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CERN SPS SPRINKLER SYSTEM: A CUSTOMIZED INDUSTRIAL SOLUTION FOR A NON-CONVENTIONAL SITE

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Abstract

Until 2018, the limited firefighting means in the SPS complex left it vulnerable to the consequences of self-ignition or accidental fire. In 2015 the SPS Fire Safety project was launched with the aim of improving personal safety and protecting property by deploying a whole set of automatic actions in the SPS in case of fire outbreak. Had nothing been done, an unmanaged fire could have threatened the lives of those working underground and could have meant losing a large part of the SPS machine and its equipment. In 2020, CERN completed the consolidation of its SPS fire safety systems. Among these, a water-based sprinkler system, following principles of standard industrial design but customized and tailor-made for SPS and its irradiated areas, is ready to operate. The system needed to take into account limitations related to the presence of fragile accelerator equipment, radioactive zones, integration constraints and comply with European norms, in particular EN12845. This paper presents the risk assessment, the selected technical solution, our experience from the planning and installation phase while discussing the custom-chosen and radiation tested equipment to conclude with the lessons learned and outlook for the future.

SPS FIRE RISK ASSESSMENT AND RECOMMENDATION

Built in 1976 the Super Proton Synchrotron (SPS), seven kilometres in circumference, is the second-largest machine in CERN's accelerator complex. SPS is composed of the main ring tunnel and the transfer tunnels to other facilities. Access to the main tunnel is made through six shafts (PA), each hosting lifts and staircases, with a depth of up to 60 m, ending in a short horizontal storage area and two-level access tunnels (TA) opening to the ring's Long Straight Section (LSS).

After more than forty years of operation, the SPS safety equipment required major renovation. In 2015, addressing safety issues, CERN launched the SPS Fire Safety study to perform the fire risk analyses and assessment and to define the scope of the project. The study was driven by a working group including the SPS operation representative, radioprotection, fire detection experts and maintenance counterparts. As part of the study, fire dynamics simulations were performed to estimate the scale of fires which could develop in the SPS underground structure. The risk assessment highlighted some of the main issues, such as high fuel load, lack of compartmentalization, activated smoke, and long evacuation routes exposed to smoke. Fire simulations showed an important fire growth before fire service crews could be deployed. The outcome of the risk assessment served as a base in the quest to define fire consolidation proposals for the SPS. A set of four work packages was defined. None of the work package can be understood as a stand-alone system and it is only the interaction of all safety systems that guarantees the target safety level.

- **WP1 Fire Compartmentalization**. A set of fire doors allows fire compartmentalization of the main ring, access galleries and access shafts.
- **WP2 Integrated Fire Safety Action System (SMSI)**. Integrated sub-systems: fire detection [1], fire alarm, evacuation, and compartmentalization door closure.
- **WP3 Firefighting means**. A dry rise system in whole SPS. Additional dedicated fire service vehicles in the bottom of each shaft.
- **WP4 Fire Sprinkler Protection System (FSPS)**. Replacement of the sprinkler system in shafts and extending it to the access tunnels and LSSs.

The sprinkler system can extinguish or hold fire in its initial stages while waiting for CERN firefighters to arrive. Even if it might not be able to fully suppress the fire, it is a solid and reliable fire protection system that limits fire spread, smoke, and gains time for personnel to evacuate from the SPS.

SYSTEM AND EQUIPMENT STUDY

The first stage of the FSPS project consisted of the evaluation of the possible various technologies that could replace the old sprinkler system and be extended to cover additional underground areas in the SPS:

- A wet-pipe system.
- A dry-pipe system.
- A double-interlock pre-action system.
- A deluge system.

An independent external fire safety expert company was consulted with the objective of choosing the most robust, reliable, easy to operate and maintain, modern fixed automatic water-based fire protection system. Preferably, the use of the existing water supply infrastructure was to be kept. In parallel to technology choice, several accelerator specific constraints were assessed:

- Exposure to electromagnetic and particle radiation of system components including the water inside piping. Polymeric material in certain system components may degrade and water exposed to radiation will form radioactive substances.
- Limited access to underground areas for maintenance activities. The systems' control equipment must be installed in the surface accessible areas.
- Increasing pressure values in the piping as the piping runs at lower levels than the water supply and control systems.
- Limited capacity of the water drainage system and sumps in the SPS.

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- Equipment and accelerator property preservation.

To maintain safety integrity levels, CERN pursued a fire protection system that was separated and independent from the new fire detection system. Deluge and double interlock technologies were therefore discarded. A significant delay in response time that may occur between fire ignition, detection, and reaction in these two systems was considered, as well, as a drawback. A dry-pipes system was also excluded. Despite the fact that it does not hold water that may be exposed to radiation, in general, dry-pipe systems require more complex infrastructure, a larger number of sprinklers are expected to activate, and are more prone to internal pipe corrosion than a wet system. Finally, the risk assessment for accidental sprinkler discharge prepared by CERN concluded that with the application of certain compensatory measures, a wet system was most suitable. Therefore, a traditional wet-pipe system was considered to be the simplest, most reliable, and least expensive of the four system types discussed.

Following the technological choice, CERN and external fire safety experts recommended we apply European Standard EN12845 [2] for design, installation and test of the SPS system. Furthermore, NFPA13 [3] standards should be consulted for complementary recommendations and NFPA25 [4] for maintenance purposes.

The preliminary design phase to select the most suitable components was mostly driven by reliability and radiation constraints. The design practices used widely in industry had to be adapted to CERN's radiation areas. For example, to avoid corrosion and possible water leaks due to material degradation, black steel pipes with air relief valves were chosen. Welded or threaded couplings were selected over industry standard silicon couplings. Similarly, the sprinkler heads sealing with PTFE tape or glue was replaced with traditional hemp.

The last step to complete the system's equipment choice consisted of the selection of sprinkler heads. High-pressure rated sprinklers were required due to the high static water pressures. Metallic heads were chosen over glass bulbs mainly because the fluid inside the bulb may react on ionising radiation with an increase in volume that may make the bulbs burst and start a water discharge. Furthermore, the industry available models have a Teflon coated water seal which is not adapted for radiation areas. For that reason, CERN decided to perform a characterization campaign which consisted firstly of irradiating sprinklers and then testing that their protective properties remained unchanged after irradiation: no leakage nor alteration of the nominal temperature rating or response time index. Three brands of sprinkler heads were selected and irradiated (with gamma rays from a Co-60 source) in several steps between 50 kGy and 3 MGy. The characterization tests which followed allowed validation and approval of two out of the three sprinkler models.

DESIGN AND INSTALLATION

SPS layout, unique accelerator equipment, radiation, safety constraints for installation, operation and maintenance have largely influenced the FSPS design and required several deviations from the EN12845 regulations which will be explored in this chapter.

Architecture Overview

The SPS sprinkler systems are integrated into six principal access points of the SPS ring and provide protection of the SPS underground. The surface technical buildings (BA) were not included in the scope. There are two independent sprinkler lines in each point (Fig. 1):

- *The Shaft-TA Sprinkler Line* ensures protection in the SPS shaft, both levels of the TA tunnels and the TA storage area.
- *The SPS-Ring Sprinkler Line* protects the SPS LSS and the junction of the LSS at both levels of the TA.

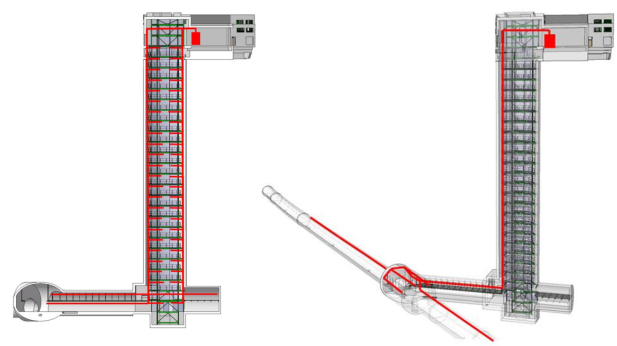

Figure 1: The SHAFT-TA (left) and LSS (right) lines.

Each line's central unit called Sprinkler Station is hosted in the corresponding BA. It is composed of a set of control valves, a flowmeter, and a control panel. The alarm signals sent from the control panel to CERN Safety Alarm Monitoring system [5] are monitored 24/7 by CERN Fire Brigade and CERN Control Centre operators. The analogue measurements are made available in the Technical Infrastructure Monitoring System [6]. The FSPS is interlocked with the SPS rising pumps system to prevent rejecting of potentially activated water. Upstream, the FSPS stations are connected to the SPS cooling water circuit operated by the SPS pumping station and directly supplied by the *Services Industriels de Genève* (SIG) using water from Geneva Lake. Downstream, the Shaft-TA main line splits into two pipelines positioned on both sides of the shaft to protect each cable tray on the even levels and the staircase structure on the odd levels. It expands to the TA galleries along the cable trays and the storage area.

The LSS pipeline descends directly to the TA/LSS junction and splits into both sides of the SPS tunnel to protect LSS cable trays and the ring's transport lanes.

In comparison to conventional industrial sprinkler architecture, the FSPS has a reversed configuration: the sprinkler station is on the surface and the areas to be protected are below its central unit, descending up to 60m underground. Therefore, contrary to classical systems which are usually built upwards, the FSPS pressure had to be reduced to ensure functioning of the system within normative limits. Following hydraulic calculations for each line, pressure reduction valves had to be installed and attuned per SPS

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point according to: exact pressure available, size of the system and the depth at which it is installed.

Integration and Installation

Preliminary design and early 3D modelling of the system revealed numerous integration issues. The major problems were related to limited space and proximity to the accelerator's equipment. These issues were addressed during the detail design phase with the CERN integration team, and solutions were subsequently validated with fire experts, machine owners, equipment groups, safety and radioprotection teams. Several derogations were approved in order to conform to the SPS machine constraints, or the CERN safety rules.

The initial concept of placing the new system in the shaft, next and in parallel to the existing system to ensure maximal fire protection during installation had to be abandoned due to lack of space and routing options. Instead, several compensatory safety measures such as an enforced shielding, a flexible hose line, and portable extinguishing equipment were requested by CERN Fire Brigade and the CERN safety team which allowed for the dismantling of the old system and the integration of the new one in its place. The same protection measures were used for installing in the TA. Shielding curtains were used in LSS to ensure maximal protection of the machine.

The system layout ensuring a proper discharge pattern, in other words the most optimal and unobstructed water dispersion paths, had to be adapted to the particularities of each site. The SPS accelerator equipment and its operational and maintenance constraints determined that some of the EN12845 prescriptions had to be compromised. For example, it was agreed that sprinkler heads had to be installed at a minimum of 400 mm away from the machine centreline section to avoid any accidental leakage. Sprinkler heads had to be installed at least 200 mm from the cable trays to allow for future re-cabling campaigns. Furthermore, due to very difficult access and consideration for workers' safety, some areas have not been covered at all. In all these areas, the absence of the sprinklers was justified, documented and compensatory measures evaluated.

Works in the radiation exposed parts of SPS were subject to the ALARA principles and committee approval. To reduce time of exposure for workers, several optimization methods were implemented. A customized method for installing long sections of the sprinkler pipeline was used. Segments of eighteen, twenty-four or thirty meters were assembled underground in a safe zone, transported to the destination by CERN's handling machines, fixed into easily mountable supports, altogether allowing for the reduction of the collective dose to ¼ of the initial ALARA estimations.

Lessons Learned and Future

This is the first time at CERN that a large-scale extinguishing system has been installed in an accelerator tunnel. The project's key phases were:

- **System Feasibility Study** to select, test, validate and certify the industrial fire safety equipment for the radiation exposed environment.
- **Integration** was a key point for implanting the system into the very limited space of the SPS underground while still ensuring that it complies with the normative regulations for sprinkler systems. Establishing the balance between the needs of different users, operators, fire safety stakeholders and other safety domains was the major challenge.

For the upcoming renovation projects, such as SPS BA7 the SPS North Zone and LINAC3, increasing attention should be given to fire safety and property protection aspects. While protecting the underground is now an unquestionable choice, one may consider expanding this protection to the strategic surface technical buildings.

CONCLUSION

The SPS Fire Safety project was a first major renovation endeavour where a set of complementary fire safety work packages was implemented to make the site ready for the next decades of safe runs. Although the risk of fire cannot be avoided, the SPS complex is well prepared and protected against its most serious consequences. The industry standards had to be adapted and required custom-built solutions in order to comply with the accelerator's environment while simultaneously meeting regulatory prescriptions. Unusual in fire safety, CERN's experience of the radiation resistance of the sprinkler material, adaptation of the design and installation procedures are valuable contributions to any future fire safety project at CERN or other nuclear physics facilities.

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