

## INSTRUMENTATION AND CONTROL SYSTEM FOR THE INTERNATIONAL ERL CRYOMODULE

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### Abstract

ALICE is a prototype ERL accelerator that is being developed at STFC Daresbury Laboratory, UK. Recently it has successfully demonstrated the energy recovery technique by accelerating an electron beam to more than 30 MeV. A new superconducting LINAC cryomodule is being developed for the operation in CW mode with high average beam current. ALICE will be used as a test bed for this new cryomodule, which will utilise cold helium gas to cool the radiation shield, HOM absorbers and the thermal intercepts for the high power RF input couplers as opposed to liquid nitrogen. The additional cooling power required at 80 K and 5 K will be provided by COOL-IT (a system for cooling to intermediate temperatures). All these modifications would require new instrumentation for diagnostics and control of the additional cryogenic processes, which will be integrated with the existing Linde cryogenic control system for ALICE. In this paper we present an overview of the additional instrumentation requirement with associated integration scheme.

### INTRODUCTION

ALICE [1], a prototype accelerator developed at the

Daresbury Laboratory UK, has successfully demonstrated the energy-recovery technique by circulating the electron beam to 30 MeV. At the heart of ALICE is a superconducting LINAC operating at 2 K [2]. Proposed future accelerators [3, 4] demand high beam intensities and high repetition rates, which can only be achieved by operating the SRF cavities in CW (continuous wave) mode. In order to develop the necessary technology to meet these demands a prototype cryomodule is being developed through an international collaboration project [5]. The cryogenic performance of this prototype cryomodule will be tested at ALICE, albeit at low average beam currents. The ERL cryomodule will incorporate the HOM absorbers, demanding additional cooling power required at 80 K and 5 K which will be provided by cold gaseous streams of helium. The existing cryogenic system for ALICE (see Figure. 1) does not have a provision to supply gaseous helium at the required temperatures and flow and COOL-IT [6], a system for cooling to intermediate temperatures, has been developed to meet the additional cooling power demand. The new ERL cryomodule and COOL-IT will be integrated with the existing cryogenic system for ALICE. An additional instrumentation system is being developed for diagnostics

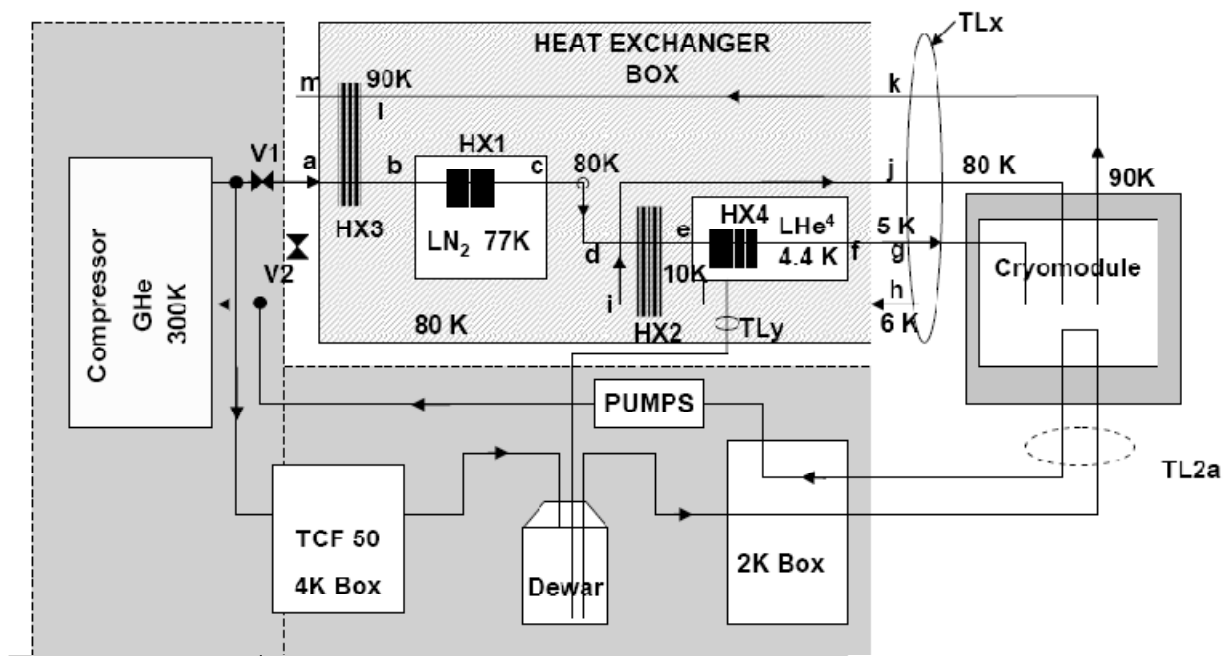


Figure 1: Schematic of the cryogenic system for ALICE with COOL-IT. Components inside the box with dashed border are the parts of the existing cryo-system for ALICE. The heat exchanger, transfer lines TLx and TLy are the components of COOL-IT.

and control. This paper gives an overview of the instrumentation system.

### SYSTEM DESCRIPTION

The cryogenic system for ALICE consists of a warm compressor, a 200-W TCF-50 Linde helium liquefier, a 1500-liters liquid helium dewar, a 2-K heat exchanger and a set of vacuum pumps for 2-K operation. (See Figure. 1)

#### Additional Heat Exchanger

The approach to the COOL-IT design was chosen such that 1) it will have minimum interference with the existing cryogenic process, 2) no modifications will be required to the existing cryo-plant, and 3) if necessary it would be possible to isolate it from the existing system with minimum efforts at a short notice. With this approach it was decided to design an independent unit, shown as the heat-exchanger box (see Figure .2) consisting of a set of 4 heat exchangers cooled by liquid helium and liquid nitrogen. This box can be isolated from the main system with the valves V1 and V2 (see Figure 1). Warm gas at a pressure between 4 bar and 12 bar follows a process path starting at ‘a’ at the compressor end, through b, c, d.... and returns back to the compressor at ‘m’. On the way it is cooled progressively by four heat exchangers to 5 K. The cold gases are transported to the cryomodule via a compound transfer line, TL<sub>x</sub>, to cool the HOM-load and RF coupler intercepts and the thermal shield. The transfer line TL<sub>x</sub> consists of four process pipes, two supply and two return, for the gas supplies at 5 K and 80 K, respectively.

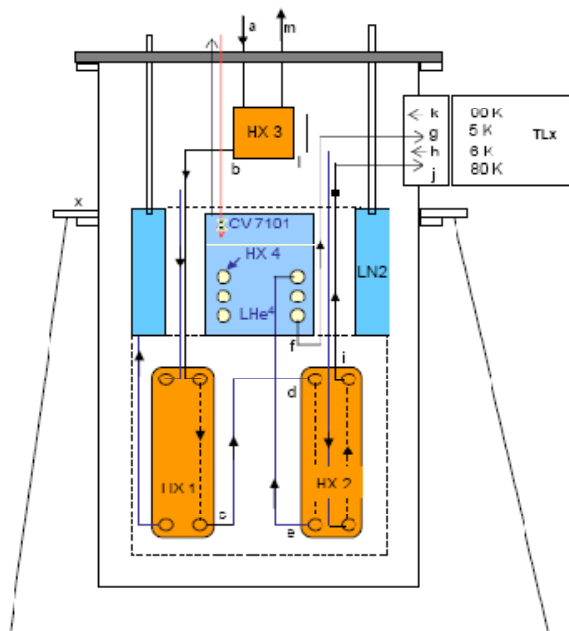


Figure 2: COOL-IT heat exchanger box.

The maximum heat-load values for the cryomodule at 5 K and 80 K have been estimated to be 1.5 W and 175 W respectively. The compressor has a capacity to handle

more than 100-g/s flow of helium gas, out of which about 80-g/s is being used by the existing system. COOL-IT is estimated to use less than 10-g/s.

#### Cooling Loops Inside the Cryomodule

The temperature of the central HOM will be used as a primary control parameter for controlling the cooling power provided by COOL-IT. A single gas stream flows through the system with the components at 5 K and 80 K configured in series (see figure 3). The 5-K thermal intercepts on three HOM absorbers (connected in parallel), are first to cool. The 5-K intercepts on the couplers are cooled through thermal straps. The 80-K loops on the three HOM absorbers (connected in parallel) are cooled next. 80-K intercepts on the couplers are also cooled through thermal straps. Finally the gas flows through the radiation shield and returns to the COOL-IT heat exchanger-3. On the way it cools the thermal shield of the compound transfer line TL<sub>x</sub>. Since the 5-K and 80-K components are connected in series the cooling power available at 5 K is much higher than required. However a control algorithm will be developed to create interrupts and interlocks with other temperature sensors for fault analysis and control.

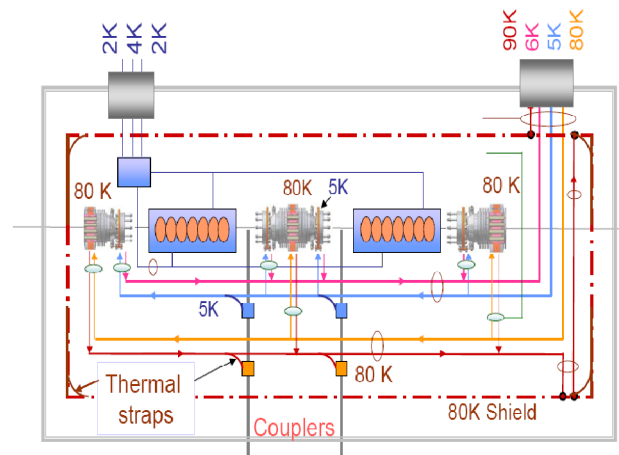


Figure 3: Cooling loops configuration inside the ERL cryomodule.

#### Process Control and Data Acquisition

Figure 4 shows the P & ID developed for process control. All the critical locations in the system will be monitored by several temperature sensors, pressure transmitters and cryogenic level sensors for diagnostic and control purposes. 100-ohm platinum RTDs will be used for monitoring the temperatures higher than 50 K. A combination of Cernox, TVO, RhFe and CLTS thermometers will be used for temperature below 50 K. Two 8 channel Lakeshore temperature monitors model 218 are used for temperature measurements. Cryogen level control is achieved by using American Magnetics models 136 and 186. The existing instrumentation and control system for 2 K operation will be used as is and an independent instrumentation system has been developed

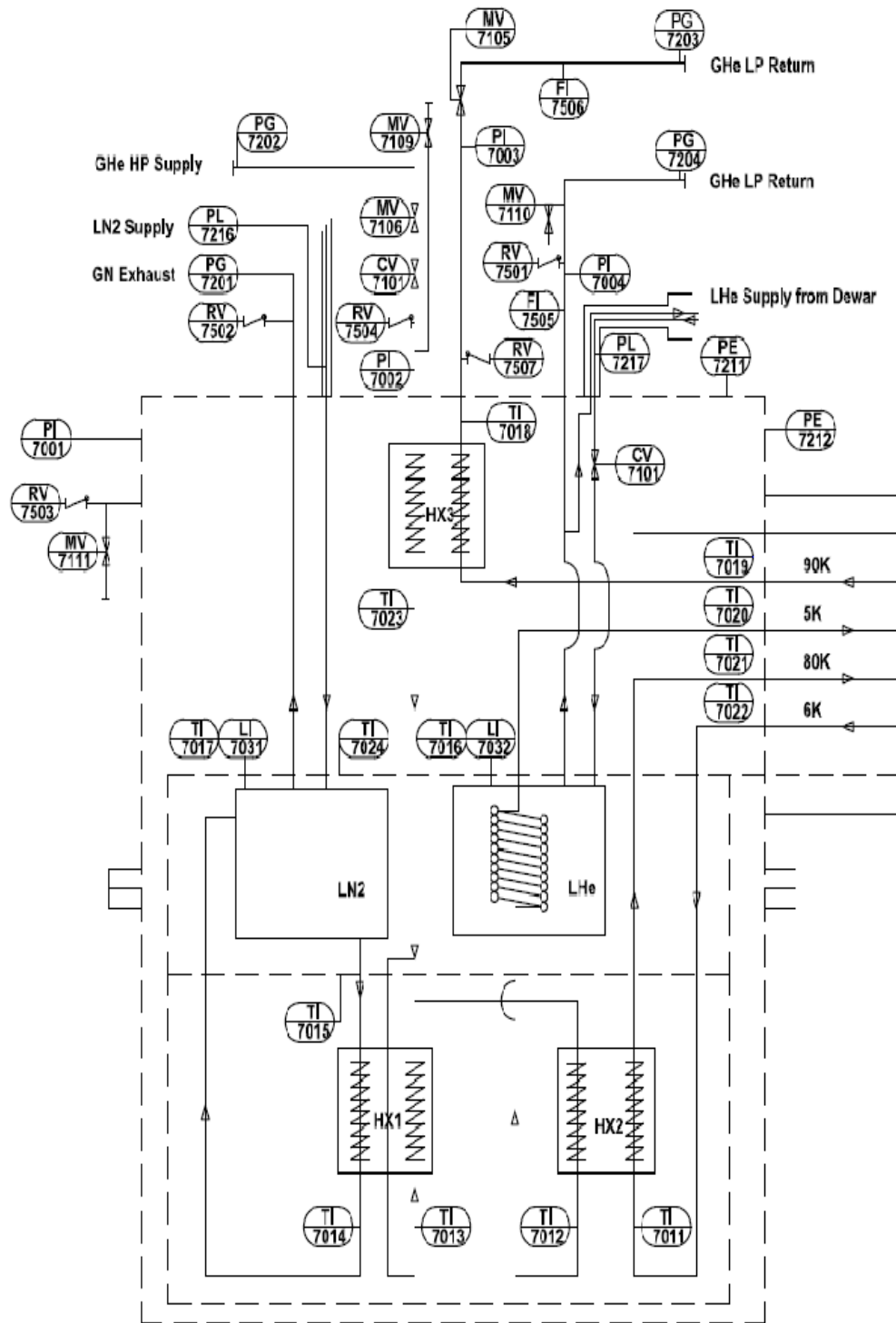


Figure 4: P&ID for the intermediate cooling process

for the additional processes. All the hardware will be accommodated in a single instrument rack located close to the cryomodule. Figure 5 shows a schematic for the hardware used for COOL-IT instrumentation. A DAQ system has been developed using LINUX with a WINDOWS based scheme to map the process parameters.

The DAQ scheme employs EPICS 3.14.10 running on Scientific LINUX PC. The DAQ equipment is connected to the PC via USB-Serial converters or ADAM network based analogue signal conversion. EPICS channel archiver is used to record the process parameters for further analysis.

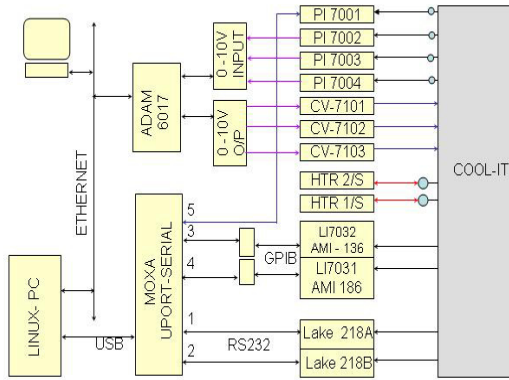


Figure 5: Hardware schematic for COOL-IT instrumentation.

### INITIAL TESTS

COOL-IT has been manufactured by AS Scientific (UK) based on the design provided by the Daresbury Laboratory. Figure 6 shows COOL-IT during assembly at the factory.



Figure 6: COOL-IT heat exchanger during assembly.

The preliminary performance of COOL-IT with full instrumentation has been verified by conducting tests using liquid helium and nitrogen from storage vessels at the factory. See Figures 7 and 8. With by-pass connections between 5-K and 6-K ports as well as between 80-K and 90-K ports, the heat exchanger performed as desired with the inlet pressures between 3 and 5 bar which is the expected operating range for final operation. Due to the pressure changes in the liquid helium supply dewar and subsequent variations in the liquid flow it was difficult to control the liquid helium level in the reservoir inside COOL-IT. In the absence of the cryomodule and the compressor the full process could not be verified with extended operation but it was possible to establish the operating range for gas flow and pressures. Actual process optimisation will be undertaken at the time of commissioning of the ERL cryomodule with ALICE.



Figure 7: COOL-IT under acceptance tests at AS Scientific (UK).

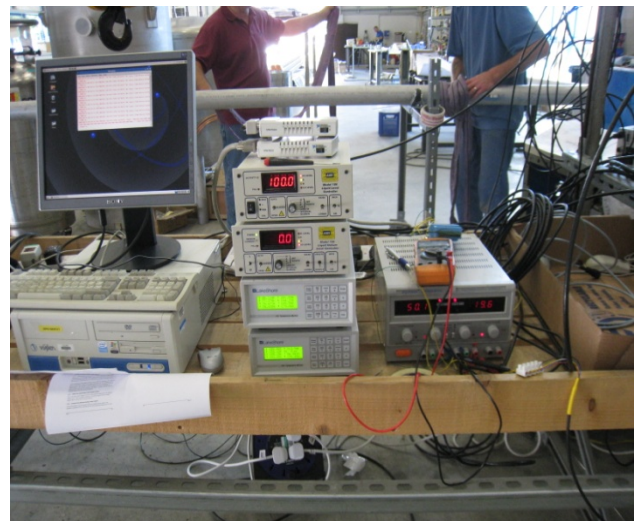


Figure 8: Instrumentation tests with COOL-IT at AS Scientific (UK).

Figure 9 shows the synoptic display (screen shots captured during the tests). It uses a Microsoft .NET client application. This client application communicates a '.NET Channel Access' interface developed at the STFC's Daresbury Laboratory [7].

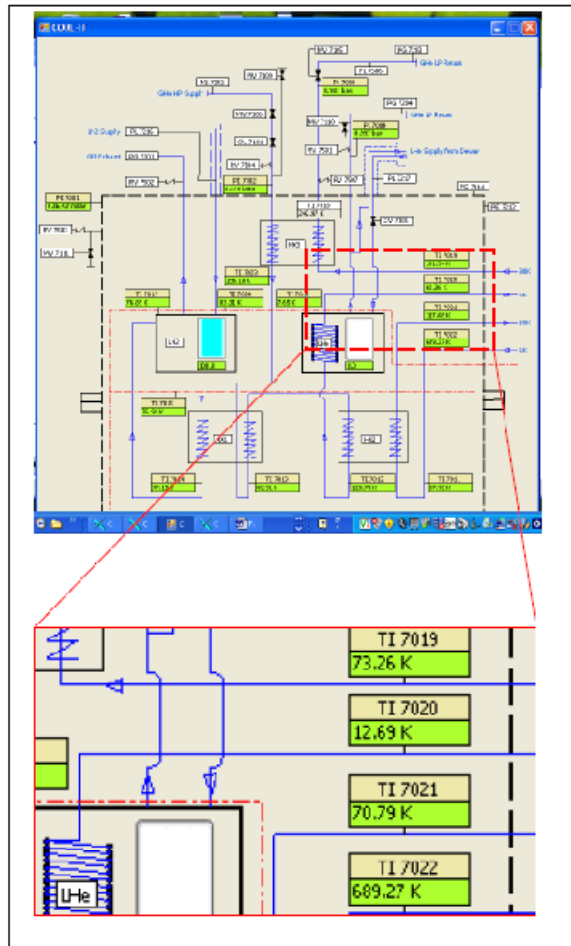


Figure 9: Synoptic display for COOL-IT processes.

## SUMMARY

The main purpose of developing COOL-IT is to provide the cooling power using helium gas at intermediate temperatures to cool the HOM absorbers, RF couplers and the radiation shield of a cryomodule. The HOM absorbers are the critical components which may demand cooling power as high as 175 W at 80 K. The cooling power will be controlled by adjusting the flow through a single control valve. The design allows the installation and operation of COOL-IT independent of the existing cryogenic system. An instrumentation system has also been developed for data acquisition and control of the cryogenic process with COOL-IT. Initial performance of the COOL-IT with instrumentation independent of the cryomodule has been tested successfully. It will be integrated and commissioned with ALICE during in the summer 2010 with the new ERL cryomodule.

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