Database Requirements for the Vacuum Systems of LHC

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Abstract

The new Large Hadron Collider (LHC) which will be built over the next decade at CERN requires two independent vacuum systems. One will be a high vacuum for the two 26 km long beam pipes and the other is needed for the insulation vacuum in the cryostat and helium distribution system for the superconducting magnets. Several thousands of components will be acquired, assembled and installed in the ring tunnel. All active components will eventually be remotely controlled. Several phases can be identified during the project lifetime, starting from the preliminary design and ending with exploitation. Each phase requires different sets of data to be available. This paper identifies the required data, when this data should be available, the needs for integration with other equipment or project databases and the tools which are felt necessary to manage the data.

1 INTRODUCTION

A considerable amount of information has to be provided, stored and exchanged during the various phases of a large project, like the LHC accelerator. Powerful database management systems are now available and ease the organisation and storing of this data. But retrieval or manipulation tools are as important as the database engine itself.

The required information varies during the project lifetime, as does the necessity to share this information. This paper tries to identify the information required to design, produce, install and eventually commission the vacuum system of LHC. It will also focus on those areas where information may not be available in the most suitable way.

2 CONCEPTUAL DESIGN PHASE

The functionality of the equipment must be defined properly during the conceptual design phase, but the components of the various systems, including the vacuum system, are only loosely defined. The aim at this stage is to provide a feasibility study, along with cost and resource estimates. This activity is carried out based on experience with previous accelerators, prototypes, manufacturers' catalogues, etc. In the case of the vacuum system, layout sketches are the primary input for the topology. From these, the vacuum specialists evaluate requirements for pumps, valves and measuring equipment. Adding them all together will provide a cost estimation.

During this phase, it is important to have access to the design and manufacturing data of previous accelerators (e.g. LEP), as well as to up-to-date supplier documentation. At CERN, design and manufacturing data from previous accelerators exists mainly in the form of paper reports and drawings, the latter often being stored in EUCLID or AUTOCAD format. Some manufacturing data for vacuum chambers exists in the form of ORACLE tables. On the other hand, manufacturers' catalogues are beginning to be published on electronic media, such as CD-ROM disks, which can be accessed from desktop computers.

At this stage, sharing of data is mostly done during formal and informal meetings. Minutes of these meetings can (and start to be) published by electronic means, like the World Wide Web. There is little need for a central database and in most cases a good spreadsheet program is an adequate tool to rapidly evaluate the cost of various solutions.

However, at the end of the conceptual design phase the cost and resource estimates should be stored in a central database, as they are key components for the planning and the follow-up of the budget and expenditure.

3 DETAILED DESIGN PHASE

The requirement for storing and sharing data considerably increases during the detailed design phase. The primary input data is the layout of the accelerator, which is derived from the conceptual design and gets more and more refined. The level of detail required is however varying strongly, depending upon the usage. For instance, the vacuum specialist responsible for distributing the pumping equipment needs to know about possible interferences with other equipment, whereas the controls team only needs to know the location of the equipment for cabling.

The layout data must allow for version handling, as it must be possible to work on several different implementations simultaneously. A good example of the implementation of such a database is given in [1]. It has been widely used by the Vacuum Group for the LEP accelerator. However, there is a strong need for better tools to access and manipulate the data.

Layouts are best represented on drawings rather than lists of equipment. The main reason for this is that these drawings are presented to various decision committees, where discussions in front of a computer screen are not easily possible. Another, almost trivial, reason is that the human eye often points to possible interferences much quicker than sophisticated analysis programs. Modifications of layouts should be possible using tools which resemble object drawing programs rather than the present method of ORACLE Forms used by Vacuum Group.

The objects themselves are drawn by the design offices using CAD tools (mainly EUCLID and AUTOCAD at CERN) and should be stored with various levels of details in a central database. The relations between the objects also have to be stored in a database. Work is going on in this field in the Vacuum Group and elsewhere at CERN [2], aiming at a generalised approach for defining and grouping objects.

It should be possible to access and manipulate these objects on a screen using essentially a "point and click" approach. For instance, the vacuum specialist in charge of placing the pumping elements would display a section of the layout of LHC and add or displace the pumps, the model of which would have been drawn by the design offices or extracted from manufacturer's documentation, when available. Again by analogy with common drawing programs, the layout should be drawn in layers corresponding to the various equipment groups.

Not all data has to be entered manually into a database. A large accelerator like LHC has a highly repetitive lattice for more than three quarters of its circumference. Hence automatic programs can be used to enter data like pump locations and the associated cabling. This approach was successfully used for LEP, where the initial cabling and routing had been produced automatically from the available description of the vacuum system in an ORACLE database. Similarly, pumps, gauges and roughing valves have been automatically placed using a FORTRAN program, the input of which was again the description of the vacuum system extracted from the database.

A large amount of experimental data will be produced during the detailed design phase. Several experiments are run to evaluate the effect of synchrotron light and the way to cope with it in a superconducting environment [3]. This data should be stored, but do not necessarily have to be in central database, as it is highly specialised.

As the volume of data increases considerably during the detailed design phase, it becomes necessary to introduce global data management tools, often referred to as Engineering Data Management Systems (EDMS). Commercial products start to be available and used in industry. An EDMS Task Force has been set up at CERN to try to use such a product for the design of LHC experiments [4].

4 MANUFACTURING OF COMPONENTS OF THE VACUUM SYSTEM

The Vacuum Group's involvement during the manufacturing process is mainly related to the tendering process, the follow up of the fabrication and the acceptance tests. At this stage all possible critical paths should be identified. Planning data must therefore be easily available and updatable. A solution to this problem is proposed in [5].

During the tendering process, detailed drawings must be made available from the design offices. In general, these drawings are produced using CAD tools but they still are output on paper, although more and more industries use CAD programs with an interchangeable output format, like AUTOCAD. An up-to-date supplier database is also a key ingredient for successful tendering, in particular to minimise the need for time consuming Market Surveys.

During the follow up of the manufacturing, critical data, such as tolerances, must be obtained from the manufacturers and stored in a database at CERN. During the construction of LEP, manufacturing data of the lead cladding process were downloaded from the supplier in Germany over telephone lines and stored in ORACLE tables. It is also at this stage that inventory data, like serial numbers, start to appear. Finally, the results of the acceptance tests must also be stored. The approach proposed in [2] seems adequate to relate the data properly with the different objects being manufactured. However, here again, a considerable effort to ease data input and retrieval has still to be done. In particular, it should be avoided as much as possible that data produced at the manufacturer's place has to be printed and later typed into a database.

5 INSTALLATION AND COMMISSIONING

During the installation phase, the primary data required is layout, planning and stock keeping. During this phase, there is little input from the Vacuum Group, except for delivery time of components and feedback from installation teams. But there is a considerable need for planning and logistics information.

The location of every component, identified by some serial number, should be recorded during installation. This data can be of great use when defects appear which could be linked to a particular series or production time of some components, requiring systematic repairs or modification. An attempt to store the location of vacuum equipment was started in LEP, where bar code labels were glued on the vacuum chambers prior to installation. A programmable bar code reader was used to scan parts of the accelerator after installation and this data was then loaded over RS-232 lines into the database computer. Unfortunately, the scan was never finished and the data has not been used. There was no technical problem, however.

The quantity of data to store increases again when the time comes for commissioning. At this stage, the main control system for LHC should be available. Hence, this data could be automatically fed into the database using data logging and archiving programs. This data is crucial for the future maintenance activities of the accelerator. Because of the tight time schedule of the installation work, some minor defects may have to be left for a later repair. The commissioning data would allow for a map to be produced of the temporary repairs which have to be fixed at the first possible occasion.

6 CONTROLS AND OPERATION

The specific database requirements for controls are multiple and start during the detailed design phase. Initially, the cabling of all remotely controllable equipment must be defined, relying on the layout data and properties of the equipment. As already mentioned, a large part of this activity can be done using automatic programs. In the exploitation phase, however, when only incremental modifications are done to the accelerator, a graphical approach is preferred.

An important effort has been made to provide operational models for the vacuum equipment [6]. These models are best described using object oriented notations. Thus, an object oriented database is likely to be the most efficient repository for the description of the properties and behaviour of the vacuum equipment. Work is presently going on in the Vacuum Group to assess to what extent a conventional relational approach could be used until commercial object oriented databases really exist. The messages and the required parameters used to drive the equipment must also be stored in the database. This has been done for LEP and allows for a coherent behaviour of the equipment, as well as for automatic decoding of the messages [7].

Finally, as soon as part of the accelerator come into operation, the pressures should be logged. Unlike all previous databases, this requires an on-line database, with update or insert times compatible with the physical data acquisition. Extracting data can be done off-line, however. Data reduction and archiving algorithms should be made available as soon as some data is available from the vacuum system via the main control system. A typical logging system should gather data at a relatively high rate (e.g. one reading every few minute). This data must remain accessible for a period of time of the order of one or two weeks, after which only a subset should be stored and kept for the lifetime of the accelerator.

7 CONCLUSIONS

The presently used Data Base Management System, ORACLE, is adequate for the storage of the huge amount of information required for the design, construction and commissioning of the LHC accelerator. Most effort will have to be put in the data manipulation tools, in particular to allow for a more graphical approach. A significant effort will also have to be put into the Configuration Management and into the global management of all this data, using the emerging commercial Engineering Data Management Systems.

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