REINSTALLATION AND INTERCONNECTIONS OF SECTOR 3-4

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Abstract

Reinstallation of the first magnets in the D-zone has already started in parallel with the removal of damaged magnets. It is planned for the last magnets to be reinstalled by end March.

The start of the interconnection (IC) work requires a minimum chain of adjacent magnets and their alignment: it is planned to start this in late February. IC work will now be performed by CERN and FSU staff, no longer with the Main Contractor as for past series work. The status of the IC situation, the new work organisation and responsibilities will be presented. Quality Control issues are particularly important, both to reproduce past quality in the new conditions, and of course to improve on critical aspects.

IC work will also continue in parallel outside the D-zone in 3-4 and in other sectors during the shutdown. The issues of resources and scheduling are addressed.

STATUS OF 3-4 (ON WEEK 05-2009)

Within hours from the 19 September incident, a vigorous work campaign on magnets and interconnections had started in sector 3-4. This work proceeded in well defined steps, initially aimed at lowering the risk represented by damaged magnets.

The first step consisted of an overall inspection: this identified important cryostat displacements of SSS with vacuum barriers, but no apparent damage to the tunnel structure and services.

The second step consisted in securing against the risk of the displaced magnets falling off their unstable supports towards the passage side, onto the floor or onto the QRL. It was correctly foreseen that dipoles adjacent to the displaced SSS could have also been damaged, specifically to their cold feet supports. The action, studied and implemented jointly by the magnet team, transport handling, the Safety Commission and the Fire Brigade, consisted to position two heavy beams under each of the four displaced SSS as well as the dipoles adjacent to each displaced SSS.

The third stage involved the campaign of disconnecting the magnets. As interconnections were opened more damage became visible: electrical short circuits, movements of dipole cold masses, soot, MLI etc. Simple restraints were installed to secure the cold masses onto their cryostats. Disconnection work was also performed outside the D-zone, specifically related to damage to the beam lines and PIM components, or to the need for endoscopy inspection or cleaning.

The fourth stage involving the transport of damaged magnets to the surface started in parallel. Special, heavier transport restraints were installed to perform the transport operation in full safety conditions.

A total of 39 dipoles (MB) and 14 Short Straight Sections (SSS) were disconnected and removed from the D-zone. Overall, 123/212 interconnections were opened and 213/424 PIMs were cut. The last magnets were transported to the surface in week 2-2009 (W02). Civil engineering work to repair the damaged areas of tunnel floor is finished. For installation of pressure relief nozzles about 60 additional interconnections will have to be partially opened.

The campaign to clean from soot and MLI the magnets remaining in the tunnel is ongoing, aiming to allow the restart of mounting and welding PIMs as early as possible. The repair of the four damaged jumper bellows of the QRL service modules is also ongoing.

The transport of new or repaired magnets back into the tunnel started end 2008: the current status is of 9/39 MB and 1/14 SSS reinstalled.

The preparation of magnets on the surface is progressing vigorously: this involves decryostating magnets returned from 3-4 to reuse their cryostat components, cleaning, cryostating, cold testing, stripping, insertion of beam screen and final tunnel preparation. An overall detailed planning exists with each activity having integrated the required additional resources to ensure their contribution. Figure 1 shows the current planning of magnet availability for transport.

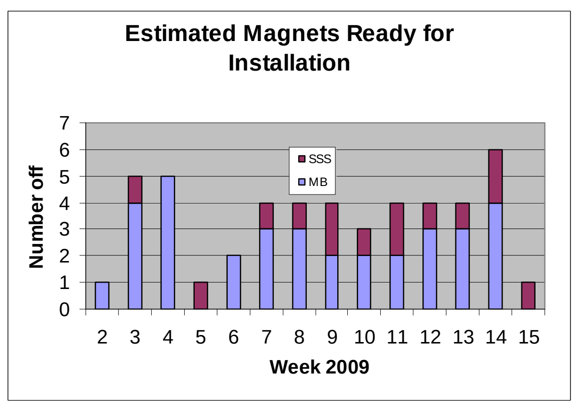

Fig. 1: planning for magnets ready for installation

INTERCONNECTION WORK

Some specific features of IC work have a direct impact on work organisation and planning:

- Different technologies involved, for both electrical connections (busbar soldering, ultrasonic spool welding), cryogenic and vacuum connections (TIG welds), and testing (visual control, leak testing, Electrical quality assurance ELQA, reflectometry, endoscopy).
- Some activities can be performed between adjacent magnets, others require chains of connected magnets

(from the half-cell, to several half-cells to the complete sector). Figure 2 shows the planning for half-cells to become available.

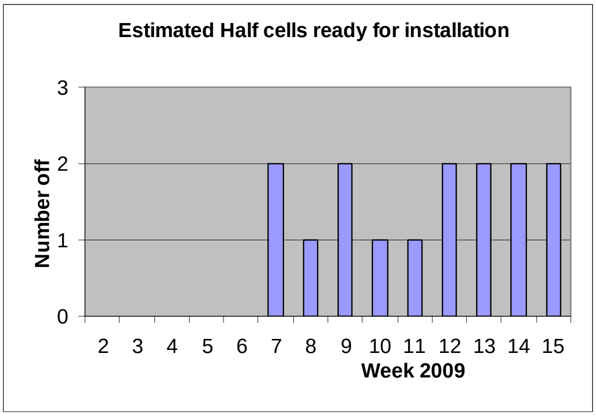

Fig. 2: planning for availability of half-cells for IC work

- These activities are chained, meaning that they represent a sequence to be respected, with each activity needing successful testing before liberating work for the successive activity: it requires ~40 activities before an interconnection between magnets can be finally closed. An important assumption in organising the 3-4 reconnection is that he original work sequence used for the arc series production is still respected: an example of possible deviation could be to avoid the ELQA AIV2 test of the US welded N-line connection.
- There is an obvious geographic constraint: two teams cannot work together at the same time on the same interconnection.
- Experience from the series work has shown clearly that the overall duration of IC work is driven by the ability to minimise the time lost between activities, rather than the duration of each activity, i.e. in coordination work. Closely associated is the quality of work, i.e. the expertise of the workers involved, since a quality problem in an activity has an immediate repercussion on the schedule of all the intervenants expecting to perform their subsequent activities. This has consequences on the type of additional resources that can be integrated and on the effort it takes to qualify and coordinate them.

IC planning

IC planning is based on the following assumptions:

- Half cells become available according to the rate shown in Figure 2, the last in W15 (<u>both</u> critieria are important);
- Surface resources (from production and Quality Control) continue their work with IC from W15 (this is in competition to the need to continue surface activity to quickly reconstitute our stock of spare magnets);
- Avoid losing production time with coactivity conflicts: e.g. transport has agreed to perform their handling and installation work during night shifts, starting W10;
- No holidays (Easter, May bank Holidays etc.) i.e. a crash program to be managed widely and consistently throughout all intervenants. Conversely this cannot extend at high intensity indefinitely in time, specifically for the IC intervenants not beyond the start of Summer;
- No contingency for technical problems: this against the accumulated experience showing that statistically some problems will arise (e.g. ELQA PAQ tests negatively affected by high humidity levels - as present in 3-4, welding defects to be corrected etc.)
- No further additional work asked to be handled “in parallel”: between week 10 and 23 all IC resources and IC-related resources will be fully engaged in 3-4.

Survey and IC work will start on the few available magnets in the D-zone on W07. The planned complete half-cell will not be available, probably delayed by 1-2 weeks. Work outside the D-zone, namely the reinstallation and welding of PIMs, is still waiting to start for the end of the vacuum cleaning.

Under the above assumptions, it is planned to close the last interconnection W bellows in W23, thus allowing the following operation of vacuum leak testing the subsectors.

Resources

During series IC work [1, 2], the Main Contractor IEG employed over 100 persons, including their internal structure for supervision and Quality Control. CERN supplied an additional 100 persons for:

- Worksite Coordination
- Inspections, endoscopy and Quality Control, including management of Non-Conformities
- Testing (ELQA, vacuum, reflectometry)
- Mechanical interventions (the “Pompier team”) dealing mainly with repair of non-conformities.

With the role of Main Contractor ended in May 2008, CERN (now TE-MSC) took upon the responsibility of performing directly mechanical interventions and the associated QC. This team relies on CERN staff and key FSUs (Field Support Unit): of the over 100 IEG workers, only 3 were still present as FSUs at CERN after May 2008.

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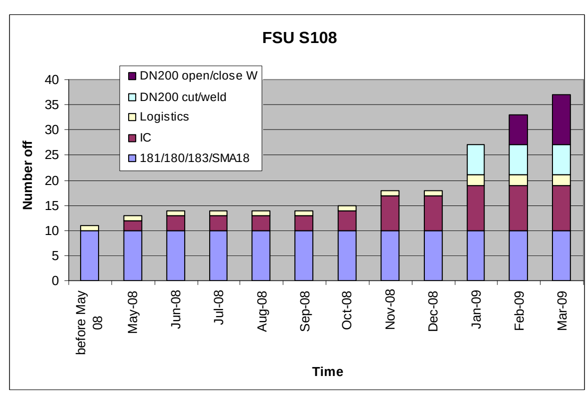

Fig.3: increase in FSU staff since September 2008

In the days after September 2008 a strong effort started to re-employ as FSUs experienced personnel, to reinvolve CERN staff from other sections, groups and indeed staff

from outside CERN (e.g. the collaboration with HNINP-Krakow for QC and with Dubna), e.g. Figure 3.
The qualification, supervision, coordination and quality control of this staff requires a considerable effort. In some activities (e.g. cold testing, beam screen integration) the duration of the peak period of activity is coming at very short notice and will last only a few weeks: hence it is not the best solution to involve newcomers, but it is preferable to obtain additional capacity by using the flexibility of existing staff. Shift (or shifted "decalé") work is to be used carefully, since it is to be considered with supervision, also of very different nature and form between surface/workshop and tunnel work.

ORGANISATION OF IC WORK

The coordination of a site or of a workpackage is ensured by the Worksite Manager (similarly to the Engineer in Charge).

The respective roles, expectations and responsibilities of workers, their supervision and Worksite Manager have been defined.

Quality Control for IC work

Particular attention is being given to the organisation of the Quality Control. With several persons having left since series work, with new intervenants and with the growing of experience the objective is to perform at least as well as before while improving specific more critical aspects. Since the technical content of each activity is quite complex (e.g. electrical connections vs TIG welding) it was decided to create Quality Control Responsibles for different activities. The job description of the QC Responsible for electrical interconnections includes:

- qualify operators/workers, equipment and tooling;
- organise/perform pre-inspections before work start;
- organise/collect/analyse production data;
- organise/perform quality inspections (visual, NDT etc.) of work done;
- organise/perform weekly audits to ensure that correct procedures, qualified tooling and operators are used;
- organiss and analyse qualification and production samples;
- ensure traceability of his work (e.g. photos);
- is attentive to the general environment constraints around his specific work;
- can close NC on delegation of the QCC
- shall stop the activity in case of Quality issue

There is finally a Quality Control Coordinator with the responsibility to harmonise the methods used by each QC Responsible, specifically over storage and traceability of documentation.

The current organizational effort is pressured to provide today the required work, specifically linked to shutdown activities in different sectors, to formally qualify workers and equipment and to harmonise the collection and traceability of production and quality information.

A positive beneficial outcome of today's situation is that workers, Quality Control, equipment and procedures are becoming increasingly merged between surface magnet activities and tunnel IC work.

OTHER SHUTDOWN ACTIVITIES

Also ongoing are other tunnel activities required in parallel to the 3-4 interventions, mainly:

- 1-2 and 5-6: ongoing since warmup W02 and W03. The RF ball test has shown 3 PIMs with buckled RF fingers in each sector.
- 1-2: removed MB2334 (B16R1) 100 nΩ. The second indication from calorimetry of a 50 nΩ resistance in the RB circuit in area Q31R1–Q31L2 has been checked. 20 of the 24 interconnections were previously checked with the US test: the remaining four were opened, similarly checked and found to be conforming.
- 6-7: warming up to remove MB2303 (B32R6) 50 nΩ, PIM checking and eventual replacement.
- 5-6: the three connection cryostats, the He level guards in the arc SSS
- Stand Alone helium level gauges in all sectors (3 week window for PIMs with partial warm-up)
- 1R and 5L: triplets copper braid.

CONCLUSIONS

The interconnection work in 3-4 will start in W07. If the current planning of surface activities and of reinstallation of magnets is respected, the last magnets will be installed in W15 and the closure of the IC work will be in W23.

The organisation structure has been set up but will inevitable require time to become fully and smoothly operational. While no major "showstoppers" exist, small technical difficulties inevitably introduce delays of a few days. Since several intervenants are involved, this accumulates easily to delays in weeks.

The schedule remains credible but extremely tight. In particular it contains no contingency against technical risks that experience has shown can and will statistically appear. From an organisational point of view it will require a generalised crash program approach, avoiding to introduce further tasks and limiting this in time.

REFERENCES

[1] P. Fessia et. al., "The LHC Continuous Cryostat Interconnections: the Organisation of a Logistically Complex Worksite Requiring Strict Quality Standards and High Output", EPAC'08 Conference, 23-27 June, 2008, Genova, Italy.

[2] F. Bertinelli et. al., "The Quality Control of the LHC Continuous Cryostat Interconnections", EPAC'08 Conference, 23-27 June, 2008, Genova, Italy.