EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics
CERN – TS DEPARTMENT

EDMS Nr. 760753 **CERN-TS-2006-005 (IC)**

OVERVIEW OF THE LARGE HADRON COLLIDER CRYO-MAGNETS LOGISTICS

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Abstract

More than 1700 superconducting cryo-magnets have to be installed in the Large Hadron Collider tunnel. The long, heavy and fragile LHC cryo-magnets are difficult to handle and transport in particular in the LEP tunnel environment originally designed for smaller, lighter LEP magnets. An installation rate of more than 20 cryomagnets per week is needed to cope with the foreseen LHC installation end date.

The paper gives an overview of the transport and installation sequence complexity, from the storage area at the surface to the cryo-magnet final position in the tunnel. The success of this task depends on a series of independent factors that have to be considered at the same time. The equipment needed for the transport and tunnel installation of the LHC cryomagnets is briefly described. The manpower and equipment organisation as well as the challenges of logistics are then detailed. The paper includes conclusions and some of the lessons learned during the first phase of the LHC cryo-magnets installation.

Presented at the European Particle Accelerator Conference 06, Edinburgh UK
June 26-30, 2006

Geneva, Switzerland
June 2006

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INTRODUCTION

The LHC is a very complex machine and the installation of many different types of equipment is very tightly linked. A delay in the delivery of one component can have a dramatic impact on the installation sequence of many other elements. The installation of a cryo-magnet in the LHC tunnel is only possible if several conditions, which depend on different factors, are fulfilled.

The different cryo-magnets pass through several sequences of handling and transport during their life between the cold mass arrival at CERN, their assembly and testing, until their final installation in the LHC tunnel.

The LHC cryo-magnet logistics have been split into surface logistics and underground logistics. However the two parts are tightly linked since a disturbance in the tunnel installation chain has consequences on the cryo-magnet preparation sequence on the surface and vice-versa. The key to success is good overall organisation but a certain degree of flexibility on both sides is vital.

INSTALLATION LOGISTICS OVERVIEW

Fig. 1 shows the transport and handling phases for a cryo-dipole with different types of equipment, ranging from standard overhead cranes to very special customised equipment for tunnel transport [1]. The same type of sequence applies for the Short Straight Section (SSS) and the stand-alone magnets in the Long Straight Sections (LSS).

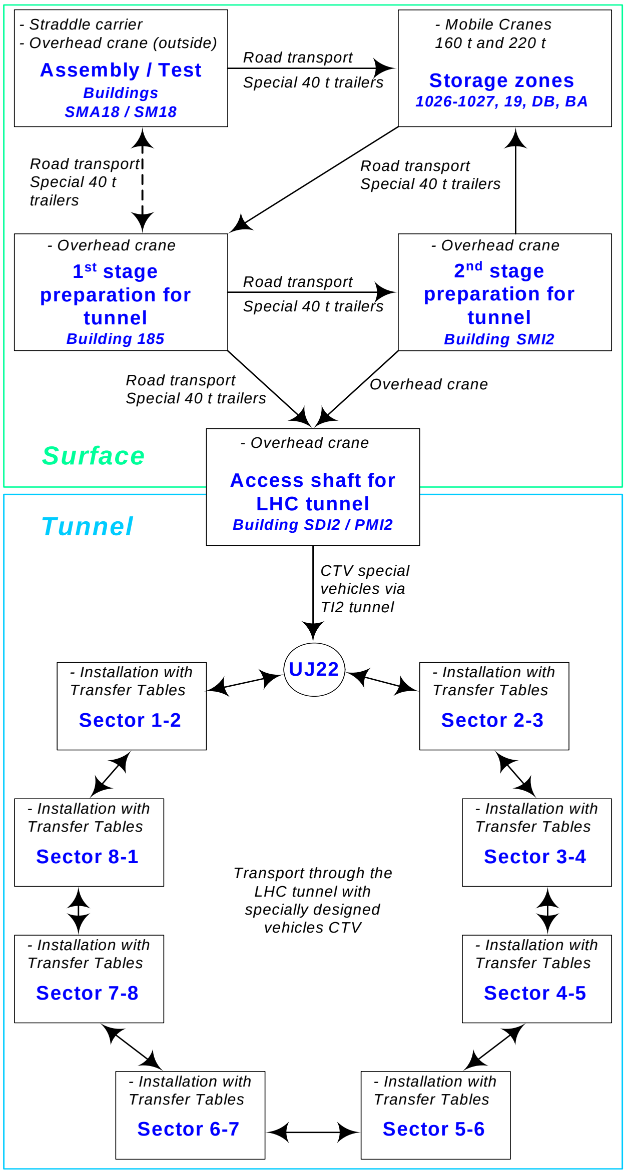

Figure 1: Cryo-dipole handling and transport sequence from surface assembly building to the final position in the LHC tunnel.

CRYO-MAGNETS TO BE INSTALLED

More than 1700 superconducting cryo-magnets of different weights and lengths have to be installed in the Large Hadron Collider tunnel, as summarised in Table 1.

These long, heavy and fragile cryo-magnets are difficult to handle and transport, in particular in the LEP tunnel environment originally designed for smaller, lighter LEP magnets.

Table 1: Cryo-magnets to be installed in the LHC tunnel

	Number	Mass (t)	Length (m)
Main dipole	1232	34	16.3
SSS Arc	360	8	7.5
SSS DS	64	11-14	8.7-10.1
LSS	90	4.7-22.7	8.5-13.2

PLANNING CONSIDERATIONS

The LHC cryo-magnet installation is planned to be finished by March 2007 but late delivery of some components of the LHC machine drastically reduced the total time available for installation activities.

The weekly installation rate, initially planned at 10, has had to be increased with great effort to more than 20 cryo-magnets in order to fit within the tight constraints of the LHC installation schedule.

A detailed planning exercise is carried out every week taking into account the current constraints for the surface (preparation stage of the cryo-magnets, position of the mobile cranes, position of the cryo-magnets in the storage zones etc.) and the tunnel (slots available in the installation sectors, available vehicles and transfer tables, position of the transfer tables, priority of sectors etc.).

SURFACE LOGISTICS

Some LHC cryo-magnets are delivered to CERN, as almost completed units, but most of them need assembly and testing before tunnel installation. All the steps in the preparation of the cryo-magnets require “intermediate surface storage” as well as transport between the different assembly / test buildings and the storage areas. Moreover, the surface storage is influenced by the tunnel installation rate so that “final storage” areas are required to hold the cryo-magnets prepared for installation before they can be lowered to the tunnel.

Road transport

The main challenge is to transport the cryo-dipoles, which are fragile 16.5 m long, 34 t objects. During transport the longitudinal, transversal and vertical acceleration cannot exceed 4, 5, respectively 7 m/s2 to avoid composite cold mass support failure [1].

Three dedicated trailers of 40 t capacity are used for this purpose [2]. Three other trailers can transport SSS by road (the cryo-dipoles trailers can also be used for this purpose).

Each cryo-magnet transported is equipped with an acceleration monitoring device.

Every week, 100 to 150 cryo-magnet road transports are made by 8 truck drivers with 6 handling persons for loading and driving the pilot cars.

Storage

The surface storage quantities are determined by the tunnel installation rate. The cryo-magnet assembly and tests were started well before the LHC installation was possible which resulted in a large number of stored cryo-magnets. Fig. 2 shows a part of the cryo-dipole storage area with approximately the amount of cryo-dipoles that are installed during one week at the time of writing (~20 cryo-dipoles installed per week).

Figure 2: Part of one of the cryo-dipoles storage area – the picture shows approximately the number of cryo-dipoles installed during one week.

The cryo-dipoles and the SSS are stored outside in three main storage zones and several small storage zones close to point 18 [3]. More than 700 cryo-dipoles and about 100 SSS were stored during the summer of 2005. Since then, the tunnel installation rate increased significantly so that the rate of cryo-magnet installation exceeded the rate of cryo-magnet assembly. The number of stored units has been reduced to about 430 cryo-dipoles and about 120 SSS at the time of writing.

Two mobile cranes (160 t and 220 t) are used for cryo-dipoles and SSS handling on the storage zones and one mobile crane of 30 t is used for SSS handling only. Four crane drivers use them.

UNDERGROUND LOGISTICS

Infrastructure

The LHC tunnel was designed and used for the resistive LEP accelerator. This means that there is little space available for the transport and handling of the larger, heavier and more fragile LHC cryo-magnets in a tunnel that also houses the cryogenic supply line, cabling and pipe work (Fig. 3). Two shafts are available for lowering the short SSS while the cryo-dipoles and some of the DS and LSS magnets can only be lowered through one shaft in the whole 27 km long tunnel.

For each cryo-magnet a specific tunnel location in the LHC accelerator is allocated based on the magnet performance (principally powering, geometry and field quality issues).

The slot where the cryo-magnet has to be installed is called “available” if the cryogenic line (QRL) has already been installed (Fig. 3) and successfully tested, and if the cryo-magnet supports have been installed and geometrically aligned.

Figure 3: LHC tunnel with, from left to right: the cryogenic line, an installed and a transported magnet.

A cryo-magnet can be installed if three conditions are fulfilled at the same time:

- The cryo-magnet's slot is available;
- The cryo-magnet is prepared, ready for tunnel installation;
- The transport and installation equipment and the infrastructure are available for installation.

The LHC tunnel is divided in 8 sectors to be installed in general one after the other. However, as any slot has to be allocated its specific cryo-magnet, the last magnets to finish the sector always take a long time to obtain since they have to fulfil a very precise magnet performance. Hence, at the present time, installation can take place in up to 5 different sectors.

Equipment and manpower

A total of 6 vehicles of three different types are used to transport the different magnets in Table 1: two vehicles for cryo-dipoles only, two vehicles for cryo-dipoles and LSS magnets and two vehicles for Arc and DS SSS [1]. The vehicle transports the magnet to the place of installation powered by the overhead power rail and automatically steered by a guidance system. It drives at a maximum of 3 km/h loaded and 4 km/h unloaded.

Five Transfer Equipment Sets (TES or "transfer tables") are available. They are modular equipment allowing the installation of the different lengths of cryo-magnets. The installation time from the time the vehicle arrives at the "slot" and the time it is ready to go back is about two hours.

A cryo-dipole transport from the loading shaft to sector 6-7 takes more than 7 hours. A complete cycle for 3 cryo-dipoles in that sector is 24 h taking into account that the vehicles cannot cross in the tunnel.

The TES are moved from one installation zone to the next while the vehicles drive around the tunnel. The installations distributed between up to 5 sectors necessitate manpower and time-consuming long-distance movements of TES. These movements are limited by a careful planning.

The installations are carried out 24h per day, 7 days a week by about 50 operators.

Preventive maintenance of the equipment is programmed between installations as explained in [4]. The reliability of the equipment is a very important factor since any delay in the installation programme has an important impact on the installations programmed for the following days, and can dramatically disturb the surface activities. A lot of effort is put into maintenance and a team is available 24 hours per day, 7 days per week to solve any unexpected problem.

Installation rates

An installation rate of more than 20 cryo-magnets per week is needed to cope with the presently planned LHC installation end date. After a difficult start, the installation was stabilised at 20 per week during the first trimester of 2006 and has been increased to 25 and even up to 30 cryo-magnets per week since then (Fig. 4). More than 750 cryo-magnets have already been installed. The current installation rate will allow all the LHC cryo-magnets to be installed by the beginning of March 2007.

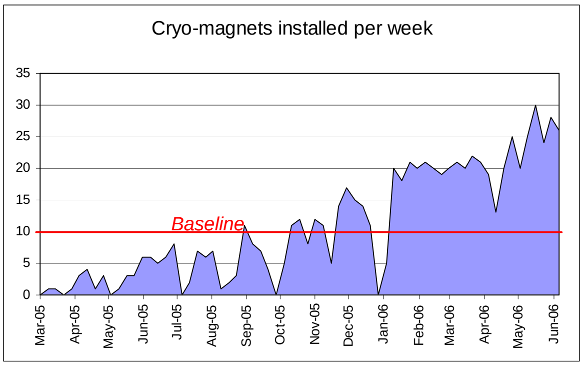

Figure 4: Cryo-magnets installation rate per week.

CONCLUSIONS

The complex logistics of the LHC cryo-magnets installation has been presented and the main challenges explained.

At the time of writing, more than 750 cryo-magnets out of 1746 have already been installed in 5 different sectors. The global cryo-magnet installation rate has been stabilised at more than 25 installations per week. Up to 30 cryo-magnets per week have been installed. The present rate will allow all the LHC cryo-magnets to be installed by the beginning of March 2007.

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