design evolves, it is expected that the temperature profile will be adjusted to meet demands.

References

[1] R. Rabehl, "LARP IR Cryogenics: Scaling of LHC I IR Cryogenics Model," LARP Document 15, October 2005.
[2] R. van Weelderen, "He II Heat Transfer in Superconducting Magnets," Next European Dipole (NED) project, February 2005.
[3] R. van Weelderen, "Heat Transfer in Superconducting Magnets," AMT 01-Beam Generated Heat Deposition and Quench Levels for LHC Magnets, March 2005.
[4] R. van Weelderen, private communication, June 2005.