

DEVELOPMENT OF RISK INFORMED METHODS FOR ESTIMATING RADIATION RELEASE FROM CABLE FIRES AT HIGH ENERGY PHYSICS FACILITIES

By: Daniel Funk

CERN operates the Large Hadron Collider (LHC), the world's largest and most powerful particle accelerator. The LHC was built to advance the state of knowledge in particle physics by increasing the energy of colliding particles to the TeV range. With this increase in capability comes increased fire safety challenges, including the need for more accurate assessment of fire-induced release of radioactive materials.

Through normal operation of particle accelerators, some materials used in the facility structure and equipment are made radioactive through a process called proton activation. Combustion is strictly a chemical process, which is blind to the radioactive process. Therefore, the radioactive materials burn no differently than non-radioactive materials. Electrical cables are susceptible to proton activation; therefore, a cable fire can generate smoke containing radioactive particles, which in turn can be released to the environment. The LHC contains a significant amount of cable to support its high energy demand and extensive control, monitoring, instrumentation, and data capture systems. Consequently, cable fires are of significant interest to CERN.

In 2018, CERN initiated a comprehensive project to develop advanced analytical tools for conducting quantitative fire risk analysis; fire-induced radioactive release is an integral part of the project. The project is called "Fire-Induced Radiological Integrated Assessment (FIRIA)". The ultimate goal of the FIRIA Project is to establish reliable, accurate, and maintainable fire risk analyses for the LHC and other important CERN facilities. In support of the FIRIA Project, Lund University sponsored a thesis research effort to investigate fire-induced radiation release from cable fires. This research led to advances in technical capabilities for estimating radiological release from burning cables through (1) development of a more accurate framework for modelling cable fire sequences and quantitatively estimating cable fire frequencies and (2) development of quantitative methods for estimating the portion of radioactive isotopes released into the smoke plume of fires involving activated electrical cables.

Improved modelling of cable fire sequences was accomplished by applying electrical engineering principles to categorise and refine cable fire sequences within a fault tree format. Ignition source frequency weighting factors are then applied to associated sequences in the fault tree to produce greater precision in the determination of cable fire risk with respect to configuration, location, operating mode, and prevailing conditions. Proof-of-concept case studies confirm the methodology is viable for "real-world" applications and can substantially improve cost-benefit analysis for risk mitigation strategies.

Conservation of mass principles were used to quantitatively analyse fractional release of radiation from burning cables. Mass balance inventory of pre-fire and post-fire radionuclides allows assessment of radioactivity levels contained in residual char, soot, and gaseous combustion products. Through rigorous accounting of the radioactivity in each of the combustion products, the fraction of radioactivity that could potentially be released to the environment can be computed. Proof-of-concept case studies demonstrate that fractional release calculations are readily achievable and provide a means to quantify fire-induced radiation release to the environment from postulated cable fire scenarios.

Although the new analytical methods are viable, further research is required to refine and characterise input variables and influence parameters prior to full implementation.