# ATLAS Infrastructure

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# Contents

**1 The civil engineering structures of the ATLAS experimental area . . . . . . 3**
1.1 Presentation of the project . . . . . . . . . . . . . . . . . . . . . . . 3
1.2 Underground structures. . . . . . . . . . . . . . . . . . . . . . . . . 4
1.3 Surface structures . . . . . . . . . . . . . . . . . . . . . . . . . . . 5
1.4 Organization of the work and time schedule . . . . . . . . . . . . . . 7
1.5 Safety . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 10
1.6 References. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 10

**2 Electrical Overhead Travelling (EOT) Cranes. . . . . . . . . . . . . . . 11**
2.1 Introduction . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 11
2.2 Design and procurement . . . . . . . . . . . . . . . . . . . . . . . . 11
2.3 Particularities . . . . . . . . . . . . . . . . . . . . . . . . . . . . 11
2.4 Installation milestones . . . . . . . . . . . . . . . . . . . . . . . . 12
2.5 Operation . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 13
2.6 References. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 13

**3 Metallic structures . . . . . . . . . . . . . . . . . . . . . . . . . . 15**
3.1 HS and HO: the UX15 steel structures . . . . . . . . . . . . . . . . . 15
3.2 Metallic structure in USA15 . . . . . . . . . . . . . . . . . . . . . . 17
3.3 Steel structures in the access shafts . . . . . . . . . . . . . . . . . 17
3.4 Steel structure in SDX1. . . . . . . . . . . . . . . . . . . . . . . . 17
3.5 References. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 18

**4 Cooling and ventilation for the ATLAS experiment . . . . . . . . . . . 19**
4.1 Introduction . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 19
4.2 Design . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 19
4.3 Installation. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 19
4.4 Commissioning . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 20
4.5 Operating conditions . . . . . . . . . . . . . . . . . . . . . . . . . 20
4.6 Specific cooling systems . . . . . . . . . . . . . . . . . . . . . . . 21
4.7 References. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 22

**5 Electrical distribution for ATLAS . . . . . . . . . . . . . . . . . . . 23**
5.1 Generalities . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 23
5.2 Electrical distribution in ATLAS experiment . . . . . . . . . . . . . . 24
5.3 References. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 29

**6 Racks for electronics . . . . . . . . . . . . . . . . . . . . . . . . . 33**
6.1 Introduction . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 33
6.2 Main design parameters . . . . . . . . . . . . . . . . . . . . . . . . 33
6.3 Specific features for magnetic environment . . . . . . . . . . . . . . 35
6.4 Procurement . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 35
6.5 In situ installation . . . . . . . . . . . . . . . . . . . . . . . . . . 36
6.6 References. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 36

**7 Cryogenic systems for ATLAS . . . 37**
7.1 Cryogenic systems for ATLAS liquid argon calorimeters . . . 37
7.2 Cryogenic systems for ATLAS magnets . . . 39
7.3 References. . . . 43

**A Contributors . . . 45**

**B Editor . . . 45**

**C Acknowledgements . . . 45**

# 1 The civil engineering structures of the ATLAS experimental area

## 1.1 Presentation of the project

Despite the fact that a major part of the pre-existing infrastructure has been re-used, the LHC project implied the construction of important underground structures including tunnels and large caverns to house its new detectors. A number of related surface buildings had also to be built.

This was in particular the case for the experimental area at Point 1, following a decision in the 1980's to install there what would become the large ATLAS detector.

Apart from being very close to the Meyrin site of the laboratory, this location presented various advantages, including a “sound” geology (molasse rock close to the surface) and the possibility to dump the excavated material only a few hundred meters away from the work site.

The most prominent of these constraints were the following:

- A track across the French-Swiss boarder had to be created in order to transport the spoil from the underground works without passing through the customs and police check points and using Swiss and French roads. Negotiations to get the necessary authorisations on both sides took about one year.
- An existing farm is situated only 30-40 m away from the site. Hence due precautions were taken in order to mitigate the nuisances to the environment. The most spectacular one has been to inverse the order of the surface and underground works within the detector area: the SX1 building was erected and completed before starting any excavation work for the two PX shafts within the building. This prevented dust, and to a certain extent noise being spread away from the works area.
- In order not to stop the progress of the underground works in the US cavern while the LEP collider was still in operation (until November 2000), it was decided to stop excavating the cavern at a level of -12 m from the vault. Then it has been given to the Contractor the opportunity to cast in situ the 10 000 tons of the vault of the cavern. To allow this enormous mass of concrete to stay in place, it has been proposed by the main Consultant to hang it to the roof of the cavern with 38 steel cables which were prestressed. These cables were de-tensioned once the floor and the walls of the cavern were in place. The whole operation was a success.
- The excavated molasse rock in one corner of the UX15 cavern was impregnated with natural hydrocarbons, forcing the contractors to execute, handle and store these “polluted” spoils from the beginning, and for CERN to send it for dedicated and costly treatment under the control of the Geneva Authorities. All other spoil was transported to the dump area across the border.

The underground and surface structures which are part of the ATLAS experimental area are described in the Chapter 1.2 and Chapter 1.3.

## 1.2 Underground structures

Except for the upper part of the shafts, all underground structures have been excavated in the molasse rock by using rock breakers and road headers (the use of explosives being forbidden in order to preserve the quietness of the neighbouring inhabitants). After excavation, they all received a temporary lining (Austrian method) with bolts and shotcrete, a waterproofing membrane connected to a drainage system and a final lining made of in-situ cast concrete of various thicknesses. On some occasions, pre-formed channels have been set in the final lining to allow easy fixing of pipes, cable trays and steel structures at a later stage.

**LEP structures (existing before LHC works)**

- PM15 shaft
  Access shafts with stairs and lift, containing services and used for the transfer of equipment to the service cavern US15.
- PX15 shaft
  Access shafts to the US15 cavern. The PX15 shaft was existing from the LEP Project, but repair works, placing a waterproofing membrane and casting of a concrete lining were carried out in the frame of the LHC project.
- UJ14 and 16 caverns
  Two service caverns housing electrical equipment dedicated to the former LEP (and now LHC) machine.
- UL14 and 16 tunnels
  Junction access tunnels between the US and UJ caverns.
- US15 cavern
  Service cavern housing electrical, electronic, cooling and cryogenic equipment adjacent to the experimental caverns.

**LHC structures (new)**

- PX 14 and 16 shafts
  Two access shafts used for the transfer of detector equipment to the experimental cavern, fitted with air ducts in the case of PX14.
- RR 13 and 17 caverns
  Two service caverns housing power converters and other electrical equipment for the LHC machine.
- UJ13 and 17 caverns
  Two service caverns housing electrical equipment for the LHC machine. They are also used as enlargements for transport purposes.
- USA15 cavern
  Service caverns housing electrical, electronic, cooling and cryogenic equipment adjacent to the experimental caverns.
- UX15 cavern
  Cavern housing the ATLAS detectors and its ancillary facilities.

## 1.3 Surface structures

All LEP buildings have been re-used in the frame of the LHC project. At point 1, the buildings are of two kinds: those related to the need of the LHC machine and those for the detector. All buildings housing

**Table 1-1** Table of dimensions of the main underground structures

| Structure | Length (m) | Width (m) | Height (m) | Diameter (m) | Area ($m^2$) | Volume ($m^3$) |
|---|---|---|---|---|---|---|
| PM15 | | | 69.15 | 9.10 | | 4500 |
| PX14 | | | 53.56 | 18.00 | | 13628 |
| PX15 | | | 79.00 | 9.10 | | 5136 |
| PX16 | | | 54.15 | 12.60 | | 6751 |
| US15 | 20.75 | 16.20 | 13.37 | 21.40 | 346 | 4635 |
| USA15 | 62.00 | 19.30 | 12.60 | | 1197 | 12951 |
| UX15 | 53.00 | 30.00 | 34.90 | | 1494 | 50002 |

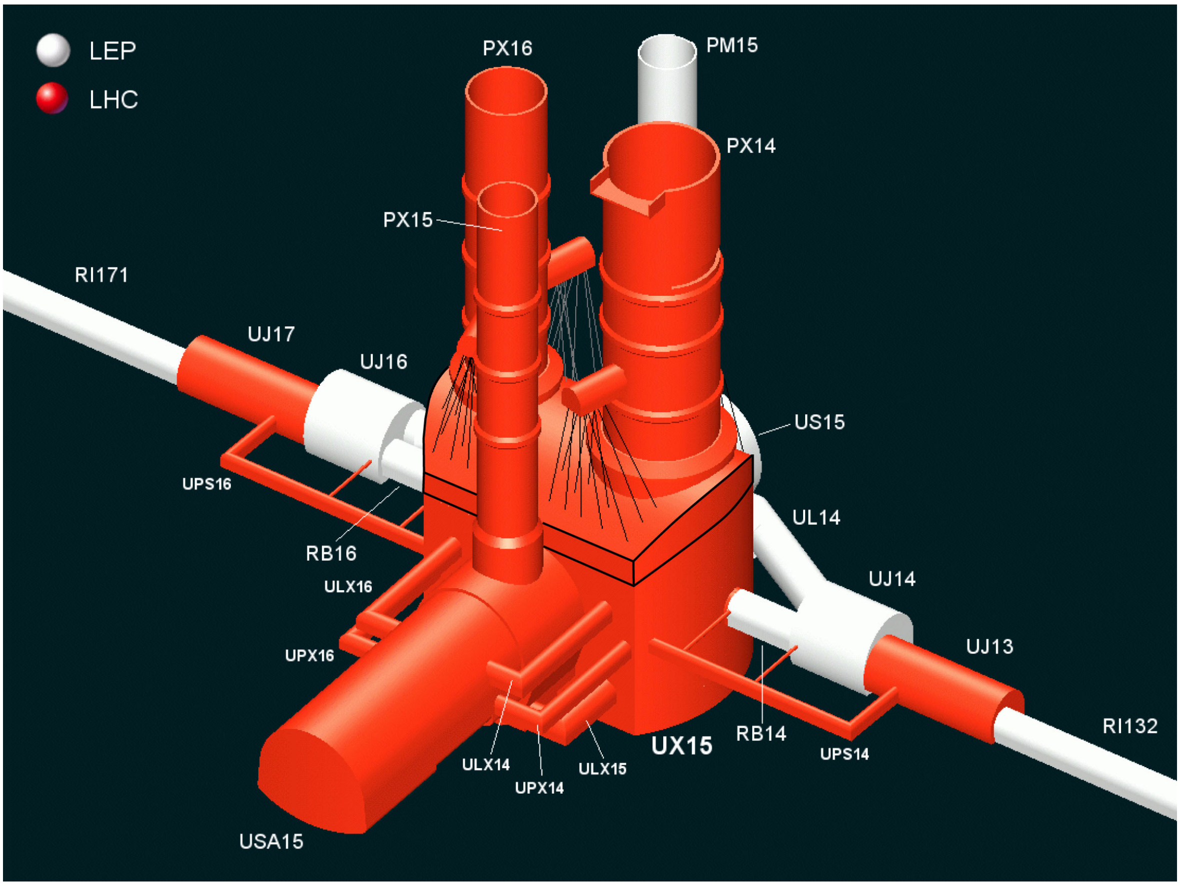


**Figure 1-1** Point 1 underground isometric view, displaying the UX15 cavern vault anchoring system

noisy equipment are built with cast in-situ or prefabricated concrete with thick internal insulation, while the other ones are made up of steel structures on which are fixed steel cladding and roofing, on top of concrete foundations. The main features of the various building types, together with their functions are summarised below:

### LEP buildings (existing before LHC works)

- SD1
  Steel building on top of the PM15 shaft, giving access to the US caverns. It is used to transfer equipment to the service cavern below, a use which is unchanged for LHC.
- SE1
  Concrete platform at ground level fitted with electrical equipment.
- SEM-SES1
  Concrete/steel single storey building with false floor, used as electrical substations. This building has been extended in the frame of the LHC project to cope with additional requirements.
- SR1
  Steel building with false floor, which was used to house the power converters of LEP. It has been given a variety of new uses including the housing of a clean room for ATLAS inner detector.
- SU1
  Concrete building dedicated to the cooling and ventilation of the machine areas. Its use is unchanged for the LHC.
- SF1
  Concrete building housing cooling systems.
- BA6
  Concrete/steel building housing equipment dedicated to the SPS.

**LHC buildings (new)**

- SCX1
  Office buildings required by the ATLAS collaboration. It is a three storey building of reinforced concrete with glass facades. It provides office space together with the main experimental control room and some technical rooms, mainly for computing facilities.
- SDX1
  Steel buildings on top of the PX15 shaft for personnel and equipment access to the underground areas through the USA15 cavern.
- SF1
  Concrete cooling towers for the ATLAS detector. The SF1 tower also cools SPS BA6. To compensate, LHC Point 1.8 is partially cooled by the SPS loop.
- SGX1
  Concrete/steel building for the storage and mixing of gases for the ATLAS detector. As for the LEP SG buildings, it has been designed so that in the unlikely case of an explosion within the building, the roof will come off, thus releasing the pressure.
- SH1
  Concrete building housing the cryogenic compressors and equipment required by the ATLAS detector.
- SHE1
  Steel tanks for storage or recuperation of helium, placed over two concrete foundations.
- SUX1
  Concrete buildings for housing the cooling and ventilation equipment required for the ATLAS underground areas

- SX1
  Steel building with wood cladding for the transfer and lowering of the ATLAS detector components down shafts PX14 and 16 into the experimental cavern below.
- SY1
  Concrete/steel building for access control and safety monitoring of the surface areas.
- SEG11
  Steel containers on a concrete slab housing the diesel power generators for ATLAS systems
- SGA1
  Concrete platform receiving outdoors cryogenics equipment

All buildings are surrounded by black topped access roads and car parks fitted with the necessary drainage facilities, including oil separators.

**Table 1-2** Table of dimension of the main surface structures used by ATLAS systems

| Structures | Length (m) | Width (m) | Height (m) | Area ($m^2$) | Volume ($m^3$) | Elect. door W (m)xH (m) |
|---|---|---|---|---|---|---|
| SCX1 | 25.00 | 6.00 | 9.65 | 150 | 1470 | |
| SD1 | 18.15 | 9.15 | 13.15 | 166 | 2185 | 6.00 x 6.00 |
| SDX1 | 34.05 | 17.00 | 13.60 | 578 | 7050 | 6.00 x 6.00 |
| SGX1 | 40.60 | 10.40 | 4.25 | 422 | 1794 | |
| SH1 | 40.60 | 26.00 | 9.15 | 1055 | 9678 | |
| SR1 | 93.10 | 17.15 | 7.46 | 1584 | 14826 | 3.95 x 4.00 |
| SUX1 | 40.60 | 24.00 | 12.20 | 974 | 11887 | |
| SX1 | 84.60 | 24.00 | 17.70 | 2030 | 35938 | 8.00 x 9.50 |
| SY1 | 10.70 | 9.20 | 3.20 | 98 | 315 | |

## 1.4 Organization of the work and time schedule

Under the heading of Package 1, the civil engineering structures for the ATLAS Experimental Area were dealt with by:

- The civil engineering group of ST (then TS) for the preliminary studies, general management, contracting and coordination.
- An architect (H. Dessimoz from Meyrin) who made the necessary decisions on the general aspect and the materials to be used for the surface structure and prepared, presented and supported the building permits applications.
- A consortium of consultants made up of EdF (France) and Knight-Piésold (United Kingdom) for the works call for tender documentation, detailed design and site supervision until the hand over of the completed structures.

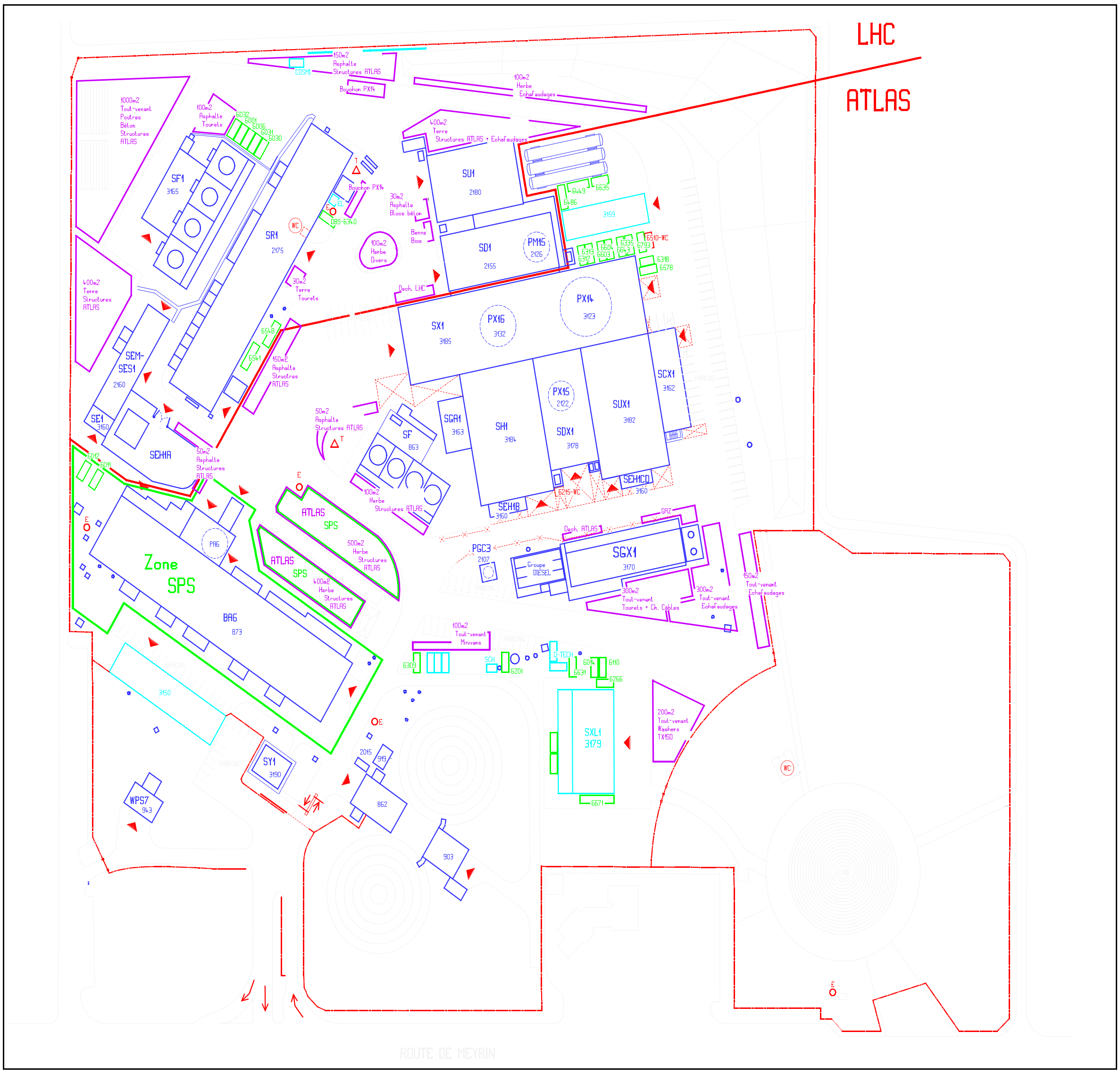


**Figure 1-2** Point 1 surface structures

- A set of experts in various domains like for instance the Deriaz SA consultant for all geotechnical matters.
- A panel of 5 international experts for dispute adjudication purpose.
- A consortium of safety consultants made up of Cossec (France) and Waterman (United Kingdom).
- A consortium of contractors made up of Zschokke-Locher (Switzerland), Baresel (Germany) and Teerag-Asdag (Austria) for the carrying out of all civil engineering works, both on surface and underground.

The calls for tenders were launched and subsequent contracts placed in due time by the civil engineering group to the above firms in order to fulfil its obligations and match the ATLAS requirements.

The main milestones were the following:

- 1994: start of pre-design by the civil engineering group and consultants selection procedure.

- July 1996: start of design by the selected consortium of consultants and contractors selection procedure.
- April 1998: start of the civil engineering works (surface).
- February 1999: start of the civil engineering works (underground).
- September 2002: hand over of the USA15 service cavern.
- April 2003: hand over of the UX15 detector cavern.
- June 2003: hand over of the last surface building (SX1).

In total, close to 300.000 tons of rocks were excavated and about 50.000 tons of concrete were casted for the civil engineering works at Point 1.

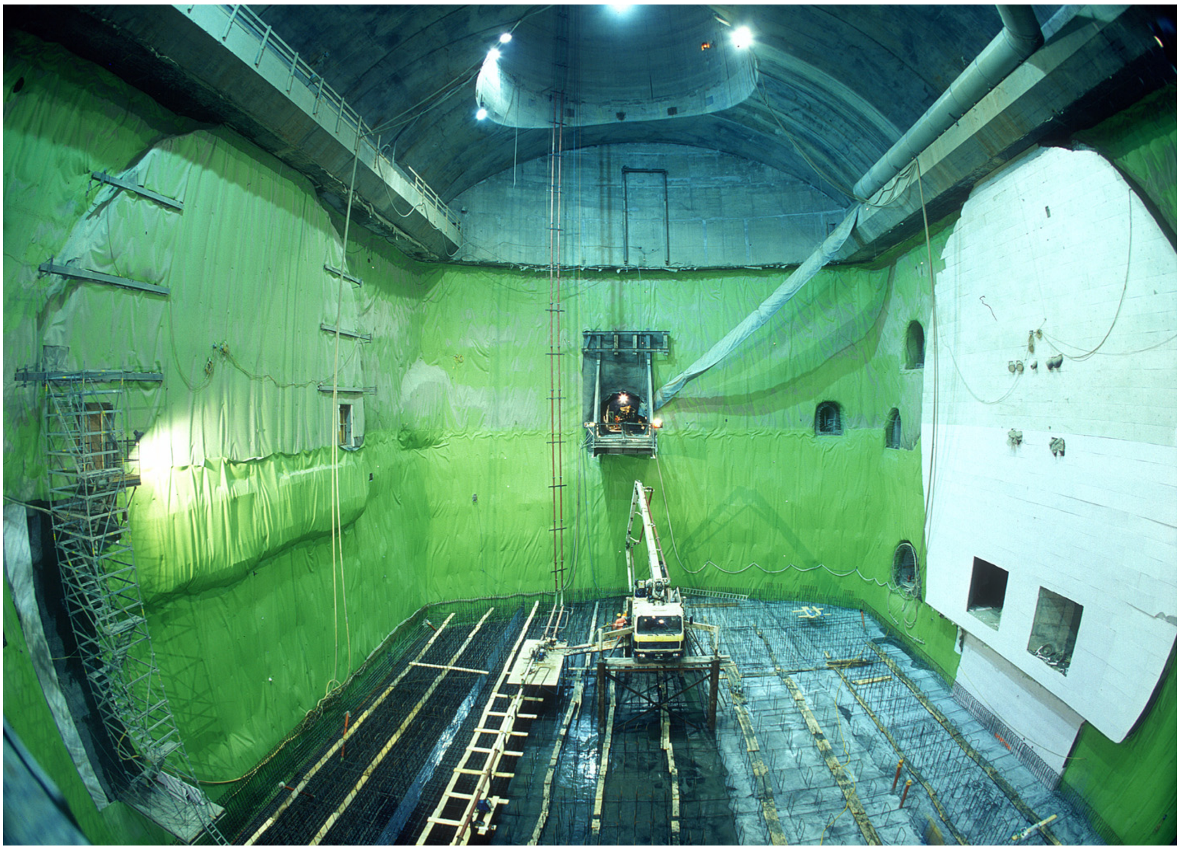

**Figure 1-3** The UX15 cavern. The excavation is finished, the water-proof liner is in place, and the concreting operations of the slab have started. The suspended vault is clearly visible.

No claim was received from the consortium of contractors during the implementation of the work (or later). All disputes were settled as they arose, and in some case before the hand over of the works, on amicable grounds. One claim only was received form the consortium of consultants. It was settled with the help of the panel of adjudicators which was appointed for this purpose since the beginning of the works.

## 1.5 Safety

Last but not least, it is to be highlighted that thanks to an efficient common CERN-French-Swiss safety organization set in place from the very start of the project (and despite the dangerous nature of the underground works) no serious injury was noted, neither amongst the 160 workers (peak time) on the contractors and consultants side, nor on the CERN management team side.

## 1.6 References

[1-1] LHC Design Report, VOL. II, The LHC Infrastructures and General Services,

[1-2] “Les ouvrages de génie civil du projet LHC au CERN”, paper for “le congrès international de l'Association Française des Travaux En Souterrain (AFTES)”, October 2005, J.L. Baldy

**Table 1-3** References to technical drawings and contracting documents

| Structures | Technical drawings in CDD[a] | Contracting documents |
|---|---|---|
| Point 1 surface and underground | LHC-JV1% | T052/ST/LHC |

a. CDD is CERN Drawing Directory, https://edms.cern.ch/cdd/plsql/c4w.get_in

# 2 Electrical Overhead Travelling (EOT) Cranes

## 2.1 Introduction

The huge scale LHC ATLAS detector project required Electrical Overhead Travelling (EOT) cranes of various capacities and technical features since the entire assembly and installation phase depended on the crane characteristics and performance.

## 2.2 Design and procurement

The mechanical classification of the EOT cranes was specified according to the estimated operation duration and load spectrum during the project lifetime, including assembly, installation, operation, maintenance and dismantling.

The five double-girder EOT cranes used for the assembly and installation of the ATLAS detector and its infrastructure at Point 1 were supplied by the German manufacturer Brunnhuber Krantechnik GmbH.

## 2.3 Particularities

The layout of the EOT cranes was based on standard industrial practice and norms. But the lifting of delicate ATLAS detector components required in addition for example micro speed for the exact positioning and precisely adjustable speed/frequency converters since many components had very limited tolerances regarding acceleration, inclination and vibration values.

The major assembly EOT cranes were also used for the transfer of components from the surface to the underground areas. These EOT cranes were adapted in terms of crane geometry and safety appliances by adding an additional safety break that operates directly on the lifting cable drum, overload and over-speed detection as well as a set up with a shaft operation mode including programmable shaft coverage zone(s).

To facilitate the maintenance of the ATLAS detector, the EOT crane PR776 in building SX1 can memorize the position of ten detector components, so that the crane will position itself as close as possible to a detector part without requiring human presence and consequently reducing the radiation dose absorbed by the on-site personnel.

The UX15 cranes were purchased with a so called “positive platform” and two “negative platforms”:

The positive platform is a scissor platform that can sit on the crane beams and be translated by a mechanical link to the chariot. It is used to reach the vault of the UX15 cavern, and proved useful for the installation of ventilation ducts, cryogenic pipes and also fire fighting foam pipes. The installation procedure of the positive platform is rather difficult and time consuming, requiring testing of the crane and platform after each installation and removal.

The negative platforms were ordered to be used for the installation of the big ventilation ducts that run below the crane railways benches in UX15. They hang 5 m below the crane beams. They were seldom used since more practical installation methods were found. It was also thought that the negative platform may be used for access between the muon chambers big wheels, but no real adaptation has been designed so far.

## 2.4 Installation milestones

The EOT cranes were amongst the first infrastructure to be installed following the completion of the surface buildings SX1 and SDX1 and the underground caverns USA15 and UX15. Indeed, they were required to proceed with the installation of general service such as ventilation and cooling units, metallic structures, cryogenic and electrical equipment before the assembly and installation works of the experiment could really start.

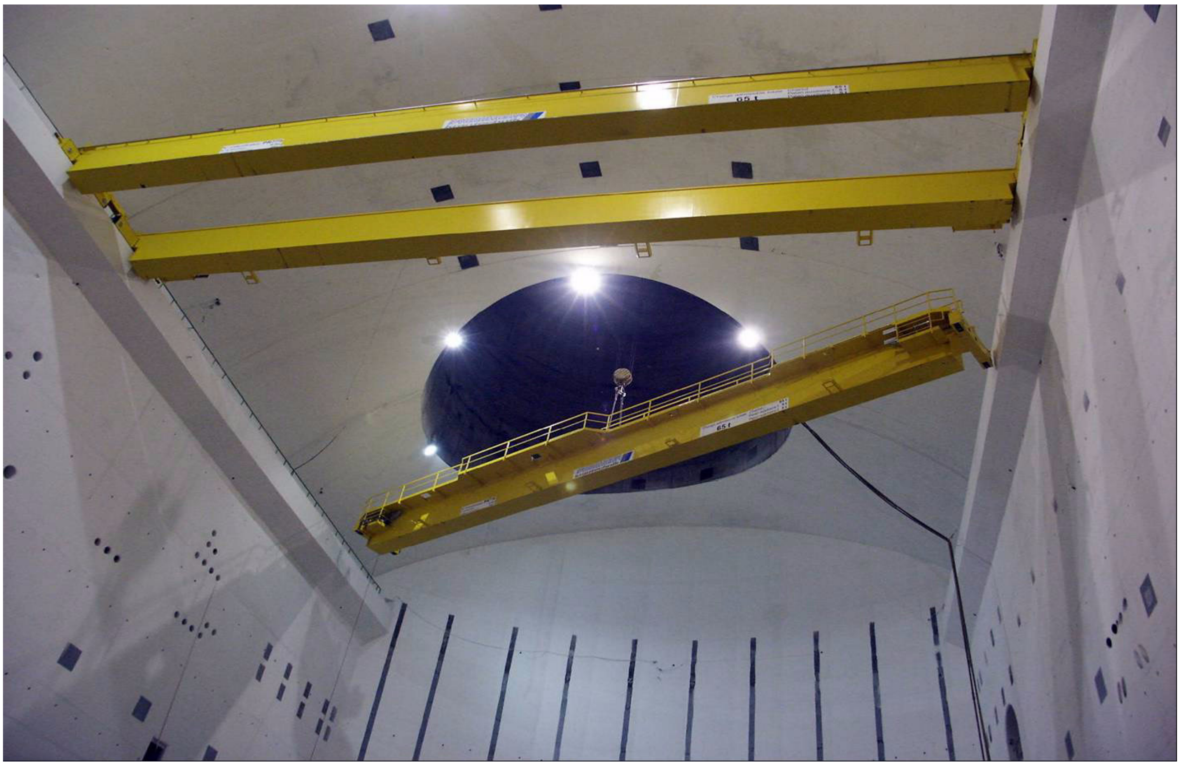

**Figure 2-1** Installation of the EOT cranes in UX15 cavern

The physical installation works were well planned and proceeded quite rapidly. Nevertheless, the commissioning of these rather complex and delicate EOT cranes required more time than expected, and they encountered a number of life start problems, that caused disruption in the installation work of other infrastructure elements. The downtime remained always short due to an efficient on site maintenance team, and the prompt intervention of the supplier, usually in the framework of the guarantee.

## 2.5 Operation

The operation of the ATLAS EOT cranes requires well trained and experienced crane drivers, an on-site maintenance team and a performing after sales service of the manufacturer. In order to assure the availability and in order to reduce the downtime, a risk analysis regarding the required spare parts was performed, which took in consideration mainly three factors:

- criticality of EOT crane
- statistical possibility of equipment failure
- spare part delivery time.

Based on the outcome of this analysis, a spare part set was assembled and put in store.

**Table 2-1** ATLAS cranes characteristics

| Crane Number | Location | Safe Working Load | Span | Lifting Height | Travel |
|---|---|---|---|---|---|
| HHLPR-0776[a] | SX1 | 2 x 140 t | 20 m | 102 m | 84 m |
| HHLPR-0777 | SX1 | 20 t | 18.6 m | 100.7 m | 84 m |
| HHLPR-0778 | UX15 | 65 t, 5 t, 5 t | 28.7 m | 25 m | 43.6 m |
| HHLPR-0779 | UX15 | 65 t, 5 t, 5 t | 28.7 m | 25 m | 43.6 m |
| HHLPR-0771 | SDX1 | 16 t | 15.4 m | 91 m | 32.62 m |

a. The layout of this EOT crane allows to increase the safe working load up to a total of 300 t but for not more than 10 hoisting operations during the equipment lifetime.

## 2.6 References.

**Table 2-2** References to technical drawings and contracting documents

| EOT crane | Technical drawings in CDD[a] | Contracting documents in CFU[b] |
|---|---|---|
| HHLPR-0776 | LHCHMOAE0002 | F420 |
| HHLPR-0777 | LHCHMOAF0001 | F420 |
| HHLPR-0778 | LHCHMOAG0001 and LHCHMOAG0003 | F420 |
| HHLPR-0779 | LHCHMOAG0002 | F420 |
| HHLPR-0771 | LHCHMOAD0001 | F420 |

a. CDD is CERN Drawing Directory, https://edms.cern.ch/cdd/plsql/c4w.get_in

b. CFU is Contract Follow-Up, https://cfu.cern.ch/cfu/first$.startup

# 3 Metallic structures

A large quantity of steel structures have been installed in underground caverns and in surface buildings. The design, manufacture and installation of these structures was managed by the CERN EST division (that later became TS department), and spanned over 9 years (between 1996 and 2005) in close relation with the ATLAS technical coordination.

## 3.1 HS and HO: the UX15 steel structures

The blue structures that surround the ATLAS detector have both roles of providing personnel access to the periphery of the detector at all heights and to support all the equipment that has to be located close to the detector: proximity cryogenics, electronics racks, gas distribution racks, electrical switchboards, services distribution lines (gas, water, coolants, power), etc. The HO structure (that covers the tympanums of the UX15 cavern) also supports the MEO precision muon end-cap chambers.

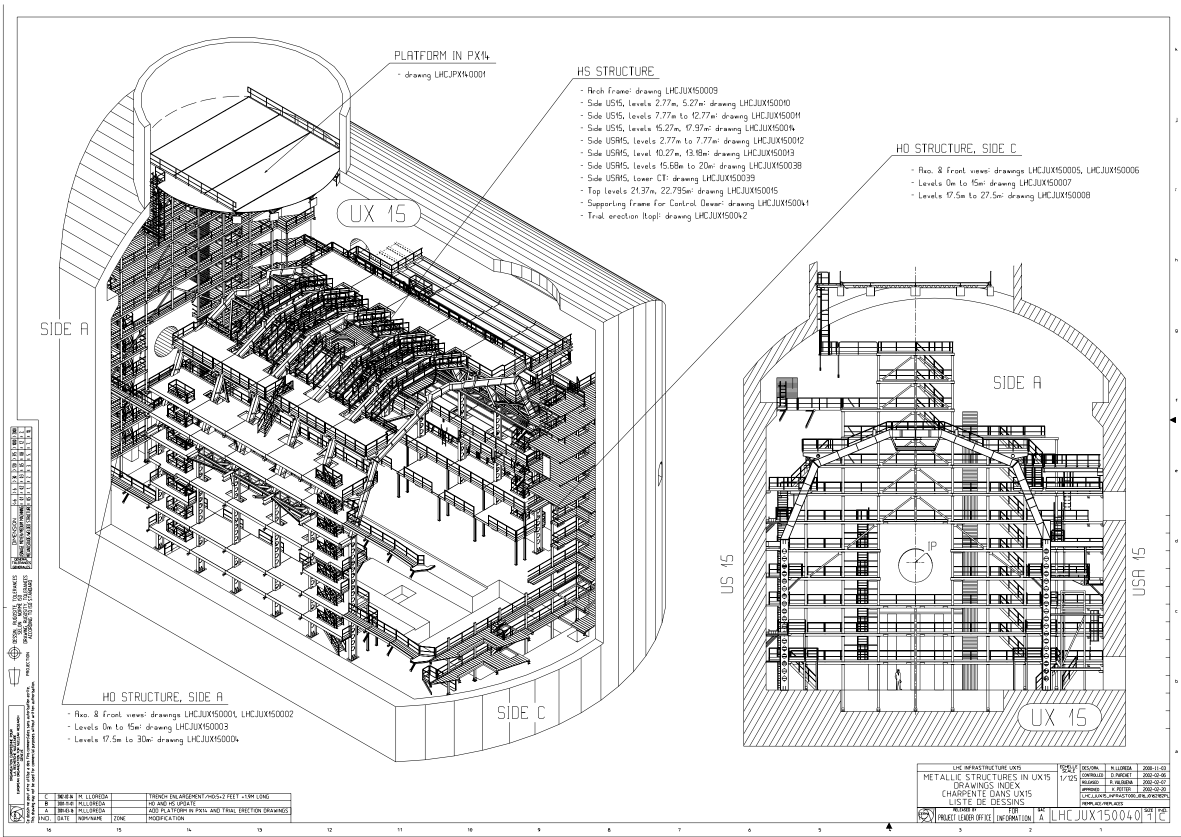


**Figure 3-1** The HS and HO steel structures in UX15

The design of these structure was a joint effort between the ATLAS technical coordination and the CERN mechanical design office in the former EST division that later became the TS department.

The design process started in 1996, and a number of iterations were needed to reach an agreement on the geometry for these 13 storey-high structures. Indeed, the design of these structures was progressing along with the design of the detector and of all the equipment to be supported, in particular the proximity cryogenics. The structures were calculated using finite element codes, according to Eurocode 3 for what concerns the statics, and Eurocode 8 for the seismic conditions.

The contract for manufacture and on-site installation of all steel structures of ATLAS underground and surface buildings (and also of CMS experiment) was awarded to the italian Cosmi group end of 2001.

The assembly of HO structure started in June 2003 and was completed by end of 2003. For this a diesel mobile crane had to be used underground since the overhead travelling cranes do not have the needed coverage. Specific measures had to be implemented, in particular adapted filters were installed on the exhaust of the diesel engine, as well as regular measurements of the quality of air in the cavern.

The HS structure that surrounds the detector was the most tricky to design and assemble since it is very close to the detector in some places, supports very heavy weights, spans over the whole width of the cavern, thus linking two opposite walls likely to move due to civil engineering deformations.

**Figure 3-2** Installation of the last HS arch above the toroid barrel magnet

It had to be assembled in 2 stages: the large pillars and gangways up to 20 m high were installed at the same time as the HO, but the top of the arches was installed only after the completion of the ATLAS barrel toroid magnet, and with very little margin left. The two structures that span more than 20 m in 3 dimensions had to match within less than 2cm. The last arch was finally and successfully installed end 2005.

## 3.2 Metallic structure in USA15

The USA15 service cavern is equipped with a steel structure splitting the volume in 3 levels and a number of specialized rooms.

The manufacturing and installation of this large structure was part of the general contract awarded to the Cosmi group.

Due to delays in the installation of the elevator in the PX15 and of the overhead hoist in USA15, the work started in degraded conditions: the access to the underground was provided by a work site lift of the "Alimak" type, which is very slow, and not too reassuring. The installation of the large steel beams of the structure had to be done with a forklift instead of the overhead hoist, which lead to some safety issues that had to be solved in an efficient collaboration between the company, the experimental area management team and the CERN safety coordination.

The installation of the partitions fireproof walls, ceilings and doors was subcontracted to a local company (Isol Application), that worked in parallel with Cosmi.

## 3.3 Steel structures in the access shafts

Both PX14 and PX15 access shafts are equipped with steel structures.

The PX14 only features a steel platform at its bottom, that acts as a plug. This plug has both roles of protecting the experiment against fall of objects (in particular when removing the concrete shielding beams that will close the shaft during the LHC operation), and of creating a barrier to ease the air conditioning of the UX15 cavern.

The PX16 is not equipped with such a plug in order to ease the evacuation of He in case of leak in the magnets cryogenic system.

The PX15 is equipped with stairs and supports for the services that link the USA15 to the surface. These stairs were installed in the shape of steel modules, pre-equipped with stairs, handrails, toe-boards and cable trays, that were stacked and bolted together in the shaft.

## 3.4 Steel structure in SDX1

The TDAQ room was installed on surface in SDX1. It is a 2 storey steel structure that hosts 100 electronics racks. It was added to the Cosmi general contract since the design was not finalized at the time of the general call for tender.

## 3.5 References

**Table 3-1** References to technical drawings and contracting documents

| **Structures** | **Technical drawings in CDD**[a] | **Contracting documents in CFU**[b] |
|---|---|---|
| UX15 | LHCJUX15% | IT-2706/EST/LHC |
| USA15 | LHCHJUSA1% | IT-2706/EST/LHC |
| PX15 | LHCJPX15% | IT-2706/EST/LHC |
| PX14 | LHCJPX14% | IT-2706/EST/LHC |
| SDX1 | LHCJSDX1% | IT-2706/EST/LHC |

a. CDD is CERN Drawing Directory, https://edms.cern.ch/cdd/plsql/c4w.get_in
b. CFU is Contract Follow-Up, https://cfu.cern.ch/cfu/first$.startup

# 4 Cooling and ventilation for the ATLAS experiment

## 4.1 Introduction

The CERN Cooling and Ventilation group in charge of the experimental area infrastructure, sent out more than 10 invitations to tender and a number of price inquiries to purchase all the CV related infrastructure for ATLAS, starting already in 1996. The whole system was designed by the CERN TS-CV, and the realisation was contracted through international tendering.

## 4.2 Design

The Heating, Ventilation and Air Conditioning (HVAC) systems for ATLAS comprise units dedicated to the control of temperature and humidity in the UX15 and USA15 caverns. In addition units are dedicated to the heating and ventilation of the surface buildings housing different items of infrastructure, units dedicated to the control of temperature and humidity in the UX15 and USA15 caverns. Finally a set of units, whose function is related to safety are included. These include the pressurization of the concrete modules forming lift shafts and lobbies, smoke extraction, gas extraction in the UX15 and USA15 and argon gas extraction in the UX15. This argon gas extract system was the subject of a special stress analysis by the contractor for the installation of stainless steel ducts in view of the very low temperatures concerned.

TS/CV has performed a number of numerical simulations to study in detail the temperature field around the muon chambers and some safety scenarios like the evacuation of argon in case of massive leak in the UX15. Simulations were also performed to analyse the effects of the magnets energy quench in the area of the resistors on the third level of the USA15. These simulations have served as basis for further analysis of the internal air cooling of the detector and promoted further studies and modifications to the layout in the ATLAS cavern. One such simulation can be seen at:
http://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=19774

## 4.3 Installation

The cooling and ventilation installation was one of the first infrastructure items to be installed when the buildings were handed over to CERN, and in particular in surface buildings.

Temporary ventilation systems were installed, as from 2004 to provide fresh air underground during the works, in particular in relation with the use of thermal engines (cranes and personnel platforms) for the installation in the UX15.

One of the most labour demanding piece of work was the SUX1 building, where the chilled water production plant and most of the air handling units for the underground structures are housed.

**Figure 4-1** Installation of air ducts in the shaft and experimental cavern.

An also very challenging tasks was the installation of air supply and extraction ducts in the PX14 shaft and on the vault of the UX15 cavern (Figure 4-1), this system having the role to extract the 180 kW of heat released into the air of the cavern by the ATLAS detector. This included the supply and extraction ducts and some safety-related systems like the gas extraction.

The foam-based fire extinguishing system (red piping and distribution canons), although responsibility of ATLAS, was installed inside the UX15 by one of the TS-CV contractors via the necessary contract amendment.

## 4.4 Commissioning

The different installations were commissioned as they were completed, the SF1 being one of the first ones to be put in service, together with the HVAC of the surface buildings. This system serves as primary cooling for the chilled water production plant in SUX1 as well as for the cryogenic compressors in SH1. These cooling towers, containing hundreds of cubic meters of water, are used as spare water supply for the fire fighting systems and services in case of need.

## 4.5 Operating conditions

Table 4-1 summarises the main thermal loads defined by ATLAS for the different conditioned spaces.

Of particular interest are the conditions specified for the UX15 cavern, where the absolute humidity must be below 10°C dew point temperature. There is also a constraint on the relative humidity (maxi. 60% at

**Table 4-1** Main thermal loads

| Building | Conditioned spaces | Cooling load (kW) |
|---|---|---|
| UX15 | Whole cavern | 180 kW after upgrade |
| US15 | Rack room level 2 | 20 kW |
| USA15 | Rack rooms level 1 and 2 | 125 kW |
| USA15 | Cryo/magnets power supply area | 80 kW |
| USA15 | TS/EL Transformers/cubicles | 80 kW |
| SDX1 | | 0 (marginal loads from UPS), not treated |
| SUX1 | | 0 |
| SCX1 | Control room/offices | 145 kW, 66 kW, 40 kW |
| PX15 | Pressurised modules | 40 kW |

the bottom of the cavern where the temperature will be the lowest, 18°C). These values are obviously attainable as long as the cavern is closed. During the construction phase ATLAS has specified an additional request to control also the humidity during the shutdown scenarios, which if in winter, can lead to very low humidity values which are of concern for the detectors. In order to improve these situations, CV has installed a humidification system by means of steam injection.

In view of the very tight installation schedule, and to make this compatible with the maintenance and operation activities of the infrastructure, a series of minor modifications have been performed in order to allow for alternative cooling during the stop periods for the most critical systems (vacuum pumps, SR1 assembly area, racks in the counting room USA15).

## 4.6 Specific cooling systems

At the request of ATLAS, CV has installed a racks cooling system, composed of mixed water (cool water slightly above the dew point temperature of the air) production and distribution station and HVAC system for the ATLAS racks installed in US15.

The cooling systems specific for the detector (some of which are installed and cooled by the station) in the USA cavern, have been brought into operation between 2005 and 2007, the last two stations (muon cooling stations, housed in the UX15) being lowered into place in October 2007.

Finally, although outside the experimental area premises, TS-CV was also involved in the cooling and ventilation infrastructure of the different assembly areas at CERN (building 180 for LAr calorimeters, building 190 for the tile calorimeters and building SR1 for the inner detector).

## 4.7 References

The different documentation in relation with the tendering process is available on EDMS (engineering specifications), on CFU (official tendering documents) and CDD (tendering and execution drawings). The whole integration process has been conducted by ATLAS via 3D Euclid models.

**Table 4-2** References to technical drawings and contracting documents

| System | Technical drawings in CDD[a] | Contracting documents in CFU[b] |
|---|---|---|
| HVAC of the experimental area | LHCU3182% | F405 (IT-2659) |
| Cooling Plant in USA15 | LHCU3125% | F478 (IT2632) |
| HVAC of surface buildings of the LHC | LHCU3182%, LHCU3178%, LHU3185%, LHCU3162% | F300 (IT2524) |
| Industrial Piping in shafts | LHCU3123% | F337 (IT2780) |
| HVAC of the SCX1 | LHCU3162% | F480 (IT-3046) |
| Underground discharge water | LHCF3122% | F526 (IT-3176) |
| HVAC computer room SDX1 | LHCU3178% | IT-3290 |

a. CDD is CERN Drawing Directory, https://edms.cern.ch/cdd/plsql/c4w.get_in

b. CFU is Contract Follow-Up, https://cfu.cern.ch/cfu/first$.startup

# 5 Electrical distribution for ATLAS

## 5.1 Generalities

The CERN electrical network is supplied from EOS (Energie Ouest Suisse), the Swiss regional grid company, by a 130 kV feed and from RTE (Réseau Transport Électrique), and from EdF, the French national grid company through a 400 kV feed. The main 400/66/18 kV substation on the Prévessin site (France) with 66 kV and 18 kV feeders, is owned and operated by CERN.

The 130 kV station on the Meyrin site (Switzerland) is owned and operated by SIG (Services Industriels de Genève), the Geneva local power distributor, and the medium voltage distribution, with its 18 kV feeders is owned and operated by CERN.

The entire CERN network is fed through the 400 kV RTE supply during accelerator operation and fed through the 130 kV SIG/EOS supply typically during the 400 kV maintenance. Power change-over between two sources (known as “auto transfer”) is performed in real conditions without power cuts at least once a year. Accelerator operation on the 130 kV supply is not possible.

### 5.1.1 66 kV LHC distribution

CERN has a 66 kV underground cable network which assures the power transmission from the Prévessin substation to the high-power LHC (Large Hadron Collider) access points (points 1, 2, 4, 6, and 8). The end users are supplied at 18 kV, 3.3 kV and 400 V voltage levels.

The 66 kV network supplies the LHC high-power points via cables laid in trenches and 66/18 kV, 38 MVA transformers installed at points 2, 4, 6 and 8 supply. A special 66/18 kV 70 MVA transformer supplies the LHC machine in point 1, ATLAS experiment and Meyrin site.

### 5.1.2 18 kV LHC machine and experiments distribution

The 18 kV LHC machine network is fed from the 66/18 kV transformers. This network supplies the LHC machine and experimental areas systems (magnet rectifiers, radio frequency generators, cooling and ventilation of the LHC tunnel).

### 5.1.3 18 kV LHC general services distribution

The 18 kV LHC general services network is fed from an 18 kV cable loop following the tunnel of the LHC machine. The loop passes through all LHC points where it supplies 18 kV switchboards, in surface and underground substations.

The main Meyrin substation is fed by a 60 MVA cable link (at 18 kV level) from the LHC point 1 substation.

### 5.1.4 Safety distribution

The safety network is a part of the CERN electrical network, which, in normal operation, is fed from the general services network in the LHC. In case of voltage loss, the secured network is automatically isolated from the rest of the network and re-supplied from the diesel generators. This network only supplies equipment designated as required for personnel safety.

### 5.1.5 Low voltage distribution

The LV distribution is designed to supply the end users equipment. As a result of the equipment diversity, the low voltage distribution has been split by utility distribution such as: machine distribution (from ERD switchboards), experimental distribution (from EXD switchboards), general services (from EBD switchboards), and safety distribution (assured by diesel generators, from ESD and EAD switchboards).

Technical systems like safety transmissions, communications, cryogenics, cryogenic instrumentation and power converter control systems, require uninterrupted power supplies, therefore they are fed through UPS systems (EOD's switchboards).

### 5.1.6 48 Vdc distribution

Auxiliary systems like high and low voltage protections, remote control, communication system, emergency lighting, emergency stop, etc., are fed by a 48 Vdc source, with battery backup.

### 5.1.7 Emergency stop system

All buildings at CERN are equipped with emergency buttons. These buttons are strategically positioned to allow an emergency interruption of all the electrical supply in the area. The buttons are interconnected into specific circuits and marshalled in dedicated racks that trip the specific equipment as defined in logic matrices. All electrical supply in the area should be interrupted except for the safety network (ESD's switchboard and some critical UPS distributions).

## 5.2 Electrical distribution in ATLAS experiment

### 5.2.1 66kV distribution at LHC-1

Point 1 is supplied by an underground 66 kV cable from the 400 kV station in Prévessin. A 66/18 kV 70 MVA transformer supplies the ATLAS experiment, LHC-1 machine and the Meyrin site. The power is distributed via three 18 kV switchboards from the SEM12 main station (building 2160) at 18 kV level.

### 5.2.2 18kV distribution in LHC-1 ATLAS

The required power in the ATLAS experiment is distributed from two switchboards (EMD2/1E and EMD4/1E) in the SEM11 station (building 3165). These switchboards are supplied by two 18 kV cable links of 30 MVA each from SEM12 station. The Table 5-1 shows the detailed distribution at 18 kV level including the installed power.

**Table 5-1** ATLAS 18 kV distribution

| **Switch board** Buildings supplied | **Feeder** | **Description** | **Equipment supplied** | **Installed power** |
|---|---|---|---|---|
| **EMD2/1E** | 200/1E | Coupling EMD2 - EMD4 switchgears | EMD400/1E | - |
| | 201/1E | Incoming Supply from SEM12 station | EMD804/1E | 30 MVA |
| | 202/1E | Backup coupling LHC loop | EMD3/1E | 12 MVA |
| SR1 | 203/1E | Power converter | LP1-LR1 | 592 kVA |
| SUX1 | 204/1E | Ventilation | UIAC114 | 2 MVA |
| SUX1 | 205/1E | Ventilation | UIAC115 | 2 MVA |
| SH1, SUX1 | 206/1E | Compressors for cryogenics (3,3kV) | EKD1/1H | 9 MVA |
| SUX1 | 207/1E | Chilled water | UIAC111 | 2 MVA |
| USA15 | 208/1E | Racks ATLAS CANALIS in USA15 | EXD1/15A | 2 MVA |
| UX15, USA15 | 209/1E | Racks ATLAS in UX15 | EXD2/15A | 2 MVA |
| USA15 | 210/1E | ATLAS cooling and ventilation | EWD1/15A | 1250 kVA |
| **EMD4/1E** | 400/1E | Coupling EMD2 - EMD4 | EMD400/1E | - |
| | 401/1E | Incoming Supply from SEM12 station | EMD904/1E | 30 MVA |
| RR13 | 402/1E | LHC machine network | ERD1/13 | 1250 kVA |
| SH1 | 403/1E | Compressors for cryogenics (3,3kV) | EKD2/1H | 4 MVA |
| USA15 | 404/1E | Control Racks cryogenics | EQD1/15A | 1250 kVA |
| USA15 | 405/1E | ATLAS magnet supply | EXD3/15A | 2 MVA |
| SF1 | 406/1E | Cooling towers | UIAC110 | 2 MVA |
| SX1 | 407/1E | Ventilation | UIAC155 | 630 kVA |
| RR17 | 408/1E | LHC machine network | ERD1/17 | 630 kVA |

**Table 5-1** ATLAS 18 kV distribution

| **Switch board** Buildings supplied | **Feeder** | **Description** | **Equipment supplied** | **Installed power** |
|---|---|---|---|---|
| US15 | 409/1E | Racks ATLAS in US15 | EXD1/15 | 1250 kVA |
| SDX1 | 410/1E | Racks ATLAS in TDAQ room | EXD1/1DX | 1250 kVA |

In addition to this point, ATLAS infrastructure supplies are taken from LHC general services loop. The Table 5-2 shows the supplied buildings from LHC loop in LHC-1.

**Table 5-2** General Services distribution in LHC-1

| **Switchgear** Buildings supplied | **Feeder** | **Description** | **Equipment supplied** | **Installed power** |
|---|---|---|---|---|
| **EMD1/1E** | 100/1E | Coupling switchgear | EMD300/1E | - |
| | 101/1E | LHC General Services Loop | EMD904/1E | 15 MVA |
| | 102/1E | LHC General Services Loop | EMD101/15 | 15 MVA |
| **EMD3/1E** | 300/1E | Coupling switchgear | EMD100/1E | - |
| SE1, SR1, SF1 | 301/1E | General Services | EBD1/1E | 1250 kVA |
| USA15 | 302/1E | General Services | EBD1/15A | 1250 kVA |
| SU1, SD1 | 303/1E | General Services | EBD1/1U | 1250 kVA |
| SR1 | 304/1E | General Services | EBD5/1R | 630 kVA |
| SDX, SX, SUX, SH, SCX | 305/1E | General Services | EBD1/1DX | 2 MVA |
| | 306/1E | Safety network coupling | EFD102/1E | 12 MVA |
| | 307/1E | Backup supply ATLAS distribution | EMD2/1E | 12 MVA |

### 5.2.3 Safety distribution in ATLAS

The safety distribution in ATLAS is assured by the 3 Meyrin diesel generators at 18 kV level. The power is transformed and distributed at 400 V from the SEM11 station (building 3165). Lifts, smoke extractors, safety lighting, oxygen deficiency, fire detection and cryogenic safety systems in USA15, SDX1 and US15 are also supplied from this distribution.

### 5.2.4 3,3kV distribution

The compressors for the ATLAS cryogenics and chilled water are powered in the SH1 building from the 18 kV distribution (from EMD2 and EMD4 switchboards) and supplied at 3.3 kV level via two 18/3.3 kV transformers of 6 and 4 MVA respectively.

### 5.2.5 General facilities in ATLAS

All the ATLAS general infrastructure supplies are taken from the LHC general services loop at 18 kV. Two 18/0.4 kV transformers installed in USA15 (1250 kVA) and SDX1 (2 MVA) provide the general services power in the ATLAS buildings (USA15, UX15, SDX1, SCX1, SGX1, SH1, US15). See Table 5-2 for more details.

### 5.2.6 ATLAS critical loads: UPS distribution

The critical electronics equipment for the experiment requires a continuity of supply. The critical electronics equipment (ATLAS control room, USA15 systems, TDAQ room, SH1 cryogenics) is supplied from a redundancy 600 kVA UPS installed in SDX1. The UPS is supplied from the LHC general services distribution and in case of mains failure, the supply is assured by a 1 MVA diesel generator set. The electronic equipment is supplied from the UPS distribution (EOD switchboards) at 400 V.
UPS distribution is not affected by any emergency stops in the area.

An automatic sequencing of this electrical distribution is performed in case of power cut by an autonomous PLC. Depending on the electrical configuration, PLC executes the required manoeuvres in the electrical distribution to ensure continuity to all critical loads in the experiment. In case of generator failure during a blackout, the UPS system will assure the supply of all critical loads from batteries for 10 minutes. After this time, a load shedding will maintain supplies to only the most critical electronics in USA15 (Argon cryogenic and MCS systems) during at least 2 hours (guaranteed batteries autonomy).

### 5.2.7 ATLAS magnets supply

The central solenoid and barrel toroid magnets are supplied from the 18 kV distribution by an 18/0.4 kV 2 MVA transformer installed in USA15 cavern. The required power for these magnets is distributed from a main 400 V switchboard (EXD3/15A) installed in USA15 cavern.

The cryogenic equipment for the magnets are supplied from the same 18 kV distribution by an 18/0.4 kV 1250 kVA transformer. The power for the magnet cryogenics is distributed from a 400 V switchboard (EQD1/15A).

Finally the required cooling and ventilation in USA15 cavern is supplied at 18 kV by an 18/0.4 kV 1250 kVA transformer. The power is distributed to ventilation equipment from a 400 V switchboard (EWD1/15A).

### 5.2.8 Vacuum and heaters distribution

The vacuum vessels heater equipment are supplied from the magnets distribution in normal operation via EXD4/15A switchboard. The supply is assured by a 910 kVA diesel generator set installed in the surface with a maximum power cut of 3 minutes. In case of a power cut, an automatic sequencing of the electrical distribution is performed by a autonomous PLC. This PLC executes the required manoeuvres in the electrical distribution to ensure the heater and vacuum systems are supplied. At the same time, the PLC linked to heaters control system reports the current electrical situation.

### 5.2.9 Electronic racks in USA15 cavern

The electronic racks in USA15 (both levels) are supplied by 5 main CANALIS distribution systems. The CANALIS are supplied from the 18 kV distribution by an 18/0.4 kV 2 MVA transformer installed in USA15. A secondary CANALIS distribution equipped with a remote control TWIDO box supplies each rack in USA15. The remote control of each rack supply is controlled by a main PLC installed in the safe room in USA15 and linked to DCS and DSS systems.

### 5.2.10 Electronic racks in US15 cavern

The electronic racks in US15 (level 2) are supplied at 18 kV by an 18/0.4 kV 1250 kVA transformer. The requested power for these racks is about 600 kW and distributed from a main 400 V switchboard (EXD1/15) installed in the US15 level 2. The racks are powered via two remote controlled switchboards supplied from the main switchboard. The remote controls of each rack supply are operated by a main PLC linked to the DCS and DSS systems in the US15.

Some critical racks are powered from an UPS 160 kVA. This UPS is supplied from the safety network in point 1 (Meyrin diesel generators). In case of a safety network and mains failure, the UPS will assure the backup supply for a minimum of 8 minutes at full load.

A new safety distribution at 400 V has been installed in US15 to supply the sniffer and oxygen deficiency detection systems.

### 5.2.11 Electronic racks in UX15 cavern

The racks for different electronic systems (muons detectors, beam instrumentation, big wheels, calorimeters, etc) in the UX15 cavern are supplied from 2 main switchboards (EXD1/15 and EXD2/15). All feeders in these switchboards are remotely controlled by a PLC. The PLC installed in the safe room in USA15 cavern also communicates with the DSS and DCS systems.

The racks are powered from a secondary distribution supplied by these 2 switchboards. This secondary distribution has been implemented by users system at different levels. An interlock is wired from each rack in the UX15 to interrupt the power supply of the concerned racks in case of fire.

### 5.2.12 TDAQ room

The whole PC farm rack mounted in the TDAQ room is supplied from the 18 kV distribution by a 18/0.4 kV 1250 kVA transformer. The requested power for the whole farm is about 800 kW and distributed from a main 400 V switchboard (EXD1/1DX) installed in the SDX1 (building 3178). The racks are powered via six remote controlled switchboards (3 at each level) each supplied from the main switchboard. The remote controls of each rack supply are operated by a main PLC linked to the DCS and DSS systems in the SDX1. Some critical racks are powered from the redundancy UPS.

### 5.2.13 Cooling towers

The cooling towers installed in SF1 for ATLAS are supplied from the 18 kV distribution network via an 18/0.4 kV 2 MVA transformer. A ventilation switchboard is powered from the secondary of this transformer.

## 5.3 References

**Table 5-3** References to technical drawings and contracting documents

| System | Technical drawings in CDD | Contracting documents, in CFU |
|---|---|---|
| USA15 - POWER & EMERG. STOP | LHCEBF__1030 to 32 | B1211/ST/ATLAS |
| USA15 - LIGHTING | LHCEBL__1033 to 35 | B1211/ST/ATLAS |
| USA15 - L.V. DISTRIBUTION | LHCEB___1043 | B1211/ST/ATLAS |
| BUILDING USA15 - EOD3/15A - SCHEMATIC DIAGRAM | LHCEB___1052 to 53 | C170/ST |
| EXPERIMENT RACKS - USA15 - SCHEMATIC DIAGRAM | LHCEB___1066 to 67 | C170/ST |
| BUILDING USA15 - EBD4/15A - SCHEMATIC DIAGRAM | LHCEB___1074 | C170/ST |
| BUILDING USA15 - EOD2/15A - SCHEMATIC DIAGRAM | LHCEB___1078 | C170/ST |
| BUILDING USA15 - EOD4/15A - SCHEMATIC DIAGRAM | LHCEB___1079 | C170/ST |
| USA15 - ATLAS - SUPERVISION - EQUIPEMENT DC - SYNOPTIQUE | LHCEB___1081 | C170/ST |
| USA15 - ECJ418/15A - FACE AVANT | LHCEB___1082 | C170/ST |
| USA15 - MONITEUR SURTENSION/SOUSTENSION QUENCH HEATER | LHCEB___1083 | C170/ST |
| DISTRIBUTION 48VDC - SAFE ROOM USA15 | LHCEC___1006 | C170/ST |
| USA15 - QUENCH CABLAGE MICRO SWITCH FU - ARM.ECG301/15A | LHCEC___1011 | C170/ST |
| USA15 - QUENCH CABLAGE MICRO SWITCH FU - ARM.ECG401/15A | LHCEC___1012 | C170/ST |

**Table 5-3** References to technical drawings and contracting documents

| System | Technical drawings in CDD | Contracting documents, in CFU |
|---|---|---|
| USA15 - MSS CABLAGE MICRO SWITCH FU - ARM.ECG501/15A | LHCEC___1013 | C170/ST |
| USA15 - MSS CABLAGE MICRO SWITCH FU - ARM.ECG601/15A | LHCEC___1014 | C170/ST |
| USA15 - EQUIPOTENTIAL NET WORK | LHCEIE__1011 | C170/ST |
| CABLE LADDERS - USA15 LEVEL 3 | LHCEIW__1033 | C170/ST |
| USA15 - ELECTRICAL DISTRI-BUTION - FOR EXPERIENCE RACKS LEVEL 1 | LHCEIW__1036 | C170/ST |
| USA15 - ELECTRICAL DISTRI-BUTION - FOR EXPERIENCE RACKS LEVEL 2 | LHCEIW__1037 | C170/ST |
| CABLE LADDERS - USA15 LEVEL 1 | LHCEIW__1038 | C170/ST |
| CABLE LADDERS - USA15 LEVEL 2 | LHCEIW__1040 | C170/ST |
| USA15 - BUSBAR TRUNKING - FOR TRANSPORT 800A | LHCEIW__1043 | C170/ST |
| BORNIERS DE RACCORDE-MENT A.U. - USA15 - RACK EYU01/15A | LHCEU___1017 | C170/ST |
| LAYOUT FALSE FLOOR - USA15 LEVEL1 LOW TENSION PANEL | LHCEY___1044 | C170/ST |
| EQUIPMENTS LAYOUT - USA15 - LEVELS 1-2-3 | LHCEY___1045 | C170/ST |
| USA15 STRUCTURE OF - TRANSFORMER PREMISES | LHCEY___1046 | C170/ST |
| LAYOUT FRONT VIEW - SAFE ROOM USA15 | LHCEY___1049 | C170/ST |
| LAYOUT FALSE FLOOR - SAFE-ROOM USA15 | LHCEY___1050 | C170/ST |
| UX15 - POWERING LEVEL 0 - STRUCTURES LEVEL 0 | LHCEBF__1035 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 1 - STRUCTURES LEVEL 1 | LHCEBF__1036 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 2 - STRUCTURES LEVEL 2 | LHCEBF__1037 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 3 - STRUCTURES LEVEL 3 | LHCEBF__1038 | B1211/ST/ATLAS |

**Table 5-3** References to technical drawings and contracting documents

| System | Technical drawings in CDD | Contracting documents, in CFU |
|---|---|---|
| UX15 - POWERING LEVEL 4 - STRUCTURES LEVEL 4 | LHCEBF__1039 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 5 - STRUCTURES LEVEL 5 | LHCEBF__1040 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 6 - STRUCTURES LEVEL 6 | LHCEBF__1041 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 7 - STRUCTURES LEVEL 7 | LHCEBF__1042 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 8 - STRUCTURES LEVEL 8 | LHCEBF__1043 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 9 - STRUCTURES LEVEL 9 | LHCEBF__1044 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 10 - STRUCTURES LEVEL 10 | LHCEBF__1045 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 11 - STRUCTURES LEVEL 11 | LHCEBF__1046 | B1211/ST/ATLAS |
| UX15 - POWERING LEVEL 12 - STRUCTURES LEVEL 12 | LHCEBF__1047 | B1211/ST/ATLAS |
| UX15-POWERING -EMERGENCY STOP - GROUPS | LHCEBF__1053 | C170/ST |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 0 | LHCEBL__1036 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 1 | LHCEBL__1037 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 2 | LHCEBL__1038 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 3 | LHCEBL__1039 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 4 | LHCEBL__1040 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 5 | LHCEBL__1041 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 6 | LHCEBL__1042 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 7 | LHCEBL__1043 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 8 | LHCEBL__1044 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 9 | LHCEBL__1045 | B1211/ST/ATLAS |

**Table 5-3** References to technical drawings and contracting documents

| System | Technical drawings in CDD | Contracting documents, in CFU |
|---|---|---|
| UX15 - LIGHTING - STRUCTURES - NIVEAU 10 | LHCEBL__1046 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 11 | LHCEBL__1047 | B1211/ST/ATLAS |
| UX15 - LIGHTING - STRUCTURES - NIVEAU 12 | LHCEBL__1048 | B1211/ST/ATLAS |
| UX15 - LIGHTING - VAULT - LEVEL 9 | LHCEBL__1050 | B1211/ST/ATLAS |
| UX15 - LIGHTING - VAULT - LEVEL 10 | LHCEBL__1051 | B1211/ST/ATLAS |
| UX15 - ULX/UPS GALERIES - LIGHTING | LHCEBL__1052 | B1211/ST/ATLAS |
| UX15 - LIGHTING - GROUPS | LHCEBL__1053 | B1211/ST/ATLAS |

# 6 Racks for electronics

## 6.1 Introduction

The need for more powerful electronics and computers to be used for the control, data acquisition and analysis at the LHC experiments led to the need for new racks to house these delicate components.

The request was focused on more inner space, as well as extra cooling capabilities, that had to be operational in the magnetic fields to be found in the close environment of both CMS and ATLAS.

## 6.2 Main design parameters

The conception of the racks was led by EST/LEA group, using the experience acquired for the LEP. No clear specification was provided by future end users, and a number of iterations were needed to achieve a satisfactory design (Figure 6-1).

The agreement was obtained to use a welded steel structure with removable panels. Overall dimensions were defined using 4 main types of racks: depth 900 or 1000 mm, height between 1900 and 2580 mm, and width of 600 mm.

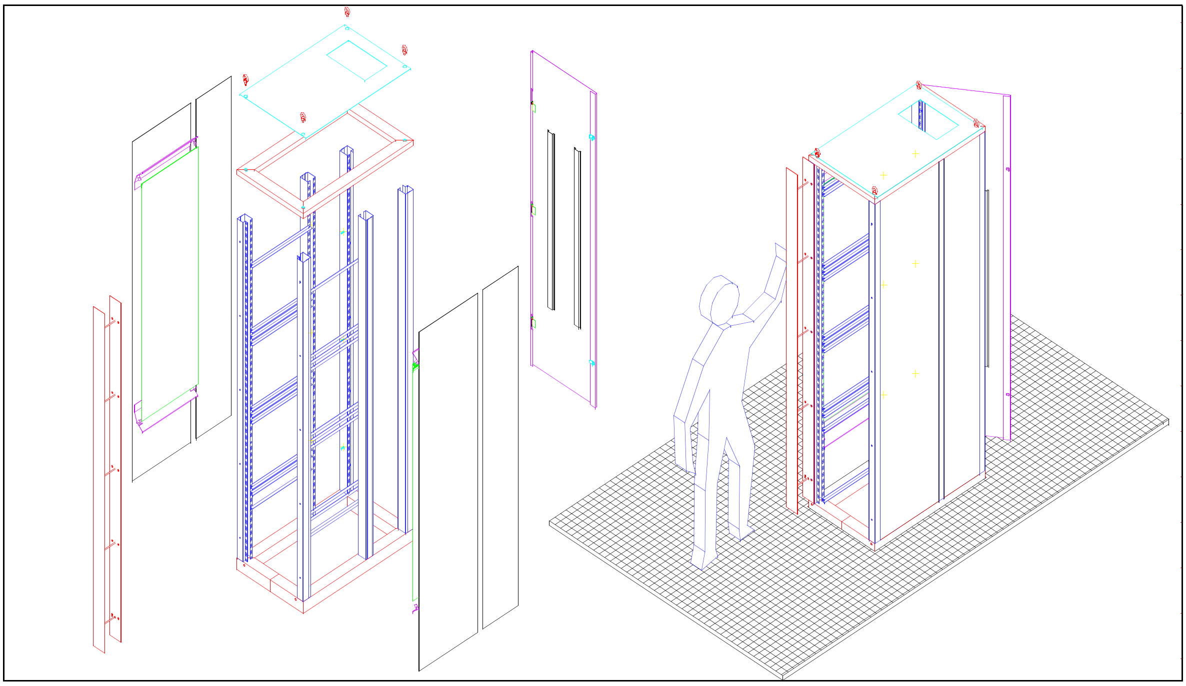

**Figure 6-1** Rack general structure

For the cooling, the LEP principle was re-used, with a closed air/water cooling circuit. The fan unit located on the top of the rack circulates air upwards through electronics and intermediate air/water heat exchanger. Additional intermediate fan trays are added when needed to speed up the air circulation (Figure 6-2).

An air/water heat exchanger is installed just below the fan unit, so that cold air is re-circulated downwards along the inner racks walls. A set of deflectors is added at the bottom of the rack to limit the impedance in the air flow.

A new development allowed to reduce the thickness of the heat exchangers from 2 U to 1 U. The whole cooling system was designed to accommodate a heat load of up to 12 kW inside the largest racks.

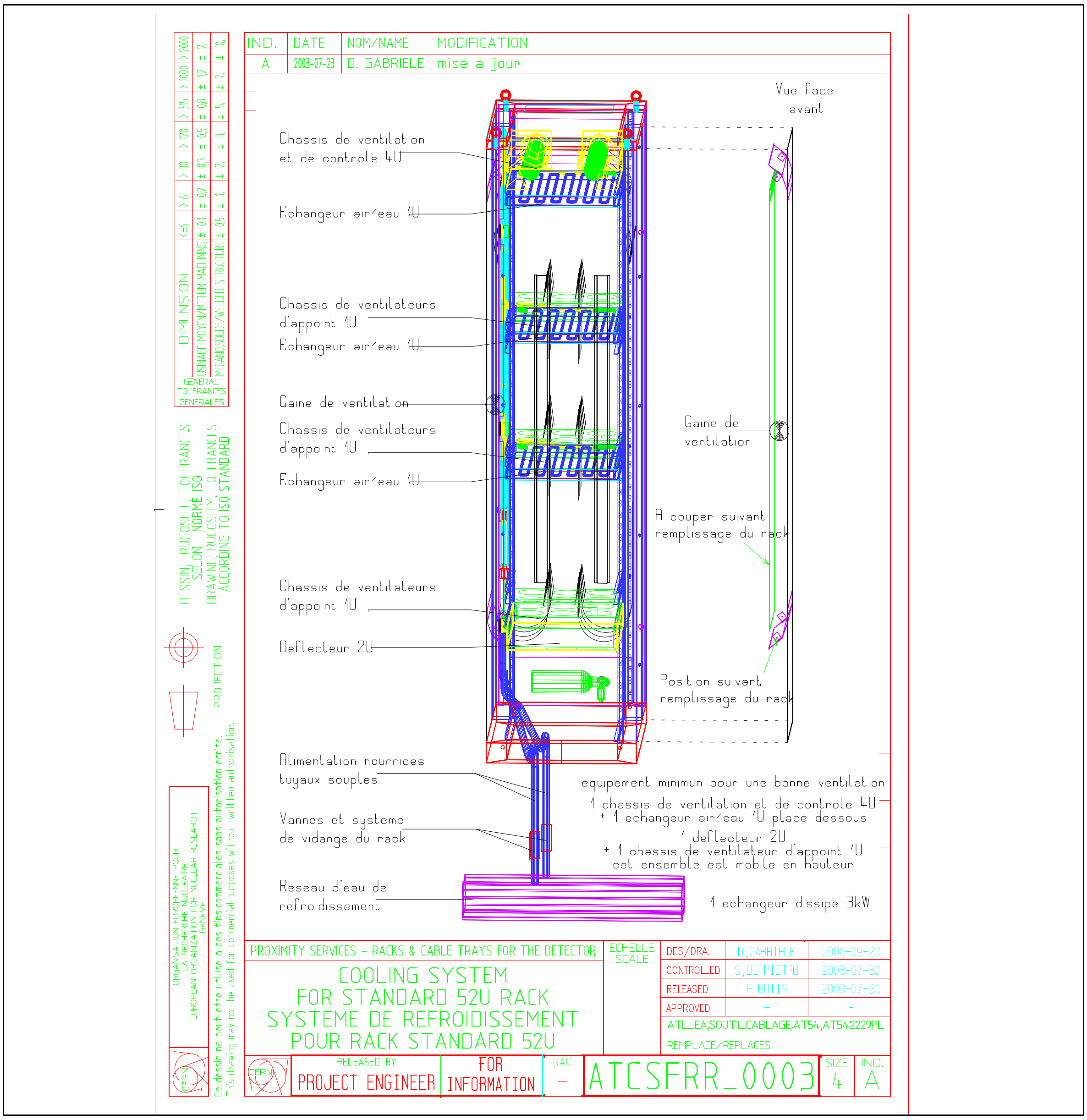


**Figure 6-2** Rack cooling general layout

## 6.3 Specific features for magnetic environment

Since the 1990's, it was known that some of the racks would have to be located close to ATLAS and CMS detectors, where the stray field coming from the very large superconducting magnets would perturb the operation of rotating metallic fans and electric motors if no specific measures were taken.

A development program was carried out successfully to integrate non-metallic turbines in the fan units, and to provide adequate shielding for magnetic fields for the motors up to 2000 Gauss, see Figure 6-3 and reference [6-1].

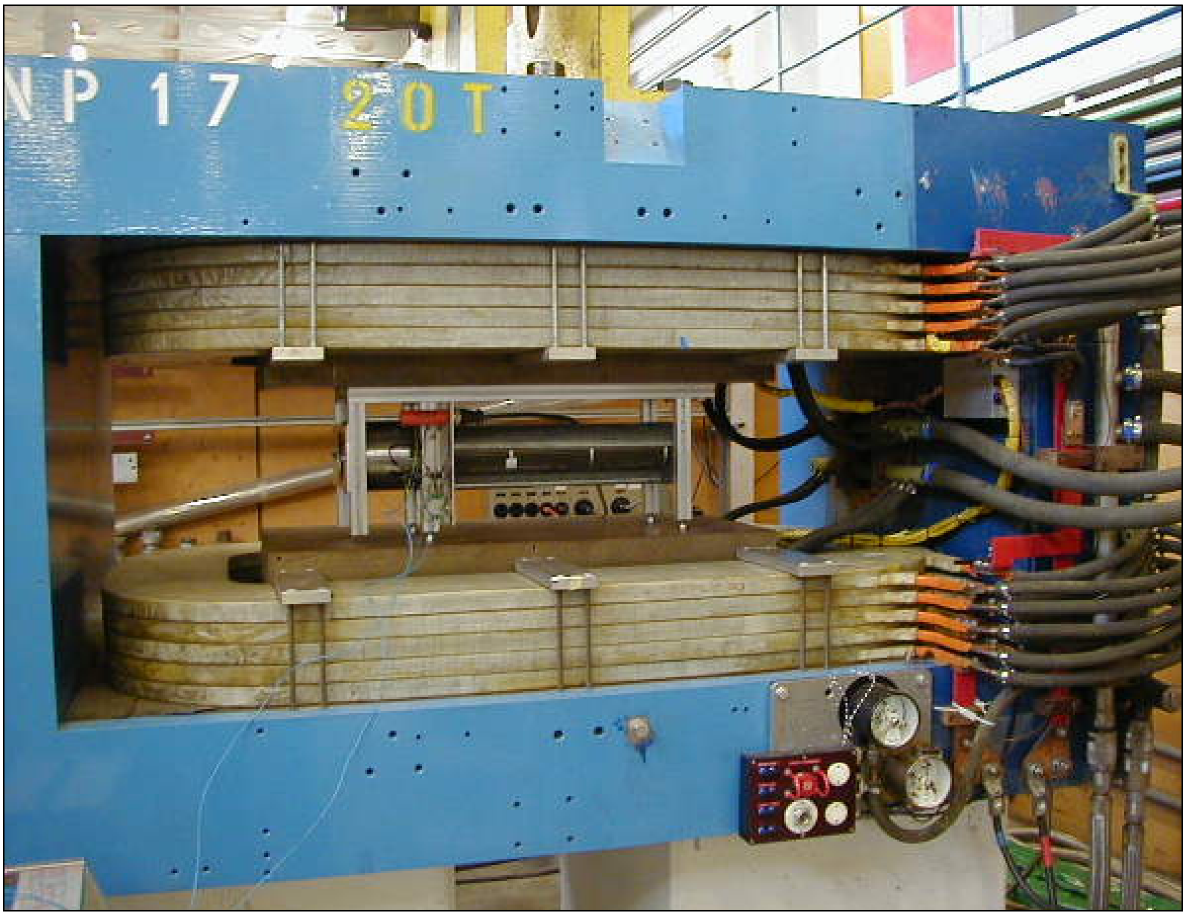


**Figure 6-3** Magnetic test on shielded electric motors coupled with a plastic turbine

## 6.4 Procurement

The procurement of the racks and the cooling parts was led by CERN purchase department, and the various parts have been entered in the CERN main store catalogue, with specific SCEM numbers (06.61.77.A). A number of suppliers have provided sample racks and cooling units that have been extensively tested before the contract was signed for procurement of several hundreds of units.
Some issues with the coupling of electric motors and plastic turbines were encountered with the first small series that was delivered. Nevertheless, delivery of racks was made in due time for the experiments to start with their in situ installation.

## 6.5 In situ installation

The in situ installation of the electronics racks started in USA15 after the metallic structure of the rack rooms were installed and the water distribution piping plus cable trays had been put in place in the false floors.

A special handling device had been designed and procured by TS/LEA group and was used to put the racks in place, directly on the I beams of the structure, by removing false floor boards.

The installation of the cooling pipes inside the racks and connection to the main water distribution lines was performed by PH/ATI group.

Racks were also installed on US15 second floor, in SDX1 rack room and in various locations in UX15 cavern. Only the ones installed in UX15 and being close to the detector are equipped by magnetic shielding.

## 6.6 References.

**Table 6-1** References to technical drawings and contracting documents

| Racks parts | Technical drawings in CDD[a] | Contracting documents in CFU[b] |
|---|---|---|
| Racks metallic structure<br>Cooling systems | ATCSFRR% | BK52/00 |

a. CDD is CERN Drawing Directory, https://edms.cern.ch/cdd/plsql/c4w.get_in

b. CFU is Contract Follow-Up, https://cfu.cern.ch/cfu/first$.startup

[6-1] "Tests magnétiques de ventilateurs tangentiels pour refroidissement des baies électroniques", S. Di Pietro, F. Butin, January 2002, CERN EDMS 336025

# 7 Cryogenic systems for ATLAS

## 7.1 Cryogenic systems for ATLAS liquid argon calorimeters

### 7.1.1 General description

The ATLAS liquid argon calorimeter cryogenic system has been designed to supply continuous cooling power to the detectors over a fifteen year period. For this reason, a redundancy has been implemented for all items vital for the functioning of the system.

The primary cooling source for the detectors is a 20 kW at 80 K nitrogen refrigerator (ANRS), the compressor station of which is placed in the surface SH1 building and cold box in the USA15 underground cavern. The high and low pressure gas lines connecting these two items pass through the PX15 pit. The cold box delivers its cooling power to a 15 $m^3$ nitrogen Phase Separator Dewar (PSD) placed in the UX15 cavern. This equipment, delivered by Air Liquide DTA, was installed over a 2 year period. The installation of these large pieces and components required delicate handling manoeuvres, in particular the too late delivered PSD (see Figure 7-1).

**Figure 7-1** Installation of liquid argon storage tanks in still empty UX15 cavern; Installation of PSD underneath existing structures

Two 50 $m^3$ liquid nitrogen storage tanks placed at the surface supply, in case of problems with the nitrogen refrigeration system, liquid nitrogen to the PSD via a 280 m long transfer line. With the liquid stored in these tanks, the cooling system can function up to 6 days independently.

A Barber-Nichols cryogenic centrifugal pump circulates the liquid nitrogen (about 200 g/s) from the PSD through the thirteen heat exchangers placed inside the liquid argon cryostats. Two other centrifugal pumps are on stand-by to take over when a malfunctioning of the first pump is encountered.

Each cryostat has been equipped with a valve box containing valves which regulate the mass flow and pressure (and thus temperature) of the nitrogen passing through each of the individual heat exchangers. These valve boxes are placed on the HS structure on USA side.

The nitrogen gas/liquid mixture coming from the heat exchangers is sent to the PSD and from there the gas is returned to the ANRS or, in case the ANRS is not functioning, vented at the surface via a 120 m long exhaust line.

The three cryostats, placed at the heart of the experiment, are linked by large diameter argon lines to their individual expansion vessel placed on the HS structure. The liquid-gaseous argon boundary of each of the cryostats can be found in its expansion vessel.

The 83 $m^3$ of liquid argon present in the cryostats can in case of problems be emptied by gravity via the cryostats bottom lines into two 50 $m^3$ argon storage tanks placed at the lowest point of the UX15 cavern. These tanks, together with the nitrogen tanks mentioned above, were delivered by the Norwegian firm SB Verksted. The argon tanks, being largely hidden behind the HS metallic structure, were the among the first equipment to be installed in the UX15 cavern (see Figure 7-1)

### 7.1.2 Transfer lines

The necessity to displace a functioning EC cryostat over a 12 meter distance required the implementation of a movement system for the argon and nitrogen lines connecting the cryostats with their expansion vessels and nitrogen regulation valve boxes. Also all cabling connected to the cryostats has to follow these displacements.

The complete installation includes a total length of 1.3 km of transfer lines and 11 valve boxes fabricated and installed by two firms: A.S. Scientific and SNLS. A DN500 safety valve line collects the eventual gas coming from pressure safety valves placed on the cryostats or storage tank volumes venting it to the surface.

### 7.1.3 Ancillary equipment

The electrical power necessary to drive the whole cryogenic system can be taken from two national networks (French or Swiss network), while in case of severe problems the electrical power can also be supplied to the most critical equipment by two individual diesel generators. As last resource, a 2 hour uninterruptible power supply can be used.

Concerning the necessary cooling water, a closed cooling water system is normally used, while in case of failure or maintenance, the system can be switched to another cooling tower or even to the drinking water system.

The compressed air is delivered by two compressors working in parallel, backed-up by compressed air batteries.

## 7.2 Cryogenic systems for ATLAS magnets

### 7.2.1 General principles

The complete ATLAS magnet system, namely the Central Solenoid, the Barrel Toroid and the two End-Cap Toroids, has a total weight of 1300 tons of which the superconducting cold mass to be cooled at 4.5 K represents 600 tons.

Two separate helium refrigerators have been installed to provide the required cooling capacity at all temperature levels between 300 K and 4.5 K: the shield refrigerator (SR) and the main refrigerator (MR). The compressors of these refrigerators are all installed in a dedicated surface building (SH1), whereas the refrigerator cold boxes are both located 90 m underground in the technical cavern (USA15) just beside the detector cavern (UX15). Figure 7-2 shows the layout of the external cryogenic piping in Point 1.

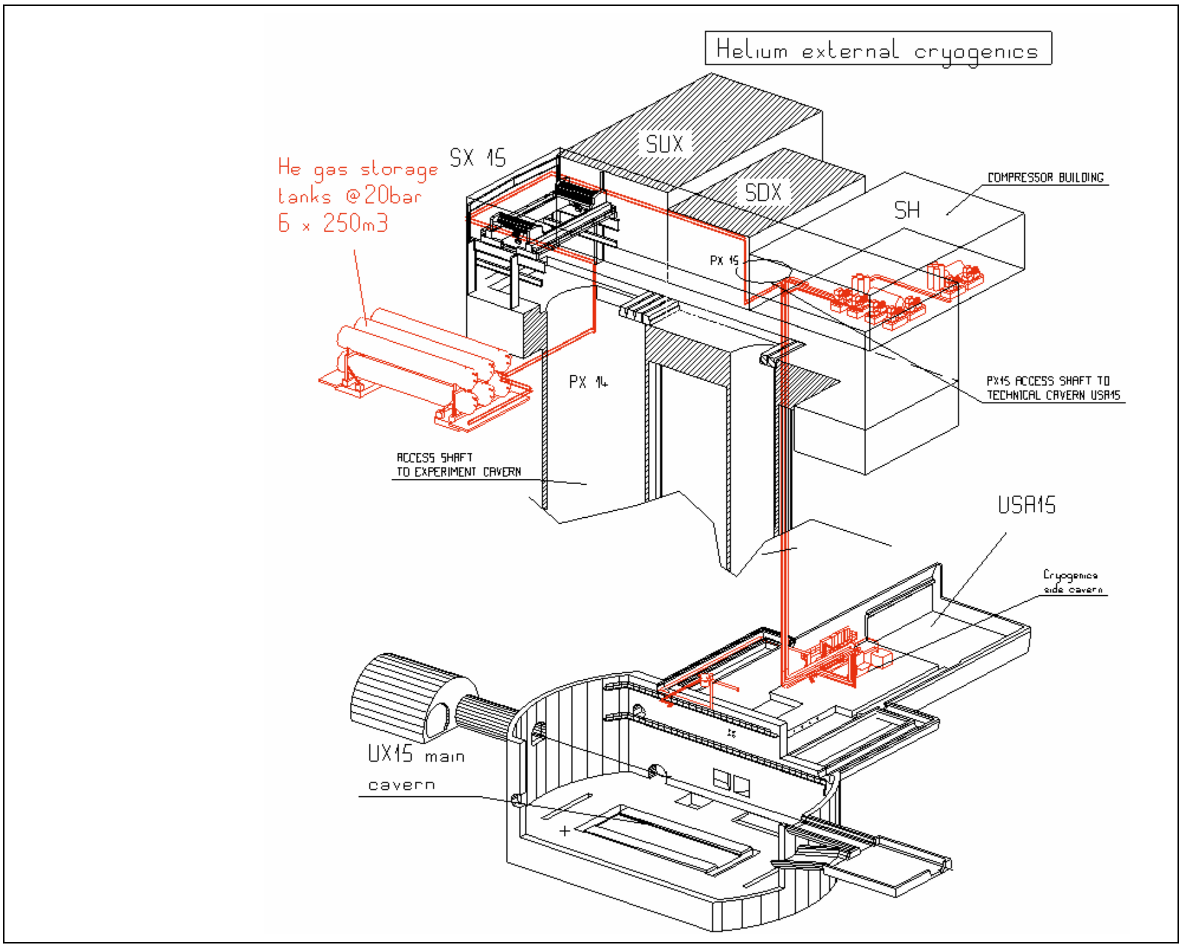


**Figure 7-2** Layout of the helium external cryogenics in Point 1

Once these two refrigerators have produced the gaseous and liquid helium required for the magnet system, this helium is sent, via transfer lines, towards two Proximity Cryogenic Systems (PCS), which finally distribute it to the different cooling circuits, just at the magnets interface. Figure 7-3 shows a simplified flow scheme of the ATLAS magnet cryogenic system.

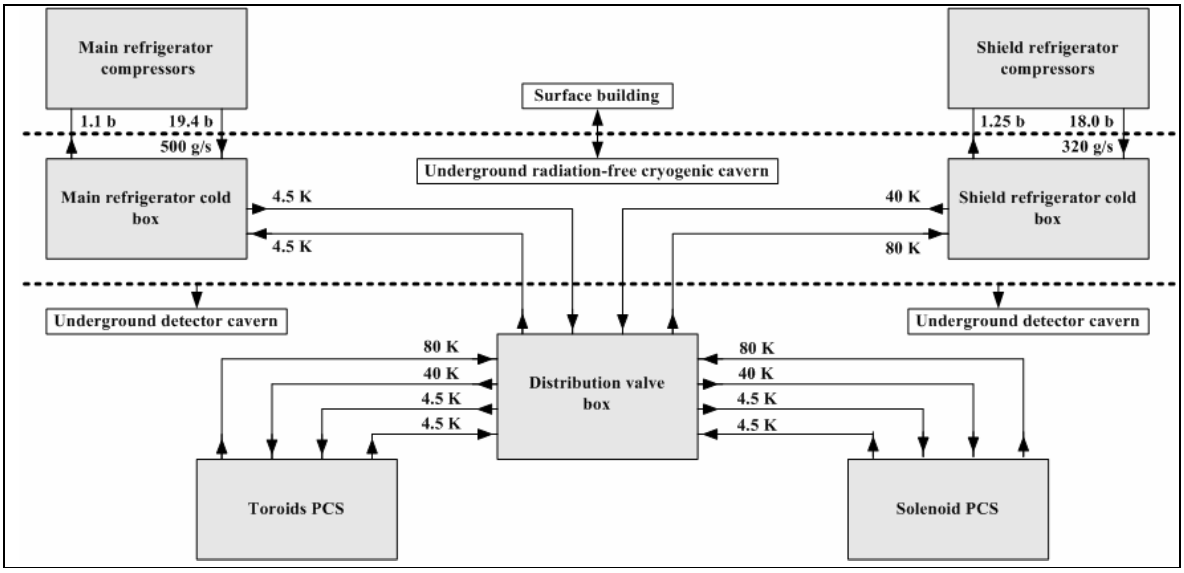


**Figure 7-3** Flow scheme of the ATLAS magnet cryogenic system

## 7.2.2 Shield refrigerator

From an operation point of view, the shield refrigerator (SR), manufactured by Linde in 2003, is used to cool-down the magnets from 300 K to 100 K and then, maintains the thermal shields between 40 K and 80 K.

The SR compressor station (in SH1), consists of 2 identical compressors of 850 kW each which can provide a total mass flow of 320 g/s of gaseous helium compressed in a single-stage from 1.25 bar up to 18 bar.

This helium flow is then fed into the SR cold box located underground in the technical cavern USA15.

The SR cold box has to provide 2 different cooling powers: 20 kW by means of 2 turbines revolving at 150'000 RPM for the normal shield cooling (40 K-80 K) and 60 kW when boosted by liquid nitrogen during the one-month magnet cool-down phase.

## 7.2.3 Main refrigerator

The main refrigerator (MR), manufactured by Air Liquide in 1991 and recuperated from a previous CERN installation, is used to cool-down the magnets from 100 K to 4.5 K and then ensure the steady-state operation of all magnets at 4.5 K, which includes the cooling of the current leads.

The MR compressor station (in SH1), consists of 5 compressors requiring a total electric power of 2.1 MW and can provide a total mass flow of 500 g/s of gaseous helium compressed in two stages first from 1.1 bar to 6 bar and then from 6 bar up to 19.4 bar.

This helium flow is again fed into the MR cold box located underground, just beside the SR cold box.

Even if the MR cold box was initially designed for a refrigeration capacity of 5 kW with a liquefaction rate of 8 g/s of liquid helium, it is actually used in a different way. ATLAS operation indeed requires

2.5 kW in refrigeration at 4.5 K for the magnet cold masses plus a liquefaction rate of 11.4 g/s for the cooling of all current leads. This has required some modifications of the MR turbines capacity.

### 7.2.4 Proximity cryogenic system for the ATLAS central solenoid

The Central Solenoid (CS) as part of the ATLAS superconducting magnet system provides an axial magnetic field of 2 T at 7600 A in a 2.5 m diameter bore with a length of 5.3 m. It is cooled to 4.4 K with two-phase helium flowing in pipes which are welded to the coil support cylinder. The cold mass of the solenoid weighs 5.5 tons and is integrated in the common cryostat together with the liquid argon barrel calorimeter detector which operates at 89 K.

The control dewar is placed on top of the ATLAS detector at a distance of 13 m of the proton beam axis. Cryogenic connections between the solenoid and the control dewar are done with a chimney which houses also the superconducting bus. The control dewar dimensions are 1.7 m diameter and a height of 1.5 m with a weight of 4 tons (Figure 7-4).

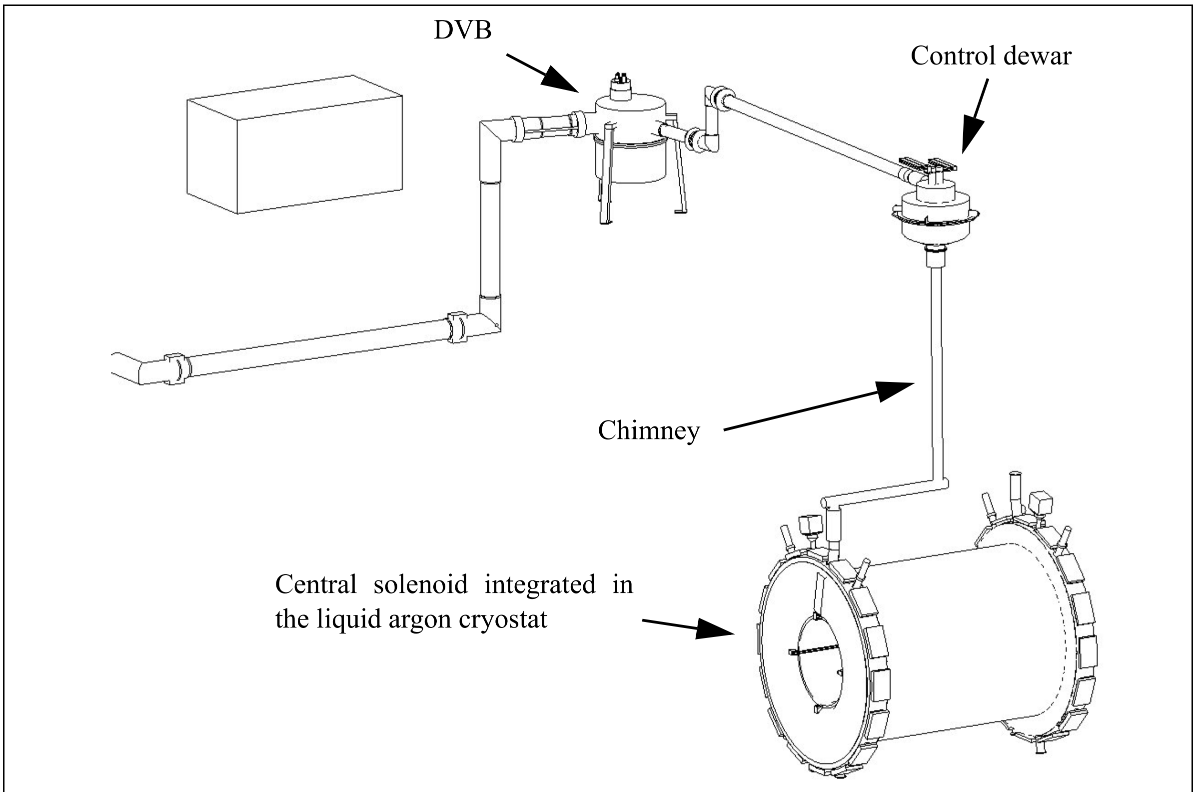


**Figure 7-4** Cryogenic layout for the central solenoid

The valve unit, as second major component, houses the warm control valves, instrumentation and the electronic equipment. As proven by radiation tests, the expected ionisation and hadron radiation in the detector cavern can severely harm the electronic equipment. It has, hence, been installed in the technical cavern USA15, requiring important instrumentation modifications.

The two refrigerators (MR and SR) housed in the technical cavern USA15 supply the control dewar with gaseous and liquid helium through transfer lines and a distribution valve box (DVB) which is common to the complete magnet system.

### 7.2.5 Proximity cryogenic systems for the ATLAS toroids

The proximity cryogenic system (PCS) is located in UX15 on the eighth level of the HS structure on USA side (Figure 7-5). The PCS distributes the liquid helium (LHe) and gaseous helium (GHe) necessary to cool down and to keep cold the toroidal superconducting magnets of ATLAS, i.e. the barrel toroid (BT), the two end caps toroids (ECT-A and ECT-C).

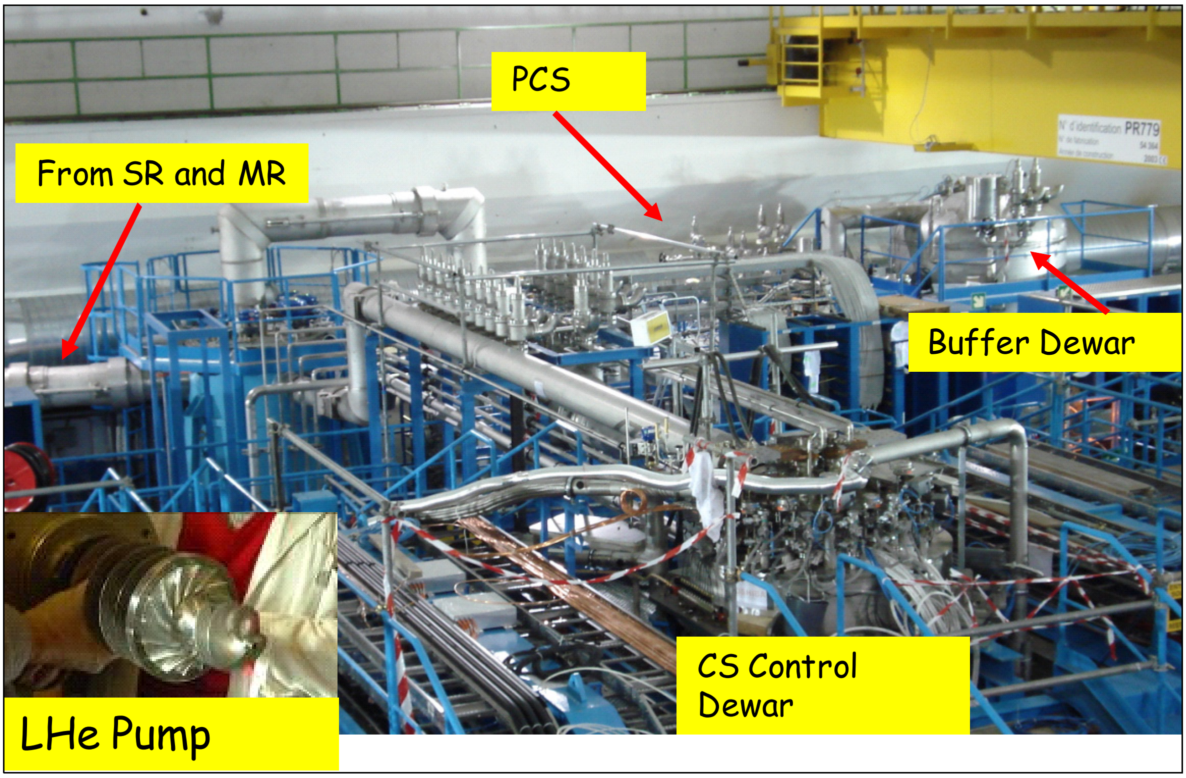


**Figure 7-5** Picture of the helium proximity cryogenic system (PCS) with the major components

The GHe, provided by the shield refrigerator (SR), is used during the cool down from ambient temperature to about 100 K and in the normal running operation for the cooling of the thermal shields. The shields are kept at around 80 K. The PCS is composed of about 43 cryogenic valves, a LHe buffer dewar, a phase separator and two high flow LHe pumps. The PCS is also equipped with dedicated instrumentation for measuring the temperatures, absolute pressure, differential pressure, mass flows of the cryogens.

The cryogenic valves are mainly used for the automatic controlled regulation of the different mass flows. The LHe buffer dewar contains up to 11000 litres of LHe to be used in case of power failure to keep the magnet cold during the complete current discharge from 20500 A. The phase separator, which contains up to 4600 litres, provides the LHe received from the main refrigerator (MR) to the centrifugal pumps. The pumps send 1200 g/s (about 10 l/s) of LHe to the magnets with a head pressure of about 400 mbar, largely sufficient to overcome the hydraulic impedance of the complete system. Two pumps, one being redundant, are installed in the pump cryostat below the phase separator. The return mixture of helium vapour and liquid is separated in the phase separator, which keeps the liquid helium and allows the vapour to go back to the MR. All magnets and their relevant thermal shields are fed in parallel and in an automatic controlled mode. A simplified lay-out can be seen in Figure 7-6, where the major quantities are also listed.

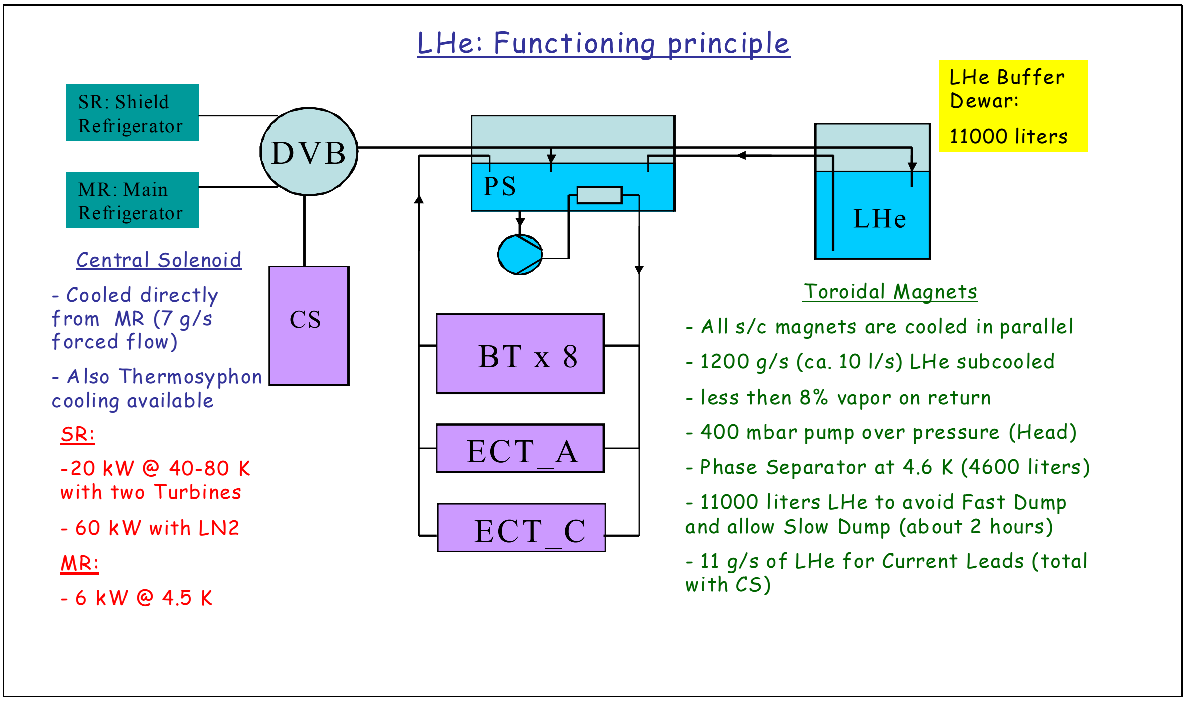


**Figure 7-6** Simplified functioning principle of the PCS

All components are installed in UX15, with the exception of the valves and instrumentation needed for the cooling of the current leads, that are located in USA15.

## 7.3 References.

The references for the most important technical specifications of cryogenic equipment are given in Table 7-1.

**Table 7-1** References to main technical specifications, drawings and contracting documents

| Components | Specifications and technical drawings in EDMS[a] | Contracting documents in CFU[b] |
|---|---|---|
| Rigid Transfer Lines | ATL-AP-CS-0005 | |
| Flexible Transfer Lines | ATL-AP-CS-0004 | |
| Valve Boxes | ATL-AP-CS-0001 | |
| Expansion Vessels | ATL-AP-CS-0002 | |
| Argon Line Guiding System | ATL-AP-CS-0006 | |
| Valve Boxes and Transfer Lines | ATF-EX-CS-0002 | |
| Liquid Nitrogen Pumps | ATF-EX-ES-0003 | |

**Table 7-1** References to main technical specifications, drawings and contracting documents

| **Components** | **Specifications and technical drawings in EDMS**[a] | **Contracting documents in CFU**[b] |
|---|---|---|
| Liquid Argon Storage Tanks | ATF-EX-EN-0004 | |
| Liquid Nitrogen Storage Tanks | ATF-EX-ES-0011 | |
| Nitrogen Refrigerator | ATF-EX-CS-0004 | |
| Helium PCS | ATL-TP-CS-0001 and ATL-TP-EF-0001 | F494/EP/ATLAS |

a. EDMS: Engineering Data Management System, https://edms.cern.ch/cedar/plsql/cedarw.site_home
b. CFU is Contract Follow-Up, https://cfu.cern.ch/cfu/first$.startup

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# B Editor

The editor of this document is F. Butin

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