TRANSPORT AND HANDLING OF LHC COMPONENTS: A PERMANENT CHALLENGE

C. Bertone, I. Rühl, CERN, Geneva, Switzerland

Abstract

The LHC project, collider and experiments, is an assembly of thousands of elements, large or small, heavy or light, fragile or robust. Each element has its own transport requirements that constitute a real challenge to handle.

Even simple manoeuvres could lead to difficulties in integration, routing and execution due to the complex environment and confined underground spaces.

Examples of typical LHC elements transport and handling will be detailed such as the 16-m long, 34-t heavy, fragile cryomagnets from the surface to the final destination in the tunnel, or the delicate cryogenic cold-boxes down to pits and detector components.

This challenge did not only require a lot of imagination but also a close cooperation between all the involved parties, in particular with colleagues from safety, cryogenics, civil engineering, integration and logistics.

THE PROBLEM OF TRANSPORT

LHC accelerator and experiments are composed of a multitude of different pieces assembled like an enormous puzzle of thousands of tons of material installed all along a 27 km long tunnel forming the underground accelerator ring plus 5 km of TI2 and TI8 injection tunnels.

Each of them represents the most advanced technical solution in its field of application; so they are generally fragile and very precious and in some cases even unique in the world (some of the experiments detector elements have required 2-3 years of construction and damaging them would mean a 2-3 years delay on the whole project).

The approach, that the heavier the pieces are the more robust cannot be applied to LHC in general since all those elements are installed in a tunnel which is situated 100 m underground; all elements shall be lowered by means of about 20 shafts (diameter of 8 to 20 m) with cranes with a rated load from 10 to 280 t.

The risks of lowering these heavy components added to the confined underground spaces make any simple installation sequence a real challenge that has to be investigated, studied and prepared in detail.

Due to the high complexity of those items that have required years of design and manufacturing, it often happens that the transport requirements as a phase of the life of the element are not taken as of primary importance and/or considered as a minor problem.

As a result, most of the LHC components have the following transport restrictions:

- Tilting of the element is not recommended (but often necessary to pass into shafts that are smaller in diameter than the length of the load).
- Limited admissible stress induced by handling tools such as internal compression due to spreaders etc.
- No lifting points situated above the centre of gravity are generally foreseen, which makes the lifting and handling operations 'unstable'
- Lifting points shall be used only with vertical slings (avoid convergence of the slings on crane hook by means of intermediate tools)
- Typical transport conditions such as vibrations, shocks and accelerations are limited to incredibly low values (up to ± 0.15 g)
- Final installation tolerances are often too small for a standard handling/positioning equipment (± 1-2 mm)

All these special requirements often impose detailed and time-consuming handling studies that may result in the procurement of special handling tools.

LHC CRYOMAGNETS

The LHC cryomagnets are a typical example of very complex components with very special transport requirements. The arc cryodipole that is 16-m long and weighs 34 t is the biggest of the about 2000 cryomagnets: 1232 out of those units will be installed all around the LHC tunnel.

Figure 1: LHC cryodipole during handling with mobile crane. A double rotating spreader is used to guarantee the correct repartition of the loads as required.

Complete handling studies concerning logistics [1] and design of special transport means [2] can be found in the documents listed as reference.

LHC CRYOGENIC PLANT

The LHC accelerator is based on superconducting technology which requires the installation of a complete cryogenic system around the machine both on the surface and in the underground.

Cryogenic Refrigerators

The cryogenic fluid (liquid helium at 1.9 K) is produced by cryogenic refrigerators (QURC) that are situated in the shafts and in the underground tunnel areas: 8 new units are being installed to reinforce the existing LEP cryogenic units. Table 1 lists the QURCs and their installation place. Each of them has an overall weight of about 25 t, the shape of a huge reversed L, 2-m wide, 7-m long and around 7-m high.

Table 1: QURC: Installation Place and Characteristics

Installation place / contractor	**Transport special requirements**
US85 / Linde	QURC to be lowered via the PX85 shaft into the UX85 cavern and transferred into the US85 cavern via a breakthrough hole into the separation wall and an ad-hoc monorail installed on the vault of both caverns
UX85 / Linde	Pipes and cables trays to be cut to insert the QURC into the existing metallic structure
UX45 (x2) / Linde	Approach distance of the crane not sufficient: additional lateral pullers needed
US25 / Air Liquide	The QURC is composed of 2 parts of 12 t each: lowered in PM25; shall be finally reassembled on site
UX65 (x2) / Air Liquide	Approach distance of the crane not sufficient: additional lateral pullers needed
PM18 / Air Liquide	The QURC is composed of 2 parts of 12 t each: lowered in PM18 and sustained with temporary independent supports; shall be finally reassembled on site

Each QURC is installed in a different cavern/pit and is surrounded by a multitude of other services; consequentially it demands a detailed handling study, the procurement/design of dedicated handling tools and several days for installation of any single part.

To help the handling studies, a large use of 3D drawing software is made as Euclid and CATIA (and AutoCAD for 2D handling schemes). Figure 2 shows a part of the 3D mock-up study of the US25 QURC installation.

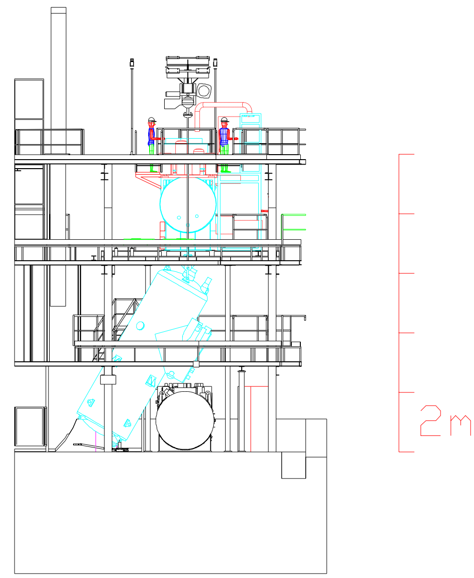

Figure 2: Part of the 3D study of the QURC US25 installation.

Cryogenic Distribution Boxes

The liquid helium exiting from the refrigerators is sent to a cryogenic distribution box (QUI) that directs the fluid into the different needed directions.

These QUIs are similar to huge horizontal cylinders (2-m diameter, about 1-m long, and 12-t weight). The LHC machine requires the installation of 5 new QUIs. Four of them are already installed (UX85, US25, UX45, UX65) and the last one in PM18 shall be installed at the end of 2004.

The cylindrical shape of those QUIs reduces the installation problems. On the other hand the fact that the corresponding lowering shafts are smaller in diameter than the length of a QUI results in difficult installation conditions.

A tilting system plus the insertion of Teflon lateral protection have been necessary to lower these elements in the caverns.

Cryogenics Lines and Tanks

LHC cryogenic plant is also composed of connection pipes and helium tanks.

Pipes (QRL) have an average length of 12 m, a diameter of 600 mm and a weight of around 1.5 t each.

Cryogenic tanks have various shapes and dimensions, and are installed everywhere on CERN sites: surface or underground. An example of a very complex tank to install is the ATLAS Dewar with an overall 14-m height to be inserted in a tilted position into the already erected metallic structure of the UX15 cavern.

The installation studies of those complex elements showed the necessity of modifying the geometry of some components in order to permit the installation: parts of the pump should be dismantled, pipes cut, etc.

EXPERIMENT COMPONENTS

All four LHC experiments have recently required the help of the handling studies unit to install their main components.

Some important examples are the LHCb and ALICE coils. 3D simulation studies are done in strict collaboration, whilst the study of required handling means is most of the times under the responsibility of the handling study group.

The design of handling tools resulting from feasibility studies often contributes to the revision of installation procedures.

For all four experiments we foresee a strong increase of the handling studies demands as the major detector pieces will be installed in 2005.

SHIELDING AND GENERAL SERVICES

Shielding blocks, bars and beams are installed everywhere in the LHC tunnel and experiments.

They are constituted mainly by standard CERN blocks (dimensions 1600x800x800 mm^3 and multiples) but some ‘key’ shielding components are fabricated ‘on request’ to sustain a wall of other blocks or to fit the round shape of the caverns/tunnel.

A recent and very spectacular example was the installation of 5 shielding beams (14.4-m long, 800-mm wide, 1000-mm high and 28.8-t weight) in the LHCb cavern. Figure 3 shows a photo of the handling sequence.

Figure 3: Tilting manoeuvre into PX85 shaft by means of coordinating building overhead crane and mobile crane.

The LHCb cavern will in fact be divided in two parts by a vertical wall: one for LHCb experiment and one for physicists’ offices and counting room. A shielding wall of the complete shape of the cavern is being constructed to separate it.

These 5 beams made of reinforced concrete are installed horizontally on 2 pillars and form the lower support of about 30 to 40 shielding blocks to shield completely the upper round part of the cavern.

Special spreaders and rotating bars have been designed to lift and tilt these beams into the PX85 shaft (10-m diameter) and put them down in the cavern. A complete 3D handling study has been developed in collaboration with LHCb engineers.

Less impressive handlings are the lowering of the whole LHC water piping cut into lengths of 12 m each.

Special containers able to be lifted from the upper side, tilted up to 70 degrees for lowering into the tunnel, pulled by tractors (equipped with steering wheels), to be stored one on top of another had to be designed.

CONCLUSION

The complex and confined environment of the LHC tunnel and experiments significantly increases the difficulties of installing all components of large dimensions and high fragility.

The fact that all materials need to pass into 100-m deep shafts and be transferred through a narrow tunnel seriously increases the risk of accidents.

For these reasons, handling schemes are now systematically developed and approved in collaboration with safety partners.

All CERN existing transport means are taken into account to minimise the procurement and to adopt solutions that already worked in the past.

Nevertheless, the challenge of our work is that every installation problem is a complete new scenario and many times no single solution is existing a priori.

To allow correct installation of all LHC components, it is very important that the project engineers involve at the earliest possible state of the equipment/component design a handling expert in order to discuss and consider the transport and handling requirements.

Anticipation is fundamental for installation. Following our experience, a handling manoeuvre that is not sufficiently studied represents a major risk of accident.

REFERENCES

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