

CAN WE OPTIMISE THE CLEANUP PROCESS FURTHER?

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Abstract

Following the sector 3-4 incident, about 5 km of beam vacuum system have been spoiled with soot, metallic and super insulation debris. During four months, several teams have intensively worked to recover the beam vacuum system. The presentation will address the successive sequences of this activity in terms of preparation, execution and control. Steps where time was lost and the possible optimisations will be presented. The obtained quality performance of the cleaning activity and possible qualification means will be showed.

INTRODUCTION

The 19th September 2008, the 2 plug-in-modules (PIM) located between magnets C24R3 and Q24R3 were destroyed. The consequence of this incident was a helium inrush inside the 2 beam vacuum tubes V1 and V2. Under this helium pressure, soot and debris of super insulation were spread along the 2 x 2.8 km vacuum sectors.

In the first paragraph, the means developed to evaluate the extend of the damage are described. The beam tube cleaning and methodology is discussed in a 2nd paragraph. Finally, the follow up of the cleanup is presented in a last paragraph.

INSPECTIONS

After the incident, access in the tunnel was made available when all the risk associated to any over-incident was eliminated. When the first PIMs were cut by beginning of October 2008, plugs equipped with safety valves were installed at the beam tube extremities to minimise the air and dust pollution of region still at 200 K.

The inspection campaign started immediately after with the areas around Q21R3 and B30R3. However, the progressing rate of the endoscopic inspection of the beam tube was rapidly reduced by buckled PIM which blocked the aperture. Therefore, these PIMs must be cut by TE-MSD at the request of TE-VSC. Little by little, most of the W bellows were systematically opened and buckled PIMs systematically cut. By mid December 2008, all required W bellows were opened and PIMs cut. A total of 122 W bellows and 204 PIMs were cut.

The beam tube inspections reveal the presence of metallic debris, super insulation debris and soot. When possible, a length up to 150 m could be inspected in one go. Due to the presence of sawteeth inside the beam

screen, the endoscopic inspection should be done in the reverse way than the proton beam path. Indeed, the reflected light onto the sawteeth was partially blinding the endoscope's camera.

Figure 1 shows extracts of reports issued by the team in charge of the inspections. In the endoscopic report, all components such as beam screens, PIMs and beam position monitors were photographed. Their aspect and the level of their cleanliness were also evaluated. In the interconnection report, the length and the aspect (deformation, presence of shocks ...) of the nested bellows and the PIMs was reported. A picture of the interconnection was also taken.



Figure 1: Left, example of endoscopic report. Right, example of interconnection report

By the end of December 2008, 4.8 km of beam tube and 122 interconnections were inspected and documented. A total of 59 % of beam tube were polluted by super insulation debris (MLI) and 19 % by soot [1].

Figure 2 shows the debris distribution along sector 3-4. Most of the super insulation debris were observed at the extremity of the sector. However, these debris were spread from Q30R3 till Q7L4.

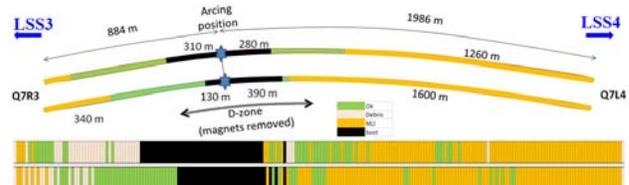


Figure 2: Debris distribution along sector 3-4.

BEAM TUBE CLEANING

Tooling development

In parallel to the inspection work, tools were developed to clean the beam tubes in sector 3-4. A foam plug was successfully tested and applied to recover the V2 line of B19R3, C19R3, Q19R3, A20R3, B20R3 and C20R3 which were polluted by soot. Preliminary test of a vacuum cleaner were based on sucking technology with a mule perforated with holes. These tests were partially unfruitful. However, following successful harvest campaign performed by end November in the tunnel from Q13R4 till Q8R4. It was decided to use the RF ball automatic pumping/venting technology to develop the cleaning tool. A nozzle designed to blow nitrogen and attached to the endoscope's head was built and tested in the laboratory by January 2009. During the validation phase, 17 PIMs cut and recovered from the sector 3-4 were subjected to 2 successive passages for a total accumulated time of 8 minutes per PIM. The removal efficiency was found to be better than 90 % [1,2]. After evaluation in the tunnel of the parameters such as the number of passages, the time per PIM, the time per beam screen and the nozzle opening, a detailed cleaning procedure was issued [3]. The maximum sector length to be cleaned was one half-cell. A summary of the procedure is given below:

- 1st Step, automatic pumping/venting of the sector during at least one hour. At the end of this time, additional automatic pumping/venting of the so-called pumping hoses (vacuum ports at each quadrupole) during at least 15 minutes.
- 2nd step, 10 passages along the vacuum sector with the nozzle-endoscope tool and the automatic pumping/venting. During passage 1, 2 and 3, the nozzle-endoscope tool should be applied during 10 minutes at each PIM then 5 minutes are required. In the beam tube, the speed of the nozzle-endoscope tool is 3 to 4 m/minute. In case of an event visible by the endoscope camera, the operator shall insist with the tool to remove the event. The beam line is subjected to automatic pumping/venting during passages 1,2,3,4,9 and 10. Additional automatic pumping/venting of the pumping hose is installed in parallel during passages 5,6,7,8. After each passage, the debris are collected in a plastic bag for future documentation.
- 3rd step, endoscopic control. Once a sector has been cleaned, quality control is ensured by a systematic endoscopic inspection in both directions. Each beam position monitor, each PIM, each entrance, mid and end part of the beam screen and finally, each unexpected event are recorded by video. A report is issued at the end of the control.
- 4th step, validation of the cleaning of the sector and release of the sector for PIM welding.

This procedure was established by end February. It asks for a challenging mean cleaning rate of 50 m of beam

tube per team and per day with a total of 3h15 min spent for the PIM cleaning. Obviously, the 2nd step was the longest of the procedure. Each PIM were cleaned during 1h5 min. Note that reducing the amount of passages from 10 to 5, *i.e.* 40 min per PIM, would gain 40 % of time at the price of a slightly lower quality.

In parallel to the establishment of the procedure, after discussions with AB-AP and following Chamonix 2009, it was agreed with the management that a maximum of one fibre per half-cell and two debris (from super insulation or other) per magnet can be tolerated after the cleanup process!

FOLLOW UP

During the cleanup work in the tunnel, a day by day reporting and analysis of the cleanliness was settled. A total of 3 teams employed to clean the beam tube and 1 team for final endoscope analysis were deployed. Figure 3 shows the dashboard of the cleanup process. After the procedure set up phase till the 23rd of February 2009, the work progressed at the requested speed. By the 11th of May, *i.e.* 4 months after the beginning of the cleaning, all the PIM were delivered to TE-MSC for welding.



Figure 3: Dashboard of the cleanup process

Of course, the work did not progress without difficulties. Several times, the endoscopes were damaged or the nozzle was stuck inside a PIM as shown in Figure 4. In this last case, TE-MSC was requested to open the W below and cut the PIM. There were also issues with coactivity which not only delayed the task but also, some time, decrease the performance of the work. Indeed, dusts were produced in the tunnel by the teams in charge of drilling a hole for the cryostat relief valve beside the team in charge of cleaning the beam tube. Obviously, this could not work!



Figure 4: Nozzle blocked by metallic debris

Finally, the validation of the beam cleanliness by simple endoscopic inspection was not always trivial. As shown in Figure 5 where fibre or MLI are hardly identifiable. A total of 101 non-conformities left as “use as is” were recorded. 58 were assigned to super insulation debris, 38 to fibre and 5 to oxidation stains. All these non-conformities were documented and archived.

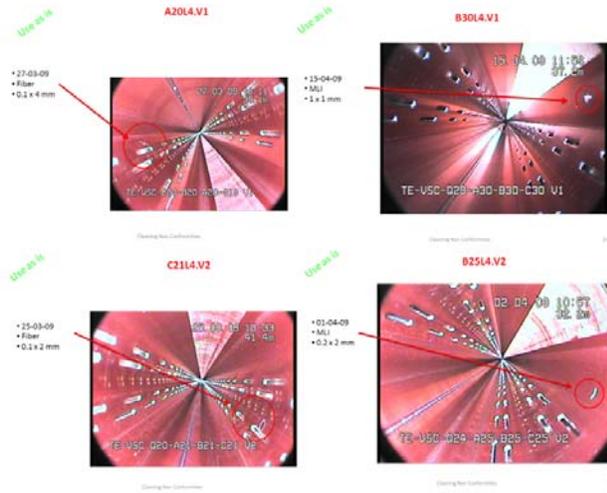


Figure 5: Examples of non-conformities left as “use as is” identified during the validation step

CONCLUSIONS

The incident of sector 3-4 spoiled all the beam tubes in the arc. It required the setting up of a team and the development of new tools and methodology to recover the beam tube. About 3 month were required to develop the tooling and perform the first inspections. 4.5 more months were also used to define the methodology, clean the beam tube and perform the final endoscopic control.

In the advent of a similar event, it is estimated that at least 2 months would be required to performed inspections which are slowed down by W bellows opening and PIM cutting. Another 3 month would be required to perform the beam tube cleaning and the final endoscopic control. The total intervention time will be

then reduced from 7.5 to 5 months. At the price of a lower cleaning quality, 1 more month could be gained.

Today, 6 sets of tooling are on the shelves, ready to interne. I hope they will stay there forever!

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