CRITICAL SPARES

R.Saban, A.Ballarino, S.Fartoukh, G.Fernqvist, S.Grau, J.Íñigo-Golfin, T.Ladzinski, V.Mertens, K-H.Meß, M.Modena, R.Nunes, R.Ostojic, A.Perin, L.Rossi, L.Tavian , CERN, Geneva, Switzerland

Ch.Darve, S.Feher, J.Strait, Fermi National Accelerator Laboratory, Batavia, Illinois, USA.

Abstract

Following the completion of the installation last year, several reviews were carried-out to draw up the inventory of the spare accelerator components as well as the status of the infrastructure systems. This paper presents the new situation following the September 19th incident and the ongoing repair.

INTRODUCTION

The conclusions of the ATC/ABOC days, Chamonix Workshops, LTC, MARIC were consulted, the data found there was skimmed and what is presented here focuses on the spares, which are perceived as critical. These are components of the machine for which there are little or no spares, as well those the provisioning of which would take longer than the warm up time of the collider and the removal of the failed component.

The study considers the LHC but also the infrastructure systems such as cryogenics, cooling and ventilation, electrical distribution, access control and safety systems.

It is worthwhile mentioning that, since the *injector chain* was reviewed regularly and actions were taken to consolidate or mitigate the effects in case of failure, no issue on these systems worth reporting was detected. It is also reported that both the *access control system* and the *safety systems* do not have a critical spare parts problem.

SUPERCONDUCTING MAGNETS

The arc dipoles

There are two cold mass types, which differ because of the two types of spool piece corrector sets (type A: sextupole and combined octupole/decapole or type B: sextupole only) and because of the internal bus-bar routing, which electrically positions the dipole either on the *go* or on the *return* line with respect to the power converter. The assembly types depend on the cold mass, the mechanical interfaces at the extremities (dipole-dipole, dipole—quadrupole, quadrupole-dipole), the beam screens (B1 internal or external). All this gives 12 different assembly types in the arc and 22 in the dispersion suppressor region. The cold mass types, which cannot be reconfigured, determine the spare inventory.

Presently, in addition to those in Sector 34, two dipoles, one in Sector 12 and one in Sector 67, have to be replaced. Only **3 cold masses of type A are available as spares**; these, however, have not yet been tested nor has their internal resistance been measured. In addition, there is a large quantity of cold masses that remain to be refurbished:

30	recovered from Sector 34, of which a few are damaged beyond “immediate” repair
1	with 100 nOhm internal resistance removed from Sector 12
1	with 47 nOhm internal resistance to be removed from Sector 67
4	with varying internal resistance (18 nOhm upwards), which were detected intercepted on the measuring benches and therefore blocked before installation. One is of type A and three of type B

Table 1: Inventory of dipoles that remain to be refurbished.

The arc quadrupoles

The situation with possible configurations is more delicate for the arc short straight sections; in fact, there are 40 cold mass types, which are made by combining different types of corrector families (octupoles, tuning quadrupoles, dipole orbit correctors, sextupoles, skew sextupoles, etc.), BPM types and the quadrupole powering scheme. Depending on their location, their interfaces (with the neighbouring magnets but also with the QRL) they totalize 61 assembly types. Again, the cold mass is the difficult part. The envelope can be adapted to the position/function in the tunnel. After the repair of Sector 34, at the time of writing, the situation with the spares is the following:

6	**cold masses; not yet cold tested. One has a suspected leak which is being investigated**
2	**full short straight sections which have been tested and qualified.**

Table 2: Inventory of arc quadrupole spares.

In addition, there are six short straight sections that have been removed from the tunnel; they will be refurbished: a few, however, are damaged beyond “immediate” repair.

Experience with Sector 34 has shown that, within certain limits, the machine optics can tolerate replacement of quadrupoles, which do not have exactly the same function as the original one.

The dispersion suppressor quadrupoles

There are 29 types of cold masses made by combining 7 different types of magnets plus the corrector families; of these, 78 sets are installed. Only **one Q9 type and one Q11 cryostated spares are at present available**. There are also one Q8 and one Q7 of the 600 series as completed cold masses ready for cryostating. Parts to produce any of the other 27 types are available in house.

The matching section quadrupoles

There are 19 types made by combining 7 different types of magnets plus the corrector families; of these, 36 sets are installed. **No complete spares are available** due to the big number of different combinations. However, tested magnets (quadrupoles and correctors) as well as other components are available. It is estimated that about two months are needed for building a new assembly, and another month for test and installation.

The separation dipoles and the inner triplet quadrupoles

There are 4 types of cold separation dipoles of which 16 sets are installed. One spare of each type is available; during the discussion following the talk, it was however noted that one of them (D1) has one (out of two) heater circuit unavailable. During the repeated tests at BNL, which aimed at further testing the heater circuit, the magnet performed correctly and no degradation was observed. In addition, this magnet has a different transfer function due to a non-conforming yoke key material. It was argued therefore that it could not be considered as a fully valid spare.

There are 3 types of inner triplet quadrupole assemblies made using 2 different quadrupoles (MQXA and MQXB) and three types of corrector packages. There is one spare for each type. Eight sets of three magnets are installed.

During the discussion following the talk it was however noted that one of them (the spare Q2) has one (out of four) heater circuit unavailable and includes a prototype dipole orbit corrector, which could limit its installation to a low luminosity IR.

In addition to the two spare Q1 and Q3 magnets, KEK has delivered to CERN two additional MQXA magnets which each can be configured either as a Q1 or a Q3 cold mass by installing the appropriate correctors, bus bars and end domes. Tooling, presently unavailable at CERN, is needed for this operation.

It is worthwhile mentioning that there is no facility for testing any of the magnets manufactured by KEK or the US-LHC collaboration on the CERN site. Like for any other magnet, these magnets must be cold tested before installation to check their electrical integrity.

THE DFBs

There are four main types of DFBs: one in the arc, (the DFBAs) and three in the long straight sections: the DFBM for the matching section, the DFBL for the superconducting link and the DFBX for the inner triplet assembly comprising the quadrupoles, and, in two out of four cases, the recombination dipoles.

For the first three, there are 31 different types of DFBs of which 56 are installed. There are **no spare DFBs nor modules but spare chimneys** (10%) and the situation of the current leads is given in the table below:

Number	Type		
8	**13**	**kA**	**hts**
25	**6**	**kA**	**hts**
6 x 4 *	**600**	**A**	**hts**
0 †	**60 -120**	**A**	**conduction cooled**

Table 3: Inventory of current lead spares for DFBAs, DFBMs and DFBLs.

The production of additional high temperature superconducting leads would require at least one year. In particular this would require the procurement, assembly and test of the BSCCO 2223 material. The know-how exists in house since all leads were designed at CERN and prototypes were assembled in the central workshop.

There are 6 different types of DFBX of which there are 8 sets installed. **No spare DFBX, module or current lead is available** on the CERN site. A couple of 7 kA lead prototypes were tested at CERN but they were then returned to the manufacturing lab and should be available.

THE INJECTION SYSTEM

A wave of debris through the beam pipe of LSS2L or LSS8R could render the full set of 4 injection kickers inoperable at once.

The scenario was not considered likely enough to justify a complete set of spares. Presently one spare magnet for eight installed is available. Following the LTC in Sept 2007 it was decided to start building a second spare, largely from remaining spare parts. This will be ready for beam in QIII/2009.

Refurbishing 4 magnets would take about 20 to 24 weeks, which are likely to be in the shadow of the repair of the *root damage*.

ACCESS AND SAFETY SYSTEMS

The LHC Access Control and the Safety systems do not have a critical spare parts problem. However, only a very limited number of spare parts for the personnel and material access devices are available on site. The consequence of an access device becoming unavailable could very easily be mitigated by the condemnation of the concerned access point. During the shutdown period however, such a solution would result in a more time-consuming access procedure and thus could delay work in the tunnel. It is also worthwhile noting that there is a severe problem with the availability of spares for the Access Control systems of the injector chain (PS & SPS) and that a complete renewal of the system is being prepared.

* 6 assemblies of four 600 A current leads

† spare components are available for final assembly

THE ELECTRICAL DISTRIBUTION SYSTEM

A number of major issues were resolved during the past year aiming at reducing the collider downtime in case of fault: these include the redesign and correction of the 24 V_{dc} power supply racks, the long term replacement program of the SPS 18 kV cables which exhibited water treeing, the spare restoration program for the cast-resin transformers and the UPS systems.

The item of major concern remains however the water-cooled DC cables linking the power converters to the high current circuits (above 5kA) in the tunnel: the hoses were found not to be halogen free and show signs of premature ageing. A negotiation with the company, which supplied the hoses around the conductor, is ongoing but a clear consolidation program is far from being ready.

THE COOLING AND VENTILATION SYSTEM

The system relies on industrial machinery, process control equipment and electrical distribution cubicles some of which date back to the LEP days. In some cases, like for the **York compressors that supply dry air at the even points**, the equipment is obsolete and its replacement is mandatory. A flying spare system for the **main water pumps in the UWs** is in place, but the replacement of a failing pump would take 2 to 3 days, entailing a much larger stop of the cryogenic system which depends on it. The funding required for these items is 5 MCHF.

A more comfortable stock of spare valves, electrical actuators, compressed air dryer units must be constituted.

THE CRYOGENIC SYSTEM

There are 64 turbines installed in 4 different types of cryoplants: 36 turbines were identified as critical, since a fault would cause an important loss of refrigeration capacity. The impact on the accelerator operation is between a few weeks to a month at worst or, when possible, operation at reduced capacity.

18 turbine spares would cover the critical needs: of these, **only one spare turbine is available**. A call for tender was issued, for which the adjudication was obtained at the November 2008 Finance Committee. The funding remains to be found within the LHC operation budget.

CONCLUSION

The findings lead to conclude that there is an acute critical spare issue for some LHC components, together with a consolidation issue for some infrastructure and accelerator systems.

A *detailed inventory* of the existing spares and spare components of the LHC elements as well as of the LHC infrastructure systems must be prepared.

The *strategy* for the quantity of spares and the consolidation must be defined.

A program to restore the spare inventory and to consolidate the vulnerable infrastructure systems must be started once the repair of Sector 34 is completed.

ACKNOWLEDGEMENTS

This review is the result of many discussions with the colleagues responsible for the components and the systems reported above before, during and after the talk at the Chamonix Workshop 2009.