DESIGN, INSTALLATION PROBLEMS AND CRITERIA RELATED TO LARGE ACCELERATORS

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Abstract

The increase in size of accelerators of the new generation either under construction or in the project phase poses a new range of design and installation problems unknown in the past : distance between accesses, moving loads and personnel, ventilation, electrical distribution, safety, search for maximum standardization, interfacing installation with civil engineering, new design and management tools.

1. Introduction

The aim of this paper is twofold : first to start an analysis of the major interrelated points to be considered preferably at an early stage while projecting the building of a new accelerator of large size, and second a description of the efforts made at CERN to use modern tools during the design and installation phase for managing the LEP project. The topics covered deal with the general layout, the services and the environmental problems. This preliminary study is based on experience acquired during the last three years of design, three years of civil engineering work and one year of LEP installation.

2. Parameters involved in large accelerator topology

Once the accelerator size has been fixed by physics considerations, then come the four basic parameters which all have tremendous consequences on the future design and cost : tunnel section (**S**), distance between accesses (**DBA**), depth (**D**) and tilt (**T**) of the accelerator plane. The systems linked to these four parameters are listed in table 1 below.

Systems	DBA	S	T	D
Civil engineering	X	X	X	X
Electrical distribution	X			X
Cooling system	X		X	X
Ventilation	X	X		
Survey	X		X	
Tunnel handling means	X	X	X	
Installation vs. Civil Eng. / Project duration	X			
Surface buildings	X			
Safety	X	X		X

3. Effects on the various systems

3.1 Civil engineering

Obviously all four parameters have a direct influence on the civil engineering. The greater the **S** , the greater the cost. Nevertheless experience of LEP shows that in the case of a diameter ranging between 3.5 and 5 m, cost is almost proportional to the diameter and not to the section. **DBA** is for the civil engineering work of prime importance. A decrease of **DBA** makes the civil engineering work more flexible : the excavation and concreting speed is mostly limited by the handling capacity in the pits so more yards in parallel make shorter delays, the possibility of splitting the work between several contractors, continuation with the rest of the work in case of local geological problems, and improvement of the design of surface buildings (see below).

Cost and mostly delays are greatly affected by **D** . In the case of LEP for instance, a 100 m depth/9m diameter pit is equivalent to 500 m of standard tunnel section (3.8 m) costwise and to 1400 m timewise.

T in this respect can minimize the tunnel depth as the accelerator plane follows the sloping ground with all the drawbacks involved.

3.2 Electrical distribution and cabling

DBA has a direct effect on the total design in this field : the cost of the low voltage distribution in the tunnel with respect to the distance between substations. In LEP a cost optimisation showed that between two access pits (distance 3300 m), 2 or 3 electrical substations were necessary; 2 were chosen.

The effect of **D** here is marginal as a pit length is only a small fraction of the tunnel length.

3.3 Cooling system

This is probably the system where the most optimisation studies have to be carried out. Here a lot of parameters are linked together : the pressure head is a function of **D** and **T** thus influencing the overall cost of the system (pump size, pipe thickness, installed power, power consumption); for a given pressure drop in the line, the pipe diameter being proportional to the **DBA** and the pipe thickness to the diameter, the material cost is proportional to the distance squared.

3.4 Ventilation

The total air flow being given by two independent parameters (air renewal for health consideration during shutdowns and heat removal during machine runs) for a given **S** the installed power is almost linear to the **DBA** .

3.5 Survey

Here **DBA** and **T** are the two parameters to be considered. The former has a direct effect on the measurement precision and the latter complicates the computation. If survey specialists deal with these skillfully, **T** induces a lot of man hours lost at the design stage to take into account slope changes, non orthogonal construction, etc. Furthermore, loss of time is common as fitters are not always able to use their plumb lines and spirit levels.

3.6 Tunnel main handling means

S , **DBA** and **T** must be taken into consideration when choosing the main handling means for the tunnel. For a small economical **S** the use of ground vehicles appears to be insufficient to transport people and bulks of material over large distances. Furthemore **T** influences the choice of energy supply for these vehicles. In LEP a monorail system was chosen in order to be : independent of the cluttered floor during installation (economic in terms of efficiency), self guided, and unlimited in range since supplied by busbars. Fig. 1 shows the monorail delivering 5 containers in the LEP tunnel.

3.7 Installation vs. Civil Engineering, project duration

Here **DBA** is by far the main parameter. Assuming one access only, obviously the civil engineering and installation times are directly added. The greater the

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number of accesses, the earlier the installation work can start, the greater the possibility of parallel

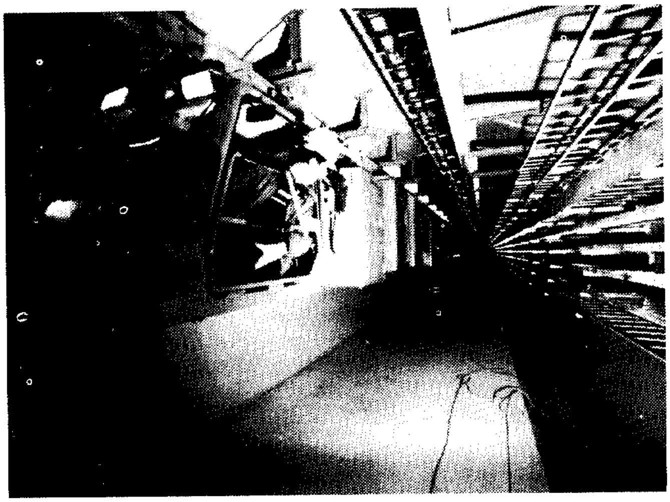

Fig. 1 Monorail delivering containers in the LEP tunnel

work, thus the shorter the project. On the other hand an early installation start has the great advantage of building a test site for the future work. An increase in **DBA** induces an increase in installation costs due to a loss of time in transport. In LEP for instance, the real working period between the pits is 5 to 6 hours for a theoretical 8 hour working day. For an estimated 10^6 hours for the whole LEP tunnel installation this "loss" of approximately \$ 10^7 is worth considering when deciding **DBA** and the tunnel main handling means.

Experience shows that for technical and mainly planning reasons the civil engineering work requires more pits than strictly needed by the project. In the case of LEP three so called civil engineering pits were excavated. Fortunately, one of them will be of great use during the installation period. Adding pits at an early stage of the project, i.e. reducing **DBA** , could combine improved civil engineering work with a better general conception of the machine.

3.8 Pits and surface buildings

Taking project duration into consideration, **DBA** , i.e. the pit number, has a great impact on the design of surface buildings and their cost. In order to reduce the overall planning length the construction of the surface building must be started at an early date. As the immediate vicinity of the pits will be occupied for a long time by the underground work, a spread out of the surface buildings is necessary. This scattering is costly as it induces more buildings, junction galleries and increases cabling, piping, etc. An increase in the pit number, i.e. reduced **DBA**, would result in the pit vicinity being available at an earlier date. The surface buildings could then be grouped at the top of the pits with a considerable saving.

3.9 Safety

If overdone, safety, could become an important part of the project cost. A good starting point to keep the cost at a reasonable level is to protect people only and not material. **DBA** and **D** are of main concern for protecting people especially against fire/smoke hazards. At LEP, to cope with **D** , overpressurized rooms are situated at the top and bottom of each access pit and linked together thus providing a buffer for people evacuation.

As **DBA** was already too large to think of a fire detection and extinguishing system covering the total length of the tunnel, the chosen human protection system was for the individual to carry breathing apparatus readily available. The most important impact on cost resulting from safety consideration comes from a decision to be taken at the very beginning : whether to have underground access to service areas during machine runs or not. If not, the saving is quite important in a lot of systems : smaller caverns, simpler ventilation, etc.

4. Search for maximum standardization

The size of LEP - or, indeed of larger accelerators being planned - implies a large number of components (about 2 x 10^4 for LEP) of various types and quite often medium serie items (between 100 and 2000). The design should take this point into consideration at an early stage of the project : standardization of "brother" components requested by the various groups involved is essential to reduce the overall cost of the project.

The design has to take into account the serie effect when defining the realization method (injection casting vs. welding for instance).

Here, modularity and prefabrication are essential. The aim being to save costly installation time. Examples for LEP are the premounting at the surface of machine elements or the pit structure which is completely prefabricated in 6 m high modules (see Fig. 2)

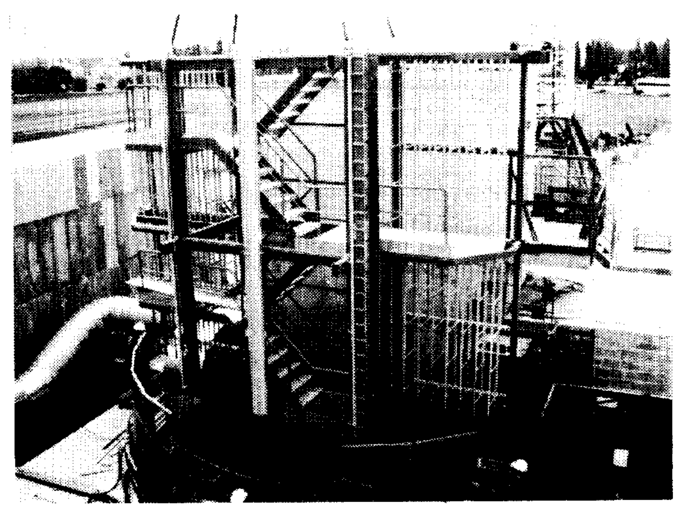

Fig. 2 A prefabricated module being lowered in pit PM15 of LEP

5. New design tools

A great deal of LEP design has been achieved using CAD. A large amount of the information needed for the design, planning and cost is accessible through a central relational database. Some computation is performed using modern tools such as finite element methods. Unfortunately all these tools are still independent. Nevertheless this is a first step.

The size range of new machines implies engineering methods much closer to the design of large nuclear or chemistry plants. The number of systems and components dictates a modernisation in design methods.

In the more standard fields, study represents about 5% of the total project cost. In our field the

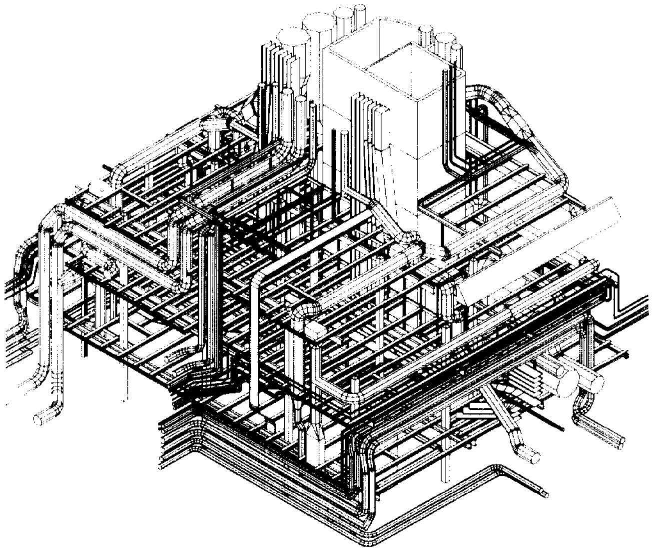

Fig. 3 Services in underground cavern US25 of LEP

figure is closer to 10%. However decisions taken at this stage determine about 80% of the total cost. A full CAE system, with its specific tools for design and simulation, where all the subsystems are integrated around a common database including all the component data, planning and cost,should be the aim for future large accelerator design in order to keep the overall cost low.

Fig. 3 shows an example of CAD system integration in an underground cavern of LEP.

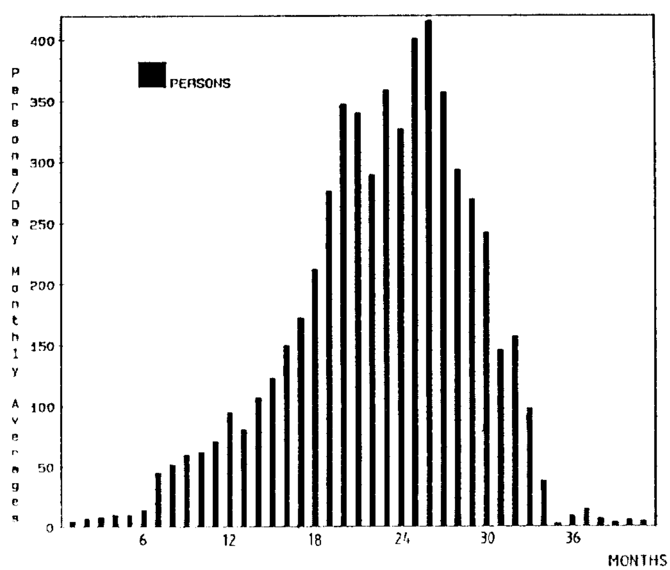

Fig. 4 Simulation of underground personnel during LEP installation

6. Management tools and installation follow up

Simulation at any stage of the project as well as follow up during the installation are essential features to keep the project on its tracks. A great effort was devoted at LEP in this field. Using a central relational database, planning prefabrication of machine components, follow up, transport of goods and personnel movements are computed weekly. This enables short term or long term simulation (Fig. 4 shows a simulation of personnel needs for underground installation spread over the total installation period), adjustment of installation tactics according to various external criteria : changes in civil engineering planning or installation rate of any contractor. During installation the data for the follow up are taken on site by means of portable computer and are fed weekly into the main system. Up to now 4500 activities have been followed this way. In the transport field a total of 2000 movements of goods have been activated; the peak monthly rate is foreseen to be 1500. Fig. 5 shows these movements as a function of time for the start of LEP underground installation.

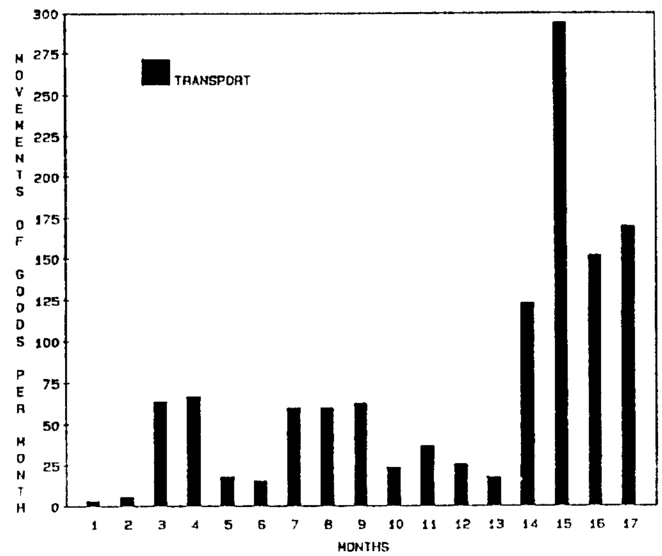

Fig. 5 Movements of goods for the first months of LEP underground installation

7. Conclusion

On one hand we show how important the choice of the four parameters **DBA** , **S** , **T** and **D** is. The number of pits (**DBA**) has by far the greatest impact on the whole project, i.e. involving almost any system. The number of accesses should not only be only determined by the completed project but also by the construction period. On the other hand the use of integrated CAE could build a powerful tool for reducing the overall project cost permitting improved coordination and standardisation.