# SPS WANF DISMANTLING: A LARGE SCALE-DECOMMISSIONING PROJECT AT CERN

S. Evrard, Y. Algoet, N. Conan, D. De Paoli, I. Efthymiopoulos, S. Fumey, H. Gaillard, J-L. Grenard, D. Grenier, A. Pardons, E. Paulat, Y. Seraphin, M. Tavlet, C. Theis, H. Vincke, CERN, Geneva, Switzerland.

*Abstract*

The operation of the SPS (Super Proton Synchrotron) West Area Neutrino Facility (WANF) was halted in 1998. In 2010 a large scale-decommissioning of this facility was conducted. Besides CERN's commitment to remove non-operational facilities, the additional motivation was the use of the installation (underground tunnels and available infrastructure) for the new HiRadMat facility, which is designed to study the impact of high-intensity pulsed beams on accelerator components and materials. The removal of 800 tons of radioactive equipment and the waste management according to the ALARA (As Low As Reasonably Achievable) principles were two major challenges. This paper describes the solutions implemented and the lessons learnt confirming that the decommissioning phase of a particle accelerator must be carefully studied as from the design stage.

## INTRODUCTION

The construction of the LHC (Large Hadron Collider) at CERN has raised interesting questions about the behaviour of materials to accidental beam impact. The LHC machine experts have put the materials through their paces. The equipment has been validated following a series of stringent tests [1]. And these tests will become even stricter now with the arrival of HiRadMat, which is a new facility at CERN. It will provide the users with the possibility to investigate the behaviour of materials when irradiated with pulsed high energy and high-intensity beams extracted from the CERN SPS. With physicists currently occupied designing the future generation of accelerators, a facility such as HiRadMat seems more indispensable than ever [2].

The tunnel that formerly housed the WANF was completely revamped from October 2009 to May 2011 to make way for the new facility. Regarding the radiation issue, this was the first dismantling operation on such a large scale since the dismantling of LEP (Large Electron Positron Collider).

## PREPARATORY WORKS

### *Inventory of Equipment to be Removed*

WANF was designed and built in 1992 and operated until 1998. A total of 7E19 protons was delivered to the T9 target. At this time, no electronic engineering document management system was in use at CERN. In order to face the lack of information, a laser scanning of the whole area took place at the beginning of the project.

At the same time, a radiation survey was completed and produced a detailed radiation map showing dose rates reaching 20 mSv/h and contamination up to 5 Bq/cm$^2$ for beta-gamma emitters and less than 2E-2 Bq/cm$^2$ for alpha emitters. Nuclides were identified by gamma-spectrometry, mainly Na-22; Mn-54; Co-60; Zn-65.

A comprehensive inventory of equipment and associated environmental conditions was issued and comprised: TAX blocks, magnets, collimators, T9 target, WANF horn & reflector, strip-lines, 100m-long Helium tubes and the infrastructure (cables, cooling circuit, air duct, shielding). After 11 years of decay without ventilation and due to the oxidation by ozone, a lot of activated dust covered all the equipment.

Figure 1: WANF before dismantling.

### *Fluka Simulations*

The interaction of high-energy hadron beams with matter causes mixed radiation fields and results in the activation of material. As an inevitable by-product of the neutrino production the secondary particle showers create radio-nuclides in the experimental area mainly by the following mechanisms:

- **spallation**: impact of high energy particles on a nucleus, which undergoes a break-up reaction. Some of the resulting fragments remain in a highly excited and unstable state which is reduced by the evaporation of nucleons, further leading to the production of radio-isotopes like Na-22: $^{27}Al\ (x,x_{2p},3n) \rightarrow {}^{22}Na\ (T_{1/2}=2{,}6$ years)
- **particle capture reactions**: low-energy neutrons are captured by a stable isotope, resulting in the production of radio-nuclides. Typical examples are the production of Co-60 found in concrete and iron shielding: $^{59}Fe\ (n,\gamma) \rightarrow {}^{60}Co\ (T_{1/2}=5{,}3$ years).

As a result, the whole WANF tunnel was classified as a controlled area – high-radiation zone where dose rates higher than 2 mSv/h can be found according to the CERN radioprotection rules. 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, TCX blocks, T9 target and downstream collimator were investigated as they are encapsulated in a thick protective shielding. They turned out to be the most activated parts of the installation. These indications were confirmed by actual measurements showing the highest dose rate of 1 Sv/h (downstream collimator blocks).

## WORK ORGANIZATION

### *RWP (Radiation Work Permit)*

The RWP is a written and approved document establishing all the radiation protection (RP) measures necessary for the safe performance of a specific activity or job. It contains the following information: date and time of the job, number of workers, description of the job, predictive dose, dose rates, surface and atmospheric contamination level dose estimates, protective suits needed, biological shielding and type of RP monitoring for the job [3]. It formalizes the optimization effort made by the team responsible for equipment or the contractor, the RP team and the area coordination team.

RWP production implies planning and anticipating the RP measures. In addition, the RP staff is informed of all planned jobs in the controlled area and can monitor the progress of work during the dismantling operations and collect the dose associated with the specific jobs for data base purpose. During the WANF dismantling, about 30 RWPs were given and 4 ALARA committees were held.

### *Planning*

The WANF dismantling activities were carefully planned to ensure that radiological protection is optimized. Planning must recognize not only the sequence of job steps, but also their relationship and their multi-disciplinary nature. The scheduling of jobs in relation to each other, the identification of potential work interferences and hazards in the work zone, and the identification of dose intensive jobs are critical to the optimal use of resources and job success.

Planning should integrate RP criteria and use feedback experience and benchmarking to ensure that the most effective approaches are implemented. It should also integrate actions for the preparation of personnel, such as pre-job briefings or mock-up training.

### *Tailor-made Training*

Trained workers contribute to dose reduction by performing their jobs with high quality, low dose and within schedule and budget. The motivation of personnel is a key element in worker involvement. To this end, a dedicated training was given to each worker of the WANF dismantling. Indeed, workers should:

- be well educated and trained in the technical aspects of their job.
- know and apply good RP practices and ALARA principles.
- work in co-operation with their team.
- draw on their experience to propose new tool or methodology.
- recognize potential problems and be able to react to them in a safe and efficient manner.

## TECHNICAL MEANS

Tailor-made protective shieldings were manufactured using Lead, Tungsten sheets and Concrete. Several new handling means have been specifically designed and built:

- Automatic hook devices (4 t capacity) fitting the overhead crane and a shielded forklift. As hundreds of activated concrete and iron blocks were to be moved, automatic and remote handling was considered as very efficient for dose reduction.
- Remote controlled overhead crane (7.5 T capacity) fitted with cameras and monitoring panel.


Figure 2: Shielded Forklift equipped with automatic hook.

## ACTIVATED MATERIAL MANAGEMENT

Based on the ALARA principles, any equipment or material whose residual dose rate was below 100 µSv/h was not considered as waste and was re-used or stored.

Following decontamination and a thorough cleaning of the tunnel carried out by a specialized company, the T9 target, collimator, horn and reflector were dismantled, cleaned and stored at CERN for further decay. In addition, cable trays, cables, lighting, air ducts, cooling pipes and beam pipes were compressed using a 300 ton capacity press. In total, the removal of 800 tons of material generated 95 tons or 323 $m^3$ of radioactive waste.

## DOSE BUDGET MANAGEMENT

Dismantling activities present specificities in comparison with operation or maintenance activities [4]:

- Lack of feedback experience: dismantling activities are new or even unique tasks, for which there is no feedback experience.

- Difficulties to accurately evaluate radiological conditions due to the lack of knowledge about the history of the facility operation.
- Constantly changing radiation exposure rates which decrease as activated material is removed, but are much greater near equipment close to the core.

Based on the dismantling of the same tunnel in 1992, the initial budget dose for WANF dismantling was estimated at 210 man.mSv. This value has been reduced to 60 man.mSv thanks to the improvement of handling means, highly optimized work procedures and personnel training. About 200 people were involved. The highest individual dose reached was 2 mSv over 12 months.

The main contributions are given by low dose rate but long-lasting activities, impossible to do remotely or carried out by less RP aware and experienced personnel.

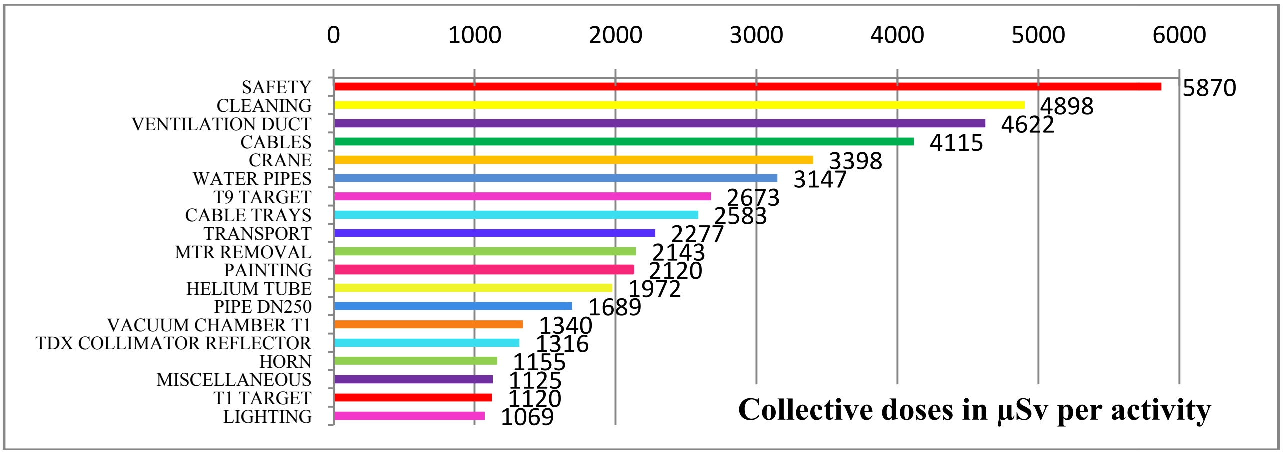


Figure 3: dose budget breakdown.

## LESSONS LEARNT

The dismantling of a non-operational facility must take place as soon as possible after a reasonable decay time. Any unjustified delay will increase the information and experience loss, as well as the degradation of the equipment. Remote control operations are the most effective way to reduce personnel exposure. However, it can take longer and must count on a highly reliable camera network. Contamination management implies the use of dedicated lifting devices and forklifts which have to be decontaminated at the end of the dismantling phase. Dose recording is essential to give accurate feedback. Individual and job-based dose recording could be facilitated by using a tele-dosimetry system. Motivation, performance and safety awareness of personnel are mandatory for success. The design of a new facility must take into account dismantling needs such as:

- special design of future highly-activated equipment (remote control handling, dedicated lifting beam, plug-in connectors)
- pre-fabricated infrastructure for easy and remote removal
- tunnels equipped with reliable data networks for remote control operations and dose recording
- walls and floors protected by rad-hard paint to minimize contamination

## CONCLUSIONS

From October 2009 to May 2011, the WANF tunnel was completely revamped to make way for CERN's latest facility, HiRadMat which is designed to test materials for the World's future particle accelerators. The extraction of certain items from WANF took a great deal of organizing, using automatic hook devices, dedicated shieldings and video cameras to allow operators to keep their distance from the radioactive components. In addition to distance, shielding and duration optimization, ALARA cannot be achieved without worker involvement. It is the worker that is exposed, and it greatly depends on the worker himself to reduce the exposure. Motivation and performance can be improved by actively engaging the workforce in decision-making processes in each stage of the work, from planning to post-job review and by taking into consideration the feedback of workers.

The activity generating the highest collective dose is not the one where the highest activated items were handled, but the one where no remote removal was possible. Therefore, it is of prime importance to carefully study and prepare the decommissioning phase of a new facility as from the design stage.

## REFERENCES

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