HOW TO MANAGE A LARGE SCALE BEAM LINE CONSOLIDATION IN A HIGHLY ACTIVATED AREA?

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Abstract

The TDC2/TCC2 consolidation is a good example showing how the complexity of interventions in high radiation areas has increased over the last five years. Due to its duration, its dispersion, the diversity of the teams involved, the fixed deadlines, the risks and external constraints, this worksite prefigures large scale-interventions in the LHC during long shutdown 2 (LS2) and even more LS3. The paper describes the three main project phases: preparation, execution (including monitoring and control) and closure emphasizing the indispensable steps in each stage. It also explains why integrating scope, schedule and dose into a single baseline is of prime importance and shows how to manage and monitor the radiation safety performance of the various interventions throughout the execution phase. Eventually, some recommendations are formulated in order to better accommodate the design of high radiation areas to their operation and maintenance constraints.

INTRODUCTION

The TDC2 and TCC2 caverns are located downstream the North extraction of SPS where the primary beam is split into three beams hitting the target stations named T2, T4 and T6, producing secondary beams which feed the various North Area experiments and test beams. Corrosion of vacuum equipment has been observed in the splitter magnet area of TDC2 since 2001. Corrosive liquid dripped on the beam line, causing vacuum leaks on the thinnest components, e.g. 0.15-mm thick bellows. The excessive corrosion was caused by a mixture of circumstances:

• High radiation producing ozone which reacts with humidity forming acids
• Chlorine contamination due to PVC in the insulation of DC power cables
• Topology: cable trays were located just above the beam lines.

A project team investigated this issue and discovered that the water tightness of the TDC2 tunnel was no longer ensured. In fact, after 30-40 years of age, the asphalt joints between underground civil engineering works were damaged. In order to tackle the corrosion problem, the following actions have been achieved:

- Eradication of water leaks: repair of magnet leaks, water circuit valves and hoses, reduction of water infiltration from the tunnel ceiling and maintenance of the drain network
- Consolidation of the ventilation system: installation of new chilled water pipes and air handling unit cooling coils
- Replacement of damaged equipment including vacuum beam pipes, beam monitors and the TCSC Collimator
- Re-routing of the cable trays and exchange of the PVC insulated DC cables in this splitter area by cables without PVC.

Additional activities have been completed in view of making this facility more reliable and safe, renovation of the low voltage electrical equipment, exchange of target boxes on T2, T4 and T6 targets and upgrade of XTAX tables and magnet cooling hoses [1].

In total, the consolidation involved 370 people and lasted 13 months. An 83mSv collective dose was spent and the physics run resumed in October'14 as initially foreseen.

Figure 1: Splitter magnet area before consolidation.

Figure 2: Splitter magnet area after consolidation.

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PREPARATORY WORKS

Scope of the Consolidation and Documentation

The consolidation of this area involved more than 15 CERN equipment groups during the first LHC long shutdown (LS1), which lasted about two years (end 2012 to end 2014). LS1 was a unique opportunity to carry out major and time consuming works not achievable during annual technical stops (only offering a three-month intervention window) and as such a large range of activities were foreseen in the same location, using the same manpower and to be executed within the same period. The project team sorted out the different tasks and priorities and delivered a work breakdown structure (WBS) of the consolidation work that was agreed upon by all stakeholders.

As both TCC2 and TDC2 caverns were designed and built in the mid-seventies, documentation was incomplete and outdated. Hence, a safety file was compiled and a laser scanning of the whole area took place at the beginning of the project. Combined with a 3D movie – “Google Street View style” – the integration team produced “as built” CAD models of all beamline equipment and associated services.

Radiation Level Survey and Fluka Simulations

The interaction of high-energy hadron beams with matter causes mixed radiation fields and results in the activation of material. As a result, the TDC2 and TCC2 caverns are classified as a high-radiation controlled radiation area i.e. an area where dose rates higher than 2 mSv/h can be found according to the CERN radioprotection rules [2]. By means of a remote operated device handled by the overhead crane, a radiation survey was completed and produced a detailed radiation map showing dose rates reaching 40 mSv/h. Wherever it was not possible to obtain dose rate information by measurement, FLUKA simulations were carried out for rough assessments and to give indications where hot spots are located. In particular, XTAX blocks (absorbers) and the T2, T4 and T6 target stations were simulated as they are encapsulated in a thick protective shielding and as such inaccessible before intervention. They turned out to be the most activated parts of the installation, having received 2.10^{18} protons on targets in the 2012 run.

Work and Dose Planning and Optimization

Integrating scope, schedule and dose into a single baseline is one of the most important elements in the “As Low As Reasonably Achievable” (ALARA) work because proper planning can reduce the exposure considerably [3]. To manage the complexity of the project, the WBS was broken down into well-defined project work components named Work Packages (WPs) assigned to each equipment group. It was also convenient to decompose each WP into smaller, more manageable components named Work Units (WUs), which correspond to a task at a specific location for a given period of time.

Each WU in a radiation area corresponds consequently to exposure to ionising radiation for personnel. Every single contribution was then precisely defined (manpower, location, schedule sequence) and estimated (duration, dose). All combined, this resulted in a Work and Dose Planning (WDP) which is the basis for the estimates of the maximum individual dose and total collective dose of all the planned work.

Further dose reduction needed dose optimization and required additional effort or smart scheduling to have high-dose tasks benefit of lower dose rates due to longer decay. In fact, an extended cool down period of 10 months took place before starting any on-site activity. Most radioactive items (splitter magnets and TCSC collimator) were temporarily removed to reduce the environment’s background dose rate. In addition, the team used different shielding configurations, remote handling and training on clean spare objects to reduce intervention time and therefore intervention dose.

For what concerns the TDC2 consolidation, this preparatory stage took about 10 months. 15 WP’s and about 100 WU’s were defined and estimated to result in a collective dose of 400 mSv, which was reduced to 200 mSv after optimization.

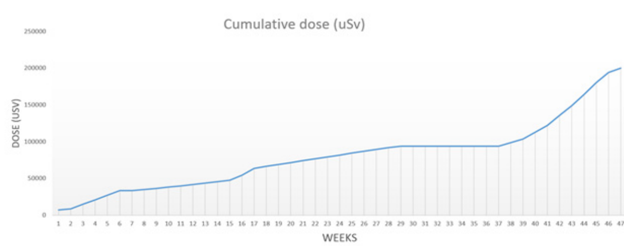

Figure 3: WDP - planned dose curve.

WORK EXECUTION

Milestone Follow-up

The overall TDC2 consolidation project was divided into 7 stages, with each stage culminating in the completion of one or more deliverables:

1. Removal of most activated equipment
2. Civil Engineering works
3. DC cable re-routing
4. General consolidation activities
5. High activated area consolidation activities
6. Activated equipment re-installation and cleaning
7. Facility re-commissioning

Each stage was separated from another by a milestone, i.e. a decision point at the end of a stage where the performance in terms of radiation protection and safety was measured. Several project team meetings and three ALARA committees involving the top management of the CERN accelerator sector were organised throughout the intervention to give the required green lights.

Monitor the Intervention

Since 2013, integrating scope, schedule and dose into a single baseline is possible on an operational basis at CERN. Thanks to the recent major improvements in the electronic dosimeter system [4] (mandatory readings of the operational dosimeter at entry and exit of the controlled areas), combined with the Impact Access System [5], the accumulated operational dose can now be monitored on a regular basis allowing rapid corrective action when and where needed.

The monitoring and control of the dose in relation to the actual work accomplished and in relation to the work planned are essential to ensure that:

- The objectives are being met;
- The working methods used are efficient and effective;
- The allocated contingency for the individual and collective dose is used correctly. [3]

They were achieved on a daily basis and didn't show any over threshold between actual and planned collective and individual doses.

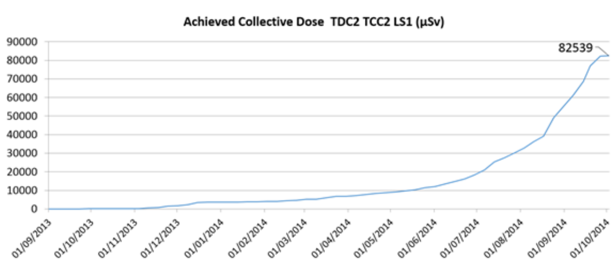

Figure 4: actual collective dose evolution.

CLOSE THE INTERVENTION

The main goal of the closing phase are to collect feedback, understand differences between estimated and achieved doses, propose improvements in order to reduce doses taken in future interventions. The deliverable is a close-out report [6] that reviews the entire intervention. It should contain at least the following:

- Overall evaluation of intervention
- Summary on risk management
- Lessons learnt
- List of modified procedures
- Summary of updates needed to the safety file.

A notable difference between the estimated optimized dose (200 mSv) and the achieved collective dose (83 mSv) was recorded. Well-known or routine operations were correctly estimated. On the other hand, dose estimates for unprecedented operation like the removal and re-installation of the three splitter magnets bore higher uncertainties. Survey at the start of the work showed lower dose rates than were estimated during the preparation phase. Since the intervention area has a large dose rate gradient, both granularity of the cartography and intervention location strongly influenced estimates. Eventually, thanks to continuous improvements in work methodology, the exposure time in the hottest areas was highly reduced.

Looking back at the entire project, the following observations led to the suggestion of improvements especially with respect to the design of high radiation areas.

Quality Assurance was insufficient. Lack of equipment tests prior installation caused unnecessary dose and delay. History and documentation of older installations were not always available.

The hardware commissioning should be better integrated into the overall planning. The status for critical beam equipment in operation should be summarised and shared before intervention.

DESIGN OF HIGH RADIATION AREAS

The design of a new facility should take into account operation, maintenance and dismantling needs such as:

- Buffer zone for radioactive waste temporary storage.
- Remote control means (overhead crane, robot) and dedicated control room.
- 3D video and live local video system.
- Special design of future highly activated equipment (material selection, remote control handling, plug-in connectors).
- Reliable data networks for remote control operations and dose recording.

CONCLUSIONS

The TDC2/TCC2 consolidation activities were successfully completed within schedule, dose budget and without major problems. The strategy defined in the preparatory work stage and validated by the ALARA committees has proven to be very successful and was based on extra decay time, planning optimization, removal of hot equipment, staff training, 360° movie and remote control operations.

The new ideas and techniques that grew from this experience can be summarized in the following five recommendations for ALARA work in high radiation areas:

- Clearly define the scope of activities;
- Break the work down in stages (prepare, execute, close);
- Monitor and control;
- Be pro-active (take some dose now to avoid taking more dose later);
- Learn and improve (increase maturity).

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