HANDLING AND TRANSPORT OF OVERSIZED ACCELERATOR COMPONENTS AND PHYSICS DETECTORS

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Abstract

For cost, planning and organisational reasons, it is often decided to install large pre-built accelerators components and physics detectors. As a result surface exceptional transports are required from the construction to the installation sites. Such heavy transports have been numerous during the LHC installation phase. This paper will describe the different types of transport techniques used to fit the particularities of accelerators and detectors components (weight, height, acceleration, planarity) as well as the measurement techniques for monitoring and the logistical aspects (organisation with the police, obstacles on the roads, etc). As far as oversized equipment is concerned, the lowering into the pit is challenging, as well as the transport in tunnel galleries in a very scare space and without handling means attached to the structure like overhead travelling cranes. From the PS accelerator to the LHC, handling systems have been developed at CERN to fit with these particular working conditions. This paper will expose the operating conditions of the main transport equipments used at CERN in PS, SPS and LHC tunnels.

INTRODUCTION

Large pre-built accelerators components and physics detectors often need to be transported on surface between construction and installation sites, and then lowered to their final position in tunnel galleries. Monitoring of transport constraints shall also be associated.

Surface transport on open roads requires drastic logistics as well as adapted trailer configurations to tackle with extra-heavy load and tilt correction. If the lowering techniques can be categorized, transport in underground requires specially designed vehicles adapted to tunnels and magnets dimensions.

SURFACE TRANSPORTS

Various trailer configurations are required for the transport on surface of large pre-built accelerators components and physics detectors. Logistics (up to 15 km on open roads) and monitoring of transport conditions are often combined to these operations.

Extendible Trailer

For long and recurrent transports, the extendible trailer is the most practical solution. This type of trailer is adapted to loads with a weight between 20 and 60 t, a length between 13 and 30 m and a width between 1 to 4 m. This technique is successfully used for the transport of LHC cryodipoles (35 t, 17 m long) [1].

Trailer with Suspended Load

The CMS Forward Calorimeters are extra-heavy (265 t) but very compact (L = 6.95 m, W = 4.06 m, H = 5.25 m) elements. The challenge is to guarantee a good weight repartition within the trailer's axles and to cope with the road obstacles (roundabouts, slopes, irregularities, etc.). The trailer configuration has a total length of 64 m and a gross weight of 448 t.

This type of trailer is particularly adapted to extra-heavy long and narrow (less than 4.5 m) pieces. The main advantages of this technique are:

- standard width,
- weight repartition along the total length of the convoy,
- possibility to lift the load by 1 m for roundabouts crossing,
- loading of the piece at the floor level.

Trailer for over-width elements with tilt correction

Accelerator and detector components are often over-width and require permanent tilt correction during the transport to guarantee the planarity of the trailer.

The technique consists of a combination of individual modules connected together mechanically and hydraulically. Once assembled, the trailer can be tilted using the 3 correction points (front, back right, back left). The correction range is generally around 450 mm, typically allowing a compensation of a 5 % slope.

This system has been successfully used for the transport of ATLAS Tile Calorimeters, Liquid Argon Barrel Cryostat and End-Caps Cryostats. It is particularly adapted for extra-heavy and over-width elements to be transported on a relatively regular road. This technique shall be combined with jacking systems for loading and unloading.

An Extreme Trailer Configuration for the RICH2 of LHCb Transport

The RICH2 detector is made of a large superstructure of 10 m x 2.5 m x 7.6 m (height) in aluminum. Inside the detector, there is an optical system consisting of 4 mirrors walls. These four mirror walls are made up by mirror segments. Each mirror segment is independently fixed and aligned with high accuracy. All these mirror segments are assembled on light sandwich panels; hence these assemblies are flexible.

The real challenge was to transport this detector between the CERN Meyrin site and its installation cavern 8 kilometers away.

Several risks were considered: temperature change (day/night), humidity, static deformations due to lifting and change of base (trailer plate), vibrations, shocks. Among other transport requirements, the most severe were:

- support base: maximum deflection load/unload and planarity error 2 mm / 10 m,
- maximum tilt 2 degrees (typical road tilt 5 degrees),
- maximum acceleration/shocks 0.1 g on the 3 axes.

A 100 t special trailer with manual tilt correction was retained for this transport, as well as a maximum speed of 1 km/h to filter transport vibration and shocks.

In order to increase the rigidity of the trailer, a massive iron base of 40 t was built at CERN and fixed on the trailer. It was composed by a box of 8400 x 3000 x 400 mm, 2 heads welded and machined to be perfectly flat and 4 arms to fix the base on the trailer (see Fig. 1). The two heads were machined to bolt the RICH2 on this base. A provisional geometric control was done to ensure the flatness of the base and the precision of the bolt seats. To cut the high and medium frequency special absorbers plates were inserted everywhere between the massive plate and the trailer.

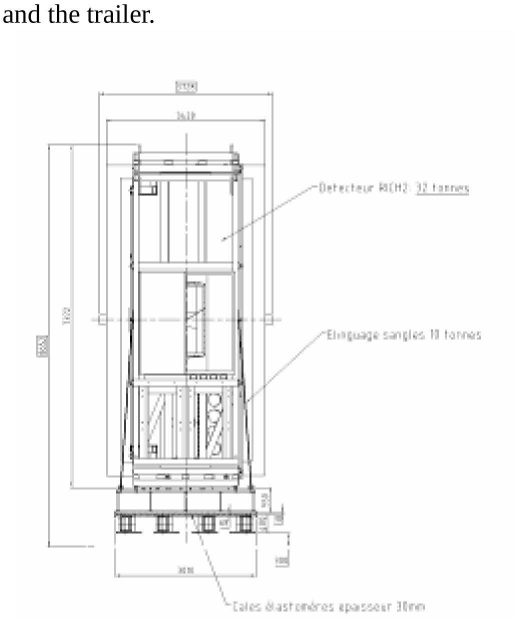

Figure 1: Trailer configuration for the RICH2 transport.

To avoid shocks during the loading of the trailer, the hydraulic jacks of the trailer were used to raise the trailer unless lowering the RICH2 on it for the very last centimeters.

The last exploit was to enter into the building door that was originally lower than the convoy. The building face was cut open to allow the passage of the convoy with a very small play (~5 cm on 3 sides) avoid to structural problems into the building if the opening would have been larger.

Another issue was the lowering into the shaft. The overall length of the RICH2 is 9.8 m while the shaft has a nominal diameter of 10 m and is 100 m deep. As the position control of a load suspended at a 100 m rope is not possible at that precision, the RICH2 chassis was equipped with 4 guiding soft wheels to ‘drive’ it down the shaft. Lifting speed has been reduced to 1 m/min to avoid possible braking shocks.

Logistics

Organisation of such extra-heavy transports on open roads requires a well prepared logistics to coordinate the different services involved: police, electricity provider, telephone provider, road services, etc.

For instance the RICH2 transport required:

- a prior pruning along the route,
- the definition by the police of traffic diversion for other vehicles,
- the customs agreement to cross the French – Swiss border without formalities,
- the load shedding of a 400 kV international electric line between France and Switzerland,
- the power cut of a 20 kV electric line.

From a logistics point of view, the balance between the short notice linked to weather conditions and the 15 days notice required to shed the load of the 400 kV international electric line was a very difficult compromise to reach.

LOWERING TECHNIQUES

Lowering pits are often adapted to the dimensions of the main elements to be installed. Thus a 20 m elliptic pit has been constructed for the lowering of LHC cryodipoles [1].

Nevertheless individual elements may oversize the pit diameter and require inclination. The following techniques are generally used at CERN:

- Rotating spreader beam: this solution is particularly adapted to containers and cryogenic line pipe elements,
- Overhead travelling crane and mobile crane combination: synchronization of the two lifting means aims to reach the inclination angle on surface. The total load is then transferred to overhead traveling crane for the lowering. This technique has been used at CERN for the lowering of the bridge, the bunker and concrete beams for LHCb experiment.
- Strand jacks: this system more adapted to heavy loads does not use any space in the surface building. The 26 m long 80 t ATLAS Barrel Torroids have been lowering in a 18 m diameter pit using this technique.

UNDERGROUND TRANSPORT

Underground transport of oversized equipment in tunnel galleries in a very scare space requires specific transport means. A set of transport vehicles has been developed at CERN, mainly for magnet transport.

LHC Cryomagnets Transport Vehicle

The LHC cryomagnets transport vehicles are specially designed to tackle with actual dimensions of tunnels and magnets [2].

LHC Warm Magnets Transport Vehicle

LHC warm magnets transport vehicle is an assembly of between 1 to 3 specially designed buggies, with a payload of 9 t per buggy (see Fig. 2). This very compact vehicle (1 m width) allows lateral translation of the magnet directly on his beam position using a perpendicular rotating wheel system.

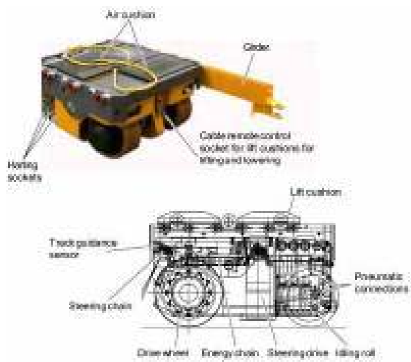

Figure 2: Warm magnet transport vehicle buggy.

SPS Magnets Transport Vehicle

The SPS magnets transport vehicle also combines transport and positioning of the magnet. With a 18 t payload and 1,20 m width, it allows a precise (less than 1 mm) positioning of the magnet on the beam, using two hydraulic arms.

Figure 3: SPS magnet installation on the beam.

PS Magnets Transport Vehicle

CERN PS accelerator is equipped with a rail system for the circulation of a locomotive and associated transport buggies with a 34 t payload.

For the positioning on the beam, the magnet is placed on transverse adjustable aluminium rails and pushed with a jack system.

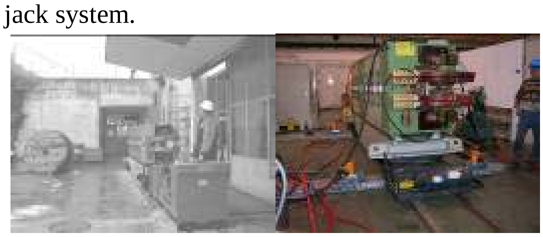

Figure 4: Transport and translation systems for PS magnets

TRANSPORT MONITORING

During the LHC installation, several structures (parts of detectors, magnets...) are transported between CERN sites. Transport and handling can be critical for delicate objects. In order to guarantee the integrity of structures during the transports and handling phases, a monitoring system is installed to check in real-time the tilt, acceleration level, displacement of the structure, humidity, etc...

One typical example is the monitoring of the RICH2 detector transport between the CERN Meyrin and its installation cavern in point 8. For this transport, a significant measurement system was set up:

- Four tri-axial accelerometers with a sensitivity of 100mV/g (resolution of 0.002m/s2) were used to measure the accelerations of the external structure, flat panel mirror and spherical panel mirror of the detector. The accelerometers were attached with fast curing glue via a small mounting base to the external structure and with a support directly on the flat panel mirror and spherical panel.
- One tri-axial inclinometer was installed on the RICH2 external structure.
- A real time multi-channel front-end: this system contains 16 input channels with DSP for each channel and can condition all type of sensors with a sampling frequency until 48 kHz. Data is transferred directly on the Laptop via a LAN or WiFi connection. The software on the Laptop permits all type of analysis most frequently used like FFT (Fast Fourier Transform) , FRF (Frequency Response Functions), filtering, trace manipulation and permits the visualization of all signals recorded, channels calculated, spectrum, overall level.

During the transport of the RICH2 detector, the acceleration level of 0.1g in the three directions and +/-1 degree for the pitch and tilt angles were not exceeded. The second target of this transport was not to excite the first bending mode of the panel and the structure (3, 6 and 12 Hz).

CONCLUSION

Different transport solutions have been found to match severe transport constraints (maximum acceleration 0.1 g, maximum tilt 1 degree) linked to the installation of pre-built accelerators and detectors components.

Standard or specially designed, the techniques involved can be monitored on real time during the transport.

REFERENCES

[1] O. Capatina et al., “Overview of the Large Hadron Collider Cryo-magnets Logistics”, EPAC’06 – Edinburgh – June 2006

[2] K. Kershaw et al., “Transport and Installation of Cryo-magnets in CERN's Large Hadron Collider Tunnel”, EPAC’04 – Lucerne – July 2004