EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics

Large Hadron Collider Project

LHC Project Report 234

Cryogenic System for the Test Facilities of the ATLAS Liquid Argon Calorimeter Modules

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Abstract

To perform cold tests on the different modules of the ATLAS liquid argon calorimeter, a cryogenic system has been constructed and is now operated at the CERN North Experimental Area. Three different test cryostats will house the modules, which can also be exposed to particle beams for calibration purposes.

The three cryostats share a common liquid argon and liquid nitrogen distribution system. The system is rather complex since it has to allow operations of the three cryostats at the same time.

Liquid nitrogen is used as cold source for both the cool-down of the cryostats and for normal operation of the cryostats filled with liquid argon.

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Presented at ICEC 17, 14-17 July 1998, Bournemouth, UK

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Geneva, 27 August 1998

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1 INTRODUCTION

To exploit the capabilities of the future CERN Large Hadron Collider (LHC) with colliding protons and heavy ions, four particle detectors are being designed and will be installed in underground caverns.
ATLAS [1] will be the largest detector comprising a complex cryogenic system for superconducting magnets and liquid argon sampling calorimetry. [2]
The electromagnetic and hadronic calorimeters will be housed in cryostats with a total volume of 83 m^3 of liquid argon at a temperature of approximately 87 K.
Prior to assembly of the final calorimeter system cold performance tests of the 128 individual detector modules immersed in liquid argon are necessary permitting exposure to particle beams for calibration. For this purpose a cryogenic test facility has been specifically designed and constructed at CERN.
This paper describes the cryogenic infrastructure, the components, the data acquisition system and the functioning of this facility operated at the CERN North Experimental Area.

2 THE COMMON CRYOGENIC DISTRIBUTION SYSTEM

The common cryogenic distribution system supplies the three argon test cryostats with the necessary cryogenic liquids. It consists of a nitrogen dewar, an argon dewar, a nitrogen phase separator, an associated distribution box and an argon distribution box, which includes an argon phase separator, a liquid argon purifier and a liquid argon pump.

2.1 The storage dewars

A 50000 liter nitrogen dewar and a 30000 liter argon dewar are installed outside the experimental hall, at a distance of about 70 meter from the experiments. The argon dewar has been equipped with a liquid nitrogen cooled re-condenser permitting the regulation of the argon pressure to a pre-set value. Therefore no argon gas has to be vented.
The two dewars are connected to the common cryogenic distribution area via vacuum insulated transfer lines passing through underground caverns. For safety reasons these caverns have been equipped with oxygen detectors to detect eventual leaks in one of the two lines. The dewars are pressurized to obtain the liquid flow towards the common cryogenic distribution area.

2.2 The nitrogen phase-separator and distribution box

The nitrogen transfer line is connected to a 3000 liter phase-separator, which is only refilled when the level drops to a pre-set minimum value. It permits the supply of 100% liquid to the heat-exchangers of the three cryostats, and allows stable regulation conditions. The phase-separator has to be slightly depressurized during a refill from the external dewar, giving a minor disturbance in the argon cryostats pressures (< 15 mbar).
The output of the phase separator is connected to a nitrogen distribution box, which divides the liquid nitrogen flow over the three test installations.

2.3 The argon distribution box

The argon transfer line connects the external storage dewar to a distribution box. The argon arriving enters a 300 liter phase separator. Included in this phase separator is a liquid nitrogen cooling loop, which is used to subcool the liquid argon and to re-condense the argon gas produced by the thermal losses. The subcooling of the liquid argon minimizes the risk of cavitation of the centrifugal pump (2000 liter/hour, Δp = 4 bar [3]) placed at the outlet of the phase separator. From there the liquid is transferred to the individual cryostats directly, or indirectly via an argon purification system depending on the purity level of the argon.
The signal generation in the argon calorimeters will be altered by the presence of electronegative impurities (O_2, CO_2, halogens, unsaturated hydrocarbons etc.). Therefore the purity of the argon in the phase-separator is continuously monitored by means of a sophisticated measuring device based on the free electron drift velocity [4]. If the impurity level is too high, the argon can be passed through a commercial Oxisorb purifier [5], which has been installed at the outlet of the argon circulator.
In case of the emptying of a cryostat, the liquid argon can, purified or not, be directed towards the storage dewar or towards another cryostat.

3 THE CALORIMETER CRYOSTATS

The 128 detector modules are one by one installed in one of the three cryostats which have a liquid argon volume of 5.5 m^3, 6 m^3 and 10 m^3, respectively.
The cryostats and detectors are cooled down, filled with liquid argon and are then exposed to a particle beam by moving the cryostats in the horizontal and the beam in the vertical plane. One cryostat mounted on a special platform with an elaborated cinematic allows for 2 D movements.

Two of the cryostats are already installed and in operation. They are equipped with a nitrogen heat-exchanger in the argon gas space. During cool-down, the temperature of the detector module is lowered at a controlled speed by a regulation of the nitrogen flow through this spiral. For reasons of thermal contractions the cool-down is temporarily interrupted when the temperature gradients between selected points of the module are larger then a pre-set value.
The argon pressure in a filled cryostat is regulated using the same heat-exchanger recondensing the argon boil-off. The pressure, and hence the temperature, can be controlled to (1.300 ± 0.005) bar resulting in negligible temperature variations.
During emptying the cryostats have to be pressurized to 2 bar to push the liquid to the argon distribution box from which it is re-distributed to another cryostat or to the argon dewar.
An electrical heater is used to warm-up the emptied cryostat and its module at a given speed.

4 THE SLOW CONTROL SYSTEM

The processes to be managed by the automatic control system are spread over five different locations: the 3 test cryostats, the storage area, and the distribution area. The digitized data coming from these locations is read out centrally via a FIP (Flow Information Process) network and is processed by means of a commercial controller [6]. The system can only be accessed from one central supervision unit, while the display of all information is available on ethernet.

5 RESULTS

At present we are in the commissioning stage of this installation. During this phase we have already been able to regulate the pressure in the two connected cryostats to (1.300 ± 0.005) bar under normal operation conditions for periods up to several weeks.
The cryogenic plant design proves to be valid and the system able to cope with various operation conditions.

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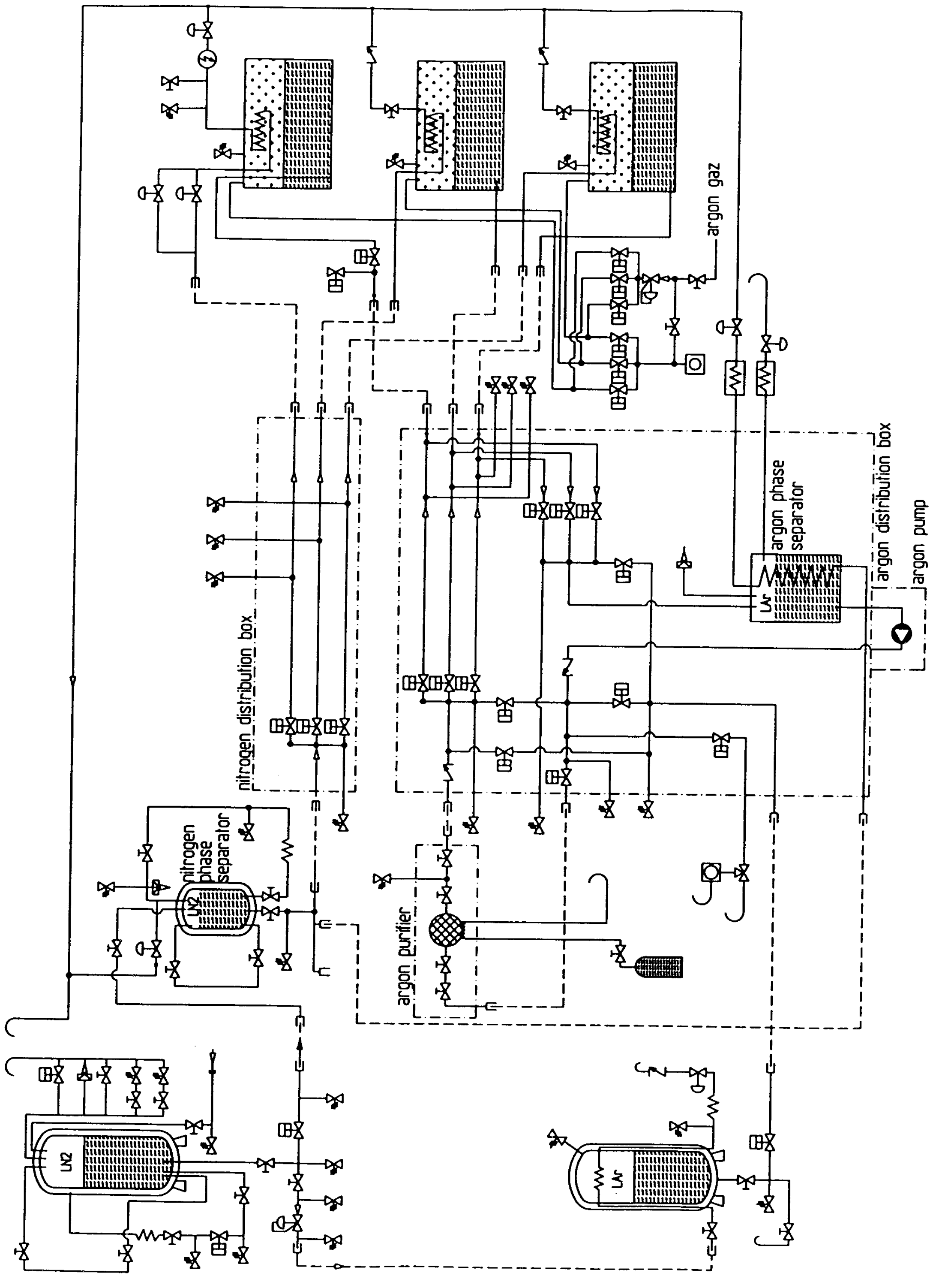

Figure 1: The cryogenic flow scheme