ALARA Activities at DOE

This section on ALARA activities is a vehicle to document successes and to point all DOE sites to those programs whose managers have confronted radiation protection issues and used innovative techniques to solve problems common to most DOE sites. DOE program and site offices and contractors who are interested in benchmarks of success and continuous improvement in the context of Integrated Safety Management and quality are encouraged to provide input to be included in future reports.

1. ALARA Activities at the Fermi National Accelerator Laboratory

At the Fermi National Accelerator Laboratory (Fermilab), a policy consistent with integrated safety management (ISM) and in accordance with 10 CFR Part 835 requirements is to conduct activities in such a manner that worker and public safety, and protection of the environment are given the highest priority. Fermilab is committed, in all its activities, to maintain any safety, health, or environmental risks associated with ionizing radiation or radioactive materials at levels that are ALARA. Likewise, Fermilab management supports related work planning and review activities in support of the Fermilab ALARA program.

During calendar year (CY) 2015, the primary activities at Fermilab that resulted in occupational radiation exposures were upgrade and repair activities of the Fermilab accelerator. Nearly all radiation doses to personnel were due to exposures to items activated by accelerator beams. During the summer and fall of 2015, Fermilab had a 16-week shutdown.

Work was performed in Proton Source, Linac, Booster, and Main Injector-Recycler Ring to accommodate higher intensities and higher Booster injection energy. Many of the repairs and upgrades made during this shutdown were also intended to improve operational reliability and hence, reduced maintenance needs in the future. A laser notching (beam gap) system was installed in the Linac to reduce beam losses. Radio-frequency (RF) accelerating activities were installed in the Booster. Main Ring components were removed to allow more efficient beam delivery to the Muon Campus. The Recycler Ring vacuum was upgraded for future high intensity running.

Shutdown work was performed to support longer term physics research goals which will deliver increased beam power to the Deep Underground Neutrino Experiment (DUNE). DUNE is a proposed international neutrino experiment that aims to make definitive determinations of neutrino properties to provide experimenters with the most powerful means to study neutrinos. This experiment will be conducted at the Long-Baseline Neutrino Facility (LBNF) at Fermilab and at the Sanford Underground Research Facility in Lead, South Dakota.

The Short-Baseline Neutrino Program will consist of three particle detectors called Imaging Cosmic and Rare Underground Signals (ICARUS), Micro-Booster Neutrino Experiment (MicroBooNE), and the Short-Baseline Near Detector (SBND). The Short-Baseline Neutrino Program will search for a fourth neutrino that may not follow the same neutrino oscillation rules than other known neutrinos. MicroBooNE is currently operational and measures low energy neutrino cross sections. The Booster Neutrino Beam (BNB) which supports MicroBooNE, also supports SeaQuest and the Fermilab Test Beam Facility (FTBF). Fermilab SeaQuest experiment is part of a series of fixed target Drell-Yan experiments designed to measure the quark and antiquark structure of the nucleon. FTBF uses secondary beamlines to provide beam for a host of energy ranges and particle types.

The shutdown also provided the opportunity for upgrades to Neutrinos at the Main Injector (NuMI) which supports Main Injector Neutrino Oscillation Search (MINOS) and NuMI Off-Axis ve Appearance (NOvA) experiments. The MINOS experiment is a long-baseline neutrino experiment designed to observe neutrino oscillations. MINOS uses two detectors, one located at Fermilab and the other at the Soudan Underground Mine State Park in Tower-Soudan, Minnesota. The NOvA experiment is designed to search for oscillations of muon neutrinos to electron neutrinos by comparing the electron neutrino event rate measured at the Fermilab site with the electron neutrino event rate measured at a detector near Ash River, Minnesota. A NuMI Horn (beam focusing device) was replaced to ensure that the accelerator complex will continue to deliver a quality particle beam to the laboratory's neutrino experiments.

Shutdown work included renovations to infrastructure needed to support the Muon Campus Program which is comprised of the Muon-to-Electron Conversion Experiment (Mu2e) and Muon g-2 Experiment. These experiments are using former antiproton source infrastructure. Mu2e will probe with excellent precision measurements required to characterize the conversion of electrons to muons as part of the Intensity Frontier. The Muon g-2 experiment will explore the interactions of muons with a strong magnetic field to determine fundamental properties of nature. During the shutdown, upgrades to support muon experiments were a major initiative. A new beamline was installed, which will send an 8-GeV proton beam from the Recycler Ring to the Muon Campus. The new beamline had to be installed amongst existing beamlines. The pre-existing beamlines were disassembled and reassembled and Tevatron components were removed to create space for the new beamline.

1.1 ALARA Job Planning Prior to Shutdown

As with all maintenance and upgrade shutdowns, it is recognized that many of the repairs to be performed must be conducted in intense radiation fields dominated by gamma rays due to induced radioactivity from years of operation at high intensities. The Fermilab Accelerator Division (AD) established a task review process that requires all work to be performed in the accelerator to be entered into a database for review by all of its support departments. This initiative improves efficiency by preventing scheduling conflicts and also affords the AD Environment, Safety, and Health (ESH) Department the opportunity to identify those radiological tasks that require special attention or might represent other environment, safety, and health issues needing mitigation.

During this shutdown, the majority of tasks were successfully performed with lower collective dose than originally planned by implementing ALARA dose-saving measures such as careful planning, conducting dry runs for hot jobs, and ongoing input from task supervisors and individual workers on how to optimize ALARA as the work proceeds. The shutdown coordinator, radiological control technicians, and workers have spent much effort to modify work schedules and procedures to reduce collective dose.

1.2 Summary of Collective Dose to Personnel

Individual radiation doses for over 200 workers who received dose were tracked during the 2015 shutdown. Nearly 60 percent of shutdown workers received individual doses of 25 mrem or less. About 20 percent of workers received individual doses between 26 mrem and 50 mrem. The remainder of the dose was distributed among 46 workers. These workers received individual doses between 51 mrem and 250 mrem. *Exhibit 1* illustrates the dose distribution per number of workers for the 2015 shutdown.

The total collective dose for the 2015 shutdown was 7,181 person-mrem. Work associated with ALARA plans resulted in a total collective dose of 3,959 person-mrem. The remainder of doses received as a result of other miscellaneous work resulted in a total collective dose of 3,222 person-mrem. Over the course of 16 weeks, 82 percent of workers received doses due to exposure rates of about 0.5 mR/hr. Likewise, 18 percent of workers received doses due to exposure rates of about 2.5 mR/hr over the 16 week shutdown. *Exhibit 2* summarizes the total collective dose received during this shutdown.

1.3 2015 Summary of Fermilab ALARA Activities

The following work in Booster, Main Injector-Recycler Ring, NuMI, and BNB highlight the continued commitment to keeping exposures ALARA at Fermilab.

Booster

The Booster is the first circular accelerator, or synchrotron, in the chain of accelerators at Fermilab. It consists of a series of magnets arranged around a 75-meter radius circle. Proton beams enter the Booster from the Linac, accelerating to an energy of 8 GeV. Shutdown upgrades to the Booster included repair of Booster magnets, cabling, turbo pump replacements, and conversion of Booster radio-frequency (RF) stations to solid state.

Exhibit 1:
Numerical Distribution of Shutdown Workers in Terms of Dose Received in 2015
Courtesy of G. Lauten, Accelerator Division

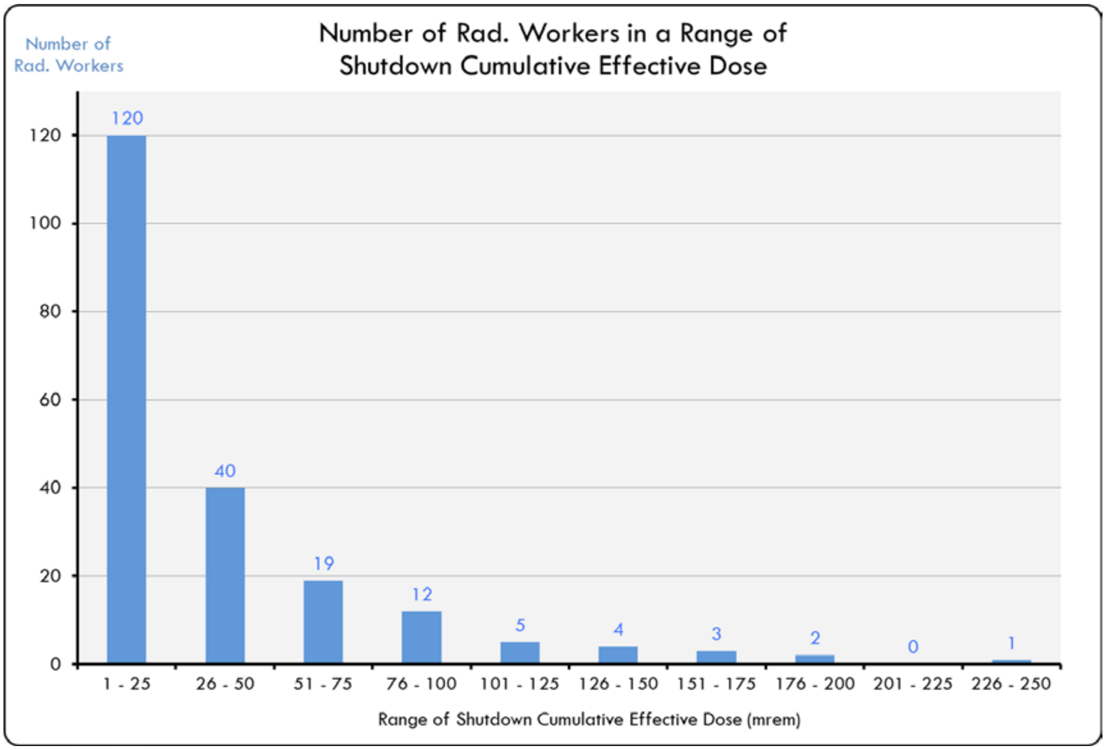
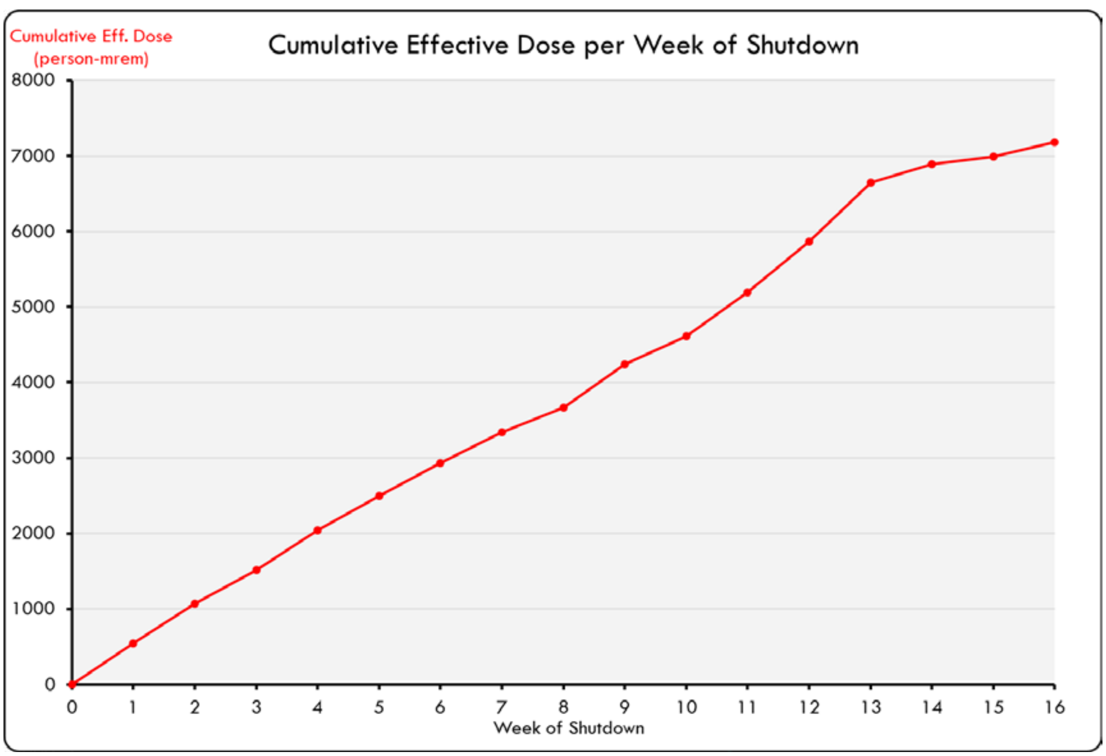


Exhibit 2:
Total Collective Dose (person-mrem) Per Week of Shutdown 2015
Courtesy of G. Lauten, Accelerator Division



Booster motion controls on collimators were inspected and replaced as needed. Using a surveyor scope to read dial gauges from outside the radiation area reduced the overall dose for this job. Additionally, exposure rates were much reduced since this work took place after 11 weeks of cool-off.

Turbo pump controls were replaced and the final 8 out of 24 new turbo pump stations were installed in the Booster during the 2015 shutdown. Because crews had previously installed 16 turbo pumps, workers were very experienced. The proficiency acquired as a result of performing this work repeatedly in lower exposure rate areas contributed to a lower actual collective dose than estimated.

Wiring maintenance and replacement was completed for all 48 Booster beam position monitors (BPM). It was anticipated that the job would take 30 minutes for each BPM replacement, but as workers acquired more skill, the time to replace each BPM was greatly reduced. As workers were replacing BPMs in higher exposure rate areas, the time to complete the work was reduced to 15 minutes for each BPM. Additionally, temporary shielding was added in the highest exposure rate areas to reduce exposure rates from 100 mR/hr to 50 mR/hr.

Power Amplifiers (PA) were removed, Low Conductivity Water (LCW) hosing was replaced with stainless steel flex hoses, and LCW sector valves were replaced.

The total collective dose estimate for these Booster shutdown jobs was 1,598 person-mrem and the actual collective dose received was 652 person-mrem. Use of mockups, proficiency in repeating tasks many times, use of temporary shielding, and waiting to work in higher exposure rate areas until later weeks in the shutdown all contributed to lower actual collective doses.

Main Injector (MI) – Recycler Ring (RR)

The Recycler is a storage ring for proton beams after they exit the Booster. Proton beams in the Recycler Ring are combined into batches to form a more intense proton beam. The Main Injector is a synchrotron accelerator with a circumference of 3,319 meters and is located directly under the RR in the same tunnel. The MI accelerates proton beams from 8 GeV up to 150 GeV. Several upgrades to the MI-RR were made during the 2015 shutdown.

An ADCW (wide-gap version of a Main Ring dipole) RR magnet was removed, repaired at the Magnet Facility, and then re-installed between locations 304 and 305. Exposure rates near the magnet were 10-15 mR/hr.

A total of 108 Ion pumps in MI locations 520 through 600 were removed and replaced with titanium sublimation pumps. Pump replacement work took about 6 weeks to complete. Exposure rates in most of these areas were less than 1 mR/hr.

Beam aperture improvements were made to reduce loss points in RR locations 421 and 425. The average area exposure rate for this work was 10 mR/hr. This work took about 7 weeks to complete. In addition to this aperture work, RR location 307 also needed aperture improvements. When the work began in July, area exposure rates were about 20 mR/hr. Lead blankets were placed over the 307 quadrupole magnet to reduce the exposure rate to 10 mR/hr. At this same RR location, elliptical beam pipe was replaced with round duplex pipe to improve beam performance. The highest exposure rate was 40 mR/hr at 1 foot from the 307 collimator. Lead blankets were placed over the highest exposure rate equipment and a lead reticulating wall was used to reduce dose to workers.

The largest MI-RR ALARA job was installation of the second phase of a new extraction beamline from MI-520 to the P-150 beamline. The ALARA plan indicated area exposure rates of 2.5 mR/hr, but actual area exposure rates were less than 2 mR/hr. This was a low-dose, but long-term job since it lasted the majority of the shutdown.

The collective dose estimate for all this work was 3,514 person-mrem and the actual collective dose received was 1,832 person-mrem. Use of effective ALARA practices, lower than anticipated exposure rates, and shielding resulted in significantly lower actual collective doses to personnel.

Neutrinos at the Main Injector (NuMI)

During the 2015 shutdown, the NuMI horn 1 was replaced. A month long cool-off time was required after the horn developed a ground fault. Water lines and striplines were removed from the horn in preparation for moving the horn to the work cell. Exposure rates on top of the horn ranged from 80-120 mR/hr. When the horn was removed, it measured 110 R/hr at 1 foot. Once the horn was in the work cell, about 15 lead blankets were placed over cracks and in areas of higher exposure rates. A camera was set up to reduce exposure to the crane operator. The ground fault also caused damage to NuMI horn 1 striplines. The exposure rate at 1 foot from the striplines was about 50 mR/hr and low levels of contamination were present. In order to replace the striplines, the chase wall had to be disassembled. Workers wore personal protective equipment and audible dosimetry devices to prevent personnel contamination and to closely monitor radiation dose.

Another job requiring an ALARA plan was coring a new 2 inch sump line for drainage. Contamination surveys during and after this work verified that no contamination was present.

The total collective dose estimate for NuMI work was 1,432 person-mrem. The actual collective dose received was 1,475 person-mrem. Although the total collective dose was slightly higher, it was well within 25 percent contingency collective dose estimate of 1,790 person-mrem.

Booster Neutrino Beamline (BNB)

Horn BNB-2 was in operation since 2004 and had to be replaced in 2015. The BNB horn replacement was conducted independently of the 2015 shutdown work described above.

Many tasks had to be accomplished in preparation for horn replacement. Control of Beryllium-7 (Be-7) contamination in the horn cave, decay pipe, and other absorber regions was the most important ALARA issue for this major job. Since Be-7 is difficult to detect using handheld instruments, contamination wipes and air samples were collected and analyzed during the entire job. All personnel were required to wear full protective clothing and respiratory protection. Booties and gloves were removed in the enclosure before personnel exited to minimize the spread of contamination to surrounding areas. Additionally, personal air monitors were worn by workers during this work to monitor airborne contaminants. Concrete shield blocks were removed. Each block was placed on herculite to prevent cross-contamination. Once all shield blocks were removed, they were covered with a tarp. Contamination wipes and air samples were collected and analyzed. The exposure rates for this preparation work were less than 1 mR/hr in the work area.

Target pile ventilation consisted of a 1,000 cubic feet per minute (cfm) fan with a high efficiency particulate air (HEPA) port that was used during access. Additionally, a 1,000 cfm fan with HEPA filter was installed at the 25 meter absorber hatch to provide negative ventilation. Lights and alarms were installed in the MI-12 enclosure and tunnel to alert personnel in case of a fan failure. Because the horn box support positioning adjusters were not functioning, the horn had to be raised using air pillow jacks and a temporary rail system had to be installed. Once the defective horn was removed, a new horn support and adjuster platform was installed. During installation of the new horn, shutters were closed to reduce exposure rates in the enclosure. Exposure rates in the tunnel ranged from 2-10 mR/hr. Cameras were used in strategic locations to minimize doses to personnel. The collective dose estimate for removal and installation of the horn was 919 person-mrem and the actual collective dose received was 635 person mrem.

1.4 Acknowledgements

The author would like to acknowledge and thank John Anderson, Kris Anderson, Tony Busch, Don Cossairt, Joel Fulgham, Cons Gattuso, Gary Lauten, Paul Sedory, and Dale White for their contributions.

2. ALARA Activities at the East Tennessee Technology Park (ETTP)

Centrus' mission is to supply enriched uranium fuel in a safe, profitable and environmentally responsible manner.

The Demo Facility Operations includes the Centrifuge Project Test Facility, which is located in building K-1600 at the East Tennessee Technology Park. This facility houses process gas systems, centrifuge process equipment and associated support systems operated under a lease, which includes safety authorization, with the Department of Energy (DOE).

Since the centrifuge process operates below atmospheric pressure and only small quantities of depleted uranium hexafluoride (UF_6) is used, Demo Facility Operations presents no significant UF_6 release potential.

Due to the small quantity of UF_6 used at K-1600 and the systems operating parameters, the primary concern is contamination control; therefore doses are expected to be low as shown in this report and the doses are consistent with previous years data.