FERMILAB CY2004 ALARA PROJECTS OVERVIEW

At the Fermi National Accelerator Laboratory (Fermilab), a policy consistent with integrated safety management and in accordance with 10 CFR 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 management 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 As Low As Reasonably Achievable (ALARA).

During CY2004, the principal activities at Fermilab that resulted in occupational radiation exposures were associated with maintenance activities of the accelerator. Nearly all of the collective dose to personnel was due to exposures to items activated by the accelerator beams. Many maintenance activities were necessary as the Fermilab accelerator complex was challenged to meet the scientific objectives of Tevatron Run II while simultaneously operating the proton beam needed for the MiniBooNE experiment. The vast majority of this work occurred during a major shutdown of the accelerator carried out during the late summer and autumn of 2004. Fermilab accomplished several vital accelerator upgrades during this shutdown. This work included extensive ALARA pre-job planning, implementation of specific ALARA activities during radiological work, and post-job analyses. Several upgrades and component replacements were conducted in the Linac and Booster. Additionally, a new pulsed beam focusing horn was installed for the MiniBooNE experiment. The following descriptions highlight ALARA efforts that were implemented as a part of these shutdown activities.

In preparation for this shutdown, a major and far reaching ALARA step was taken when the Accelerator Division Head requested that the MiniBooNE experimental beamline be disabled one week in advance of the shutdown to reduce the proton production demand on the 8 GeV Booster synchrotron and to allow for adequate cool-down of the Booster in preparation for the planned extensive Booster work. This ALARA effort not only reduced the overall exposure during the planned work, but also reduced exposure to personnel as they prepared accelerator areas for initial entry.

1. Linac Tank 5 Drift Tube Replacement

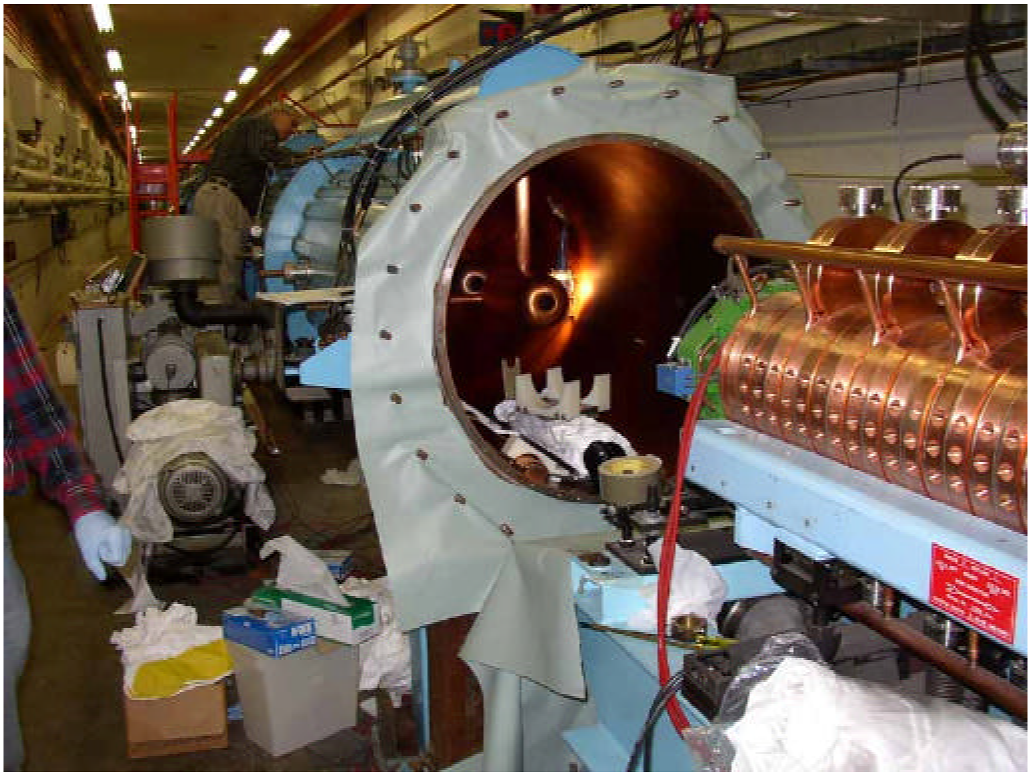
A quadrupole magnet failed within drift tube 19 in Linac tank 5. The Linac ran without it for several months, but the fall 2004 shutdown offered an opportunity to replace it. In this cylinder, only 30 inches in diameter, a worker was required to be very near activated components. The job was complicated because this vacuum vessel is a non-permitted confined space that must be kept free of contaminants including skin oil, and which has a smooth, soft copper surface that must not be scratched or damaged. Furthermore, the position and orientation of the new drift tube needed to be identical, to within a few thousandths of an inch, to that of the old drift tube. This demanded precise measurements which could be time-consuming. Initial exposure rates taken remotely with a long probe radiation survey instrument were greater than 2 R/hr near the upstream end of the drift tube.

Therefore, a four-week cool-down period was required before work was allowed to begin. During this cool-down period, extensive ALARA pre-job planning was performed. To maintain worker exposures ALARA, several items were built:

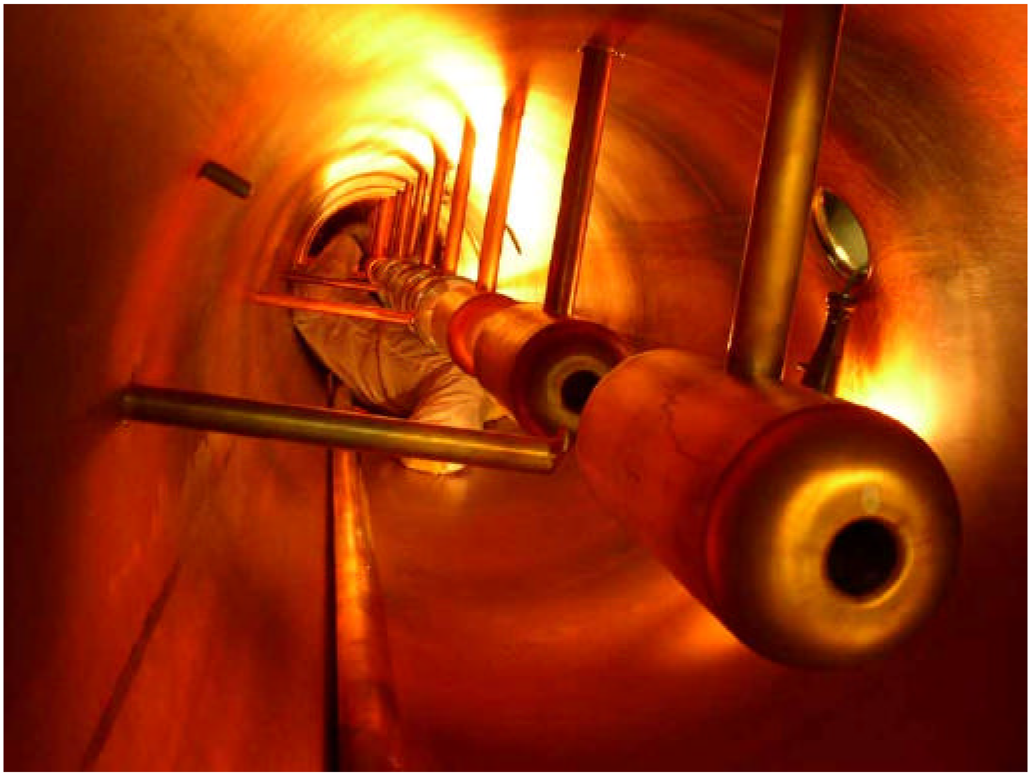
- Shields to cap the ends of drift tubes, with flat surfaces to make end-to-end gap measurements easier and much faster.
- An azimuthal measuring fixture for quicker measurement of the distance between a drift tube and cavity walls.
- A teflon™ cart with jack, for transporting drift tubes out and in, and elevating them, so that removal and installation work did not require anyone to sit in the cavity. This cart consisted of a scissors jack that was manipulated remotely by electric motors, levers, or by a ratchet wrench. The cart slid on nylon sliders (like a snow sled), and supported the quadrupole magnet for alignment as well as for removal and installation. This fixture eliminated the need for personnel to access the drift tube to manually hold up the quadrupole for this and subsequent jobs.

Other ALARA activities that occurred during cool-down of this drift tube were dry-runs of the work to be performed. These dry-runs were conducted on low activity drift tubes at the downstream end of the tank. These rehearsals allowed task durations to be estimated for ALARA planning purposes. It also provided every worker the opportunity to practice the work in a less hazardous environment. The ambient exposure rate during the job was 5 mR/hr. The estimated collective dose for the replacement of the drift tube was 127 person-mrem. The actual collective dose was 109 person-mrem.

By allowing at least four weeks cool-down, use of an un-manned cart for exposure rate measurements, and use of additional shielding, significant personnel dose reduction was achieved.



Linac Tank 5 Drift Tube Replacement Set Up



Linac Tank 5 Drift Tube Replacement Work

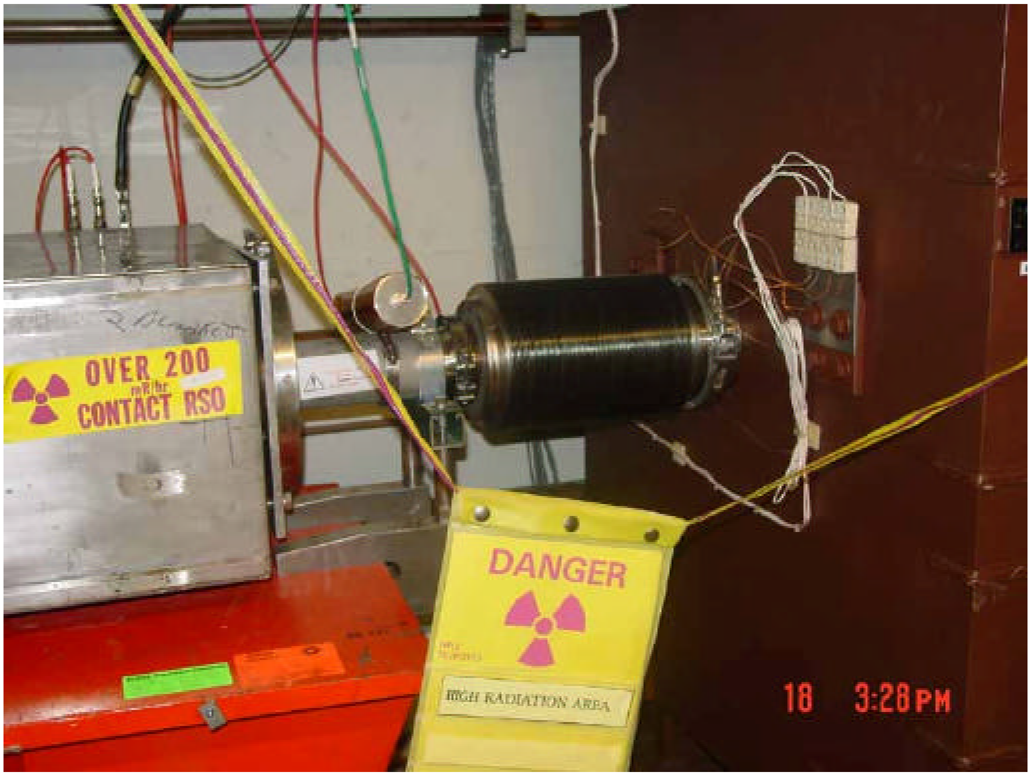
2. Booster Long 13 MP01 Magnet Replacement

This ALARA work consisted of magnet replacement and reconfiguration at a location identified as Long 13 in the Booster. Two dogleg magnets, along with magnets ML01 and MP01 were replaced in this area. A four-week cool-down was required before work was performed in this area. Cool-down time also allowed radioactive contamination to decay, thus reducing overall decontamination efforts. The highest exposure rate measured during the removal phase of this work was 100 mR/hr at one foot. However, the removal of highly activated components from the area and use of lead walls and lead blankets resulted in a ambient exposure rate of only 20 mR/hr during all phases of this work. The projected collective dose for the removal of Long 13 magnet was 226 person-mrem. The actual collective dose for the removal phase was 181 person-mrem. The projected collective dose for the installation phase was 1825 person-mrem and the actual dose received was 1208 person-mrem. The reduced values actually realized resulted from enthusiastic worker participation in all facets of dose minimization planning. A total of 18 people worked on this job and the installation phase of this work lasted approximately 18 days. The ALARA plan for the installation phase was revised to account for adjusted time estimates for certain tasks, based on experience and observations by the Radiological Control Technician covering this work. As a result of this work, it is anticipated that beam losses during future operations of the Booster synchrotron will be reduced, with anticipated lower future exposures to maintenance personnel.

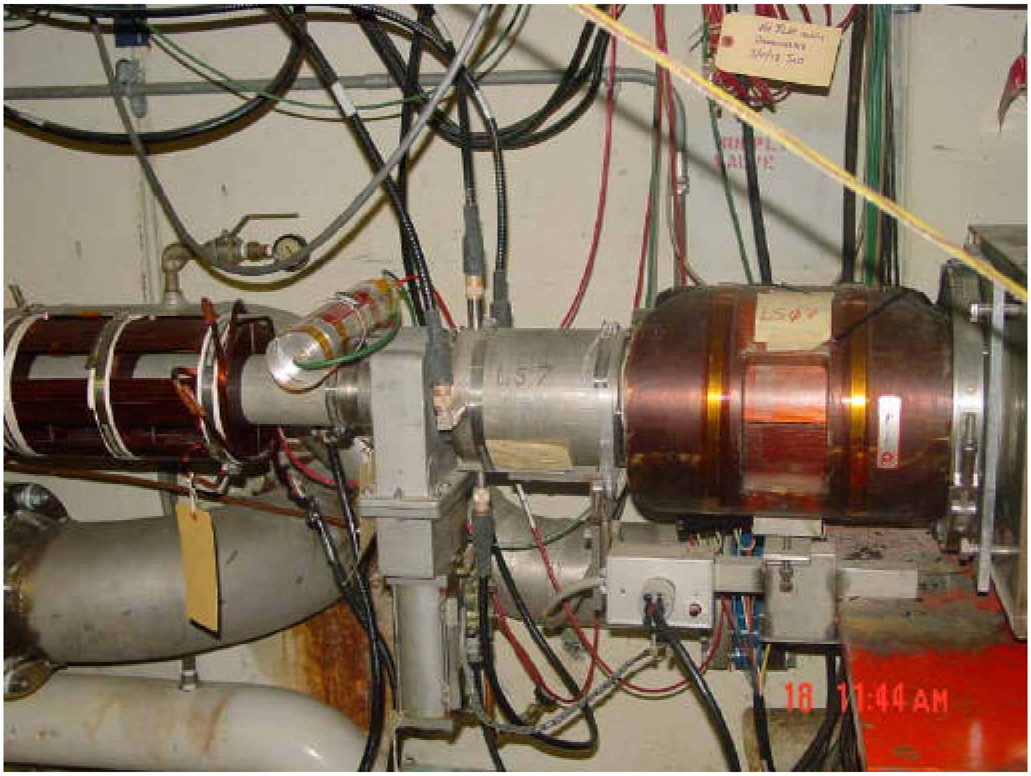
MP01 Long 13 Magnet Replacement

3. Booster Beam Positioning Monitors (BPM) Replacement in Long 6 and 7

The tasks in the Booster also included beam positioning monitor (BPM) replacement at two separate locations. By allowing at least four weeks cool-down, personnel dose was significantly reduced. Because the highest exposure rate observed during this job was 100 mR/hr, this work required detailed ALARA pre-job planning. The projected dose for this work was 486 person-mrem. The actual dose received was 42 person-mrem. The discrepancy in dose received vs. projected dose was due to the highly localized nature of the exposure rate encountered when the work actually commenced. Workers were not required to spend any significant time in the highest exposure rate area. Workers either worked under or behind the area of highest induced radioactivity. Time estimates for each task were overestimated and this work was completed in less than half the time estimated in the ALARA plan. Prefabrication of some parts in low dose areas also reduced personnel exposure. In summary, it is clear that steps were well planned and performed efficiently in less time than anticipated due to careful ALARA planning.



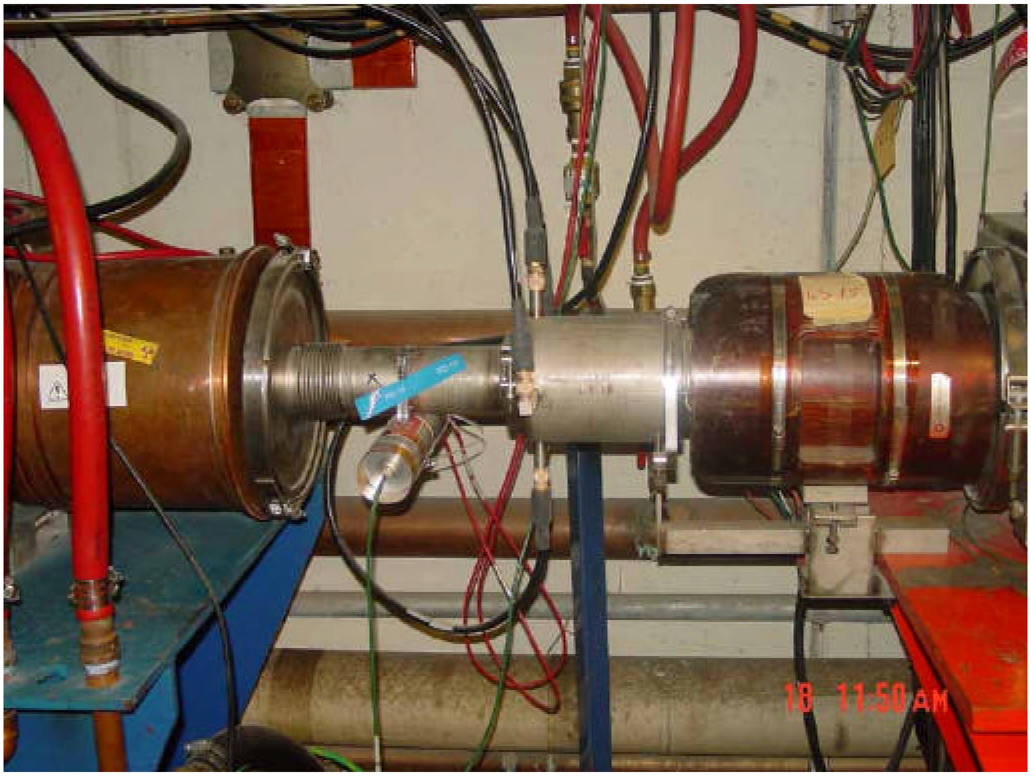
Beam Positioning Monitor Replacement in Long 6



Beam Positioning Monitor Replacement in Long 7

4. Booster Water Tube Replacements

Water tubing replacement work occurred at four locations in the Booster lattice. The previous plastic tubing and orange "garden" hoses were replaced with PEEK™ tubing. PEEK™ tubing is quite resistant to the effects of radiation damage. This work was performed to minimize potential water leaks in the future, thus preventing personnel exposure due to repair work that would have to be performed under higher exposure rate conditions. Also, this work was performed to increase machine reliability. Lead blankets and self-shielding of magnets were used extensively to reduce personnel exposure during this work. As the work progressed, the ALARA plan was revised to reflect a change in procedure that included brazing coupling fittings and the use of shorter lengths of PEEK™ tubing. The highest exposure rate observed during the work was 80 mR/hr at one foot. The ambient exposure rate was 5 mR/hr. The projected collective dose was 371 person-mrem and the actual collective dose received was 200 person-mrem. The actual dose was lower than anticipated because localized exposure rates allowed workers to position themselves in lower exposure rate areas.



Booster Water Tube Replacement

5. Replacement of MiniBooNE Pulsed Beam Focusing Horn

The MiniBooNE horn is a pulsed beam focusing device which is subjected to high flux densities of high energy hadrons and intense instantaneous electrical currents during operations. After two years of operation, the horn began to malfunction. This was exhibited by water leaks and electrical failures. The horn module was expected to fail over time due to mechanical stress as a result of delivering beam through the horn module to run the MiniBooNE experiment. This particular focusing horn had withstood a world-record number of pulses, but finally unexpectedly failed only a few weeks before the scheduled shutdown. While the "bare" horn was never directly exposed, it is estimated that the residual dose rates were as high as 120 R/hr at one foot. The MiniBooNE horn replacement work presented several radiological issues. Therefore, ALARA considerations for this complicated task included contamination controls, exposure rate controls, and airborne radioactivity controls. The ALARA planning phase of this task lasted several months. Because of the various non-radiological safety aspects associated this task, a complete written hazard analysis was also prepared.

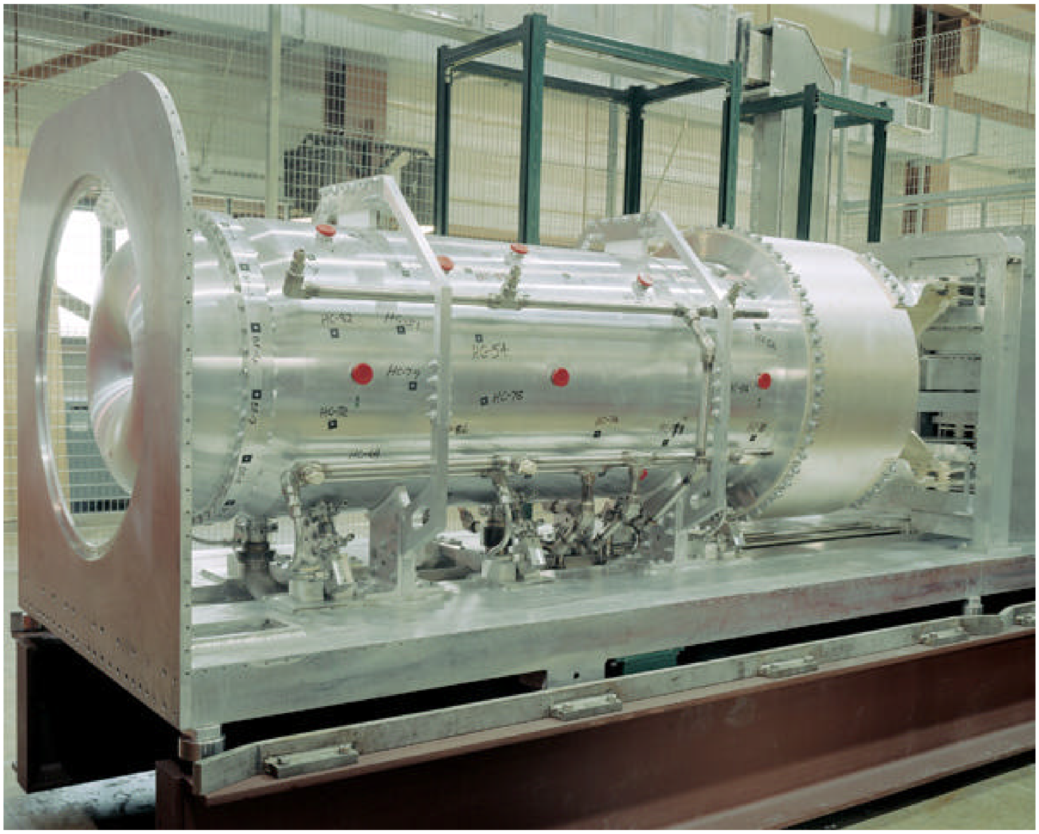
Initial work for this task involved the removal of all shielding blocks and steel plates from the MI-12 B enclosure. Magnets, magnet stands, and other beamline components were removed from the enclosure. Next, all systems were disconnected from the horn module. The power striplines were disconnected from the upstream end of the horn module, the radioactive water system was disconnected, and the target air cooling system components were removed. The horn module was pulled out of the target vault into a set of steel coffins using a system of extension rods connected to hydraulic cylinders. The set of inner and outer coffins were used to accommodate the 20-ton lifting capacities of the cranes at the removal and storage locations. The horn module contained inside these coffins was transported to Target Service Building for storage. The new horn module was installed by pushing it into the target vault using the same system of extension rods and hydraulic cylinders. Once the new horn module was installed, the power striplines, radioactive water system and target air cooling systems were reconnected. The magnets and other beamline components were installed in the MI-12 B enclosure as well. The shielding blocks, steel plates and two air barriers between the first and fourth layers of shield blocks were re-installed.

The highest exposure rate near the horn (with target vault shutter doors open) in the MI-12 B enclosure was 200 mR/hr. However, the ambient exposure rate during horn removal and installation was only 2 mR/hr. This low ambient exposure rate was achieved by removal of various radioactive beamline components, closing target vault shutter doors as much as possible, and by use of steel coffins which provided effective shielding of the horn module when it was outside of the target vault. As part of the ALARA planning process, collective dose estimates were predicted for both the MiniBooNE horn removal and installation phases of the work. The predicted collective dose for the MiniBooNE horn removal was 260 person-mrem. Upon completion of the horn removal, the collective dose received was 141 person-mrem. The predicted collective dose for the horn installation was 189 person-mrem. Upon completion of the horn installation, the collective dose was 186 person-mrem. Therefore, the total collective dose received for the replacement work was 327 person-mrem. The following actions were taken to maintain contamination levels, airborne radioactivity and radiation exposure levels ALARA:

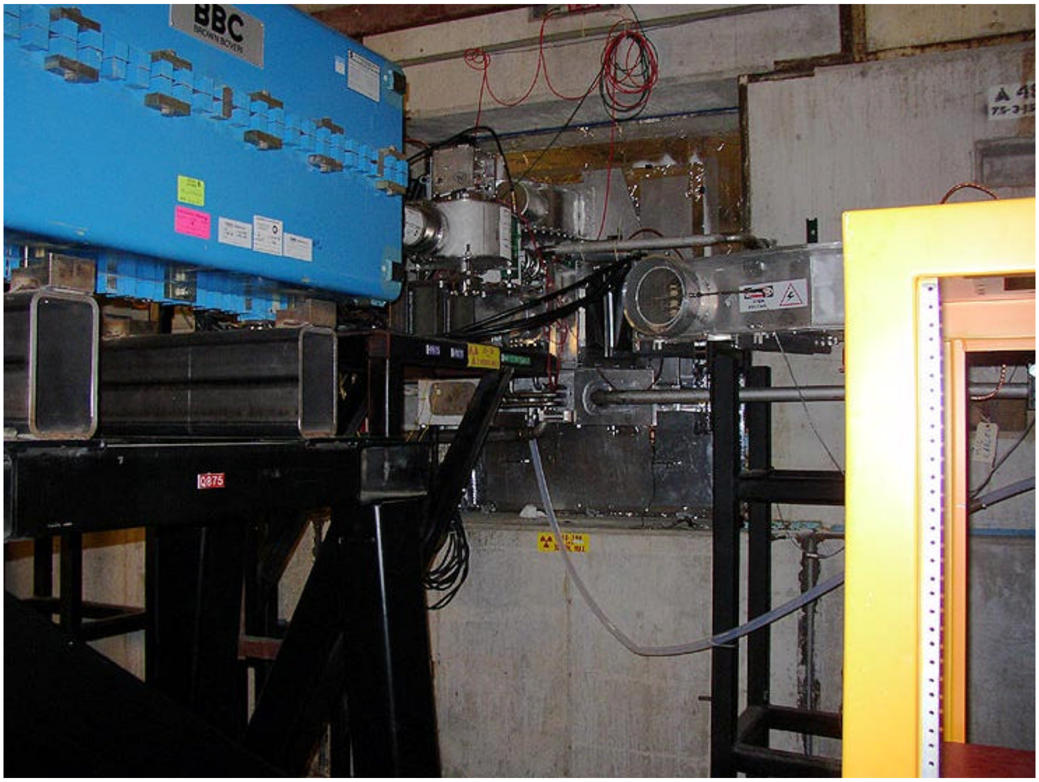
- A dry-run of the MiniBooNE horn replacement was conducted when the original focusing horn was installed in the MI-12 B enclosure. These dry-run activities were videotaped, and thus provided excellent time estimates for ALARA planning purposes. As in all dry-run activities, it also provided workers the opportunity to practice difficult, tedious, and time-consuming tasks on non-radioactive components.
- Considerable decontamination efforts were completed before horn removal work began, upon completion of horn removal, and prior to the new horn installation. The floors, stairs, and stairwells were decontaminated as well as beamline components that were removed from the enclosure. Continuous Radiological Control Technician (RCT) coverage was in place during all phases of horn removal and installation work.
- All beamline components, power stripline components, radioactive water system pipes, and target air cooling components that were disconnected and removed from the horn module were bagged and all end pieces were capped and sealed to prevent the spread of contamination.
- A contamination catch-tray was built and installed under the front of the used horn module to catch loose contamination during horn removal and to contain any radioactive liquids that were removed from the horn.
- To maintain ALARA, new power stripline parts, air barrier panels, and other components were machined to replace highly contaminated components that were removed. These new parts were installed to prevent handling contaminated components.
- The prominent exposure control factor utilized during removal of the horn module was the use of one inner and two outer steel coffins. The inner coffin was 1.5 inches thick, whereas the steel outer coffins were 3.5 inches thick, for a total shield thickness of 5 inches. Two outer coffins were used to allow the inner coffin to be lifted from the enclosure and placed in a second outer coffin staged on the truck bed while the first outer coffin remained on rails in the enclosure.
- Target vault shutter doors remained closed as much as possible during horn removal and installation to reduce exposure to personnel working in the enclosure.
- Temporary shield walls were located both in the enclosure pit and also on the main floor of the MI-12 Service Building. Workers used these temporary shield walls at appropriated times during horn removal.

- An outdoor perimeter was established to prevent personnel exposure while the inner coffin was being lifted out of the enclosure and placed inside the outer coffin located on a low boy truck bed.
- Numerous high volume air grab samples were collected at various key times during horn removal and installation. The results of these airborne radioactivity grab samples were used to determine area work conditions and personal protective equipment (PPE) requirements for workers and observers.
- Because there was a potential for airborne radioactivity, all workers were required to wear air-supplied hoods during most horn removal and installation work to maintain exposures ALARA.
- Immediately following the removal of the aluminum air barrier panels, a temporary plastic air barrier was installed to control airborne radioactivity. This plastic air barrier remained in place and was cut out around the coffin as it was being pushed into the target vault. This greatly minimized airborne exposure to workers.
- When work was not being performed, a large blue curtain was pulled down over the plastic air barrier in front of the target vault opening to reduce air movement in this region.

The MiniBooNE pulsed focusing horn removal and installation project was a complicated task. Additionally, all phases of this work presented numerous radiological issues. The MiniBooNE horn replacement project was successful in maintaining exposures ALARA due to careful ALARA planning, performance of dry-run activities, thorough decontamination efforts, effective airborne radioactivity controls, and extensive use of shielding by means of steel coffins, use of target shutters, lead blankets, and portable shield walls to control personnel exposures.

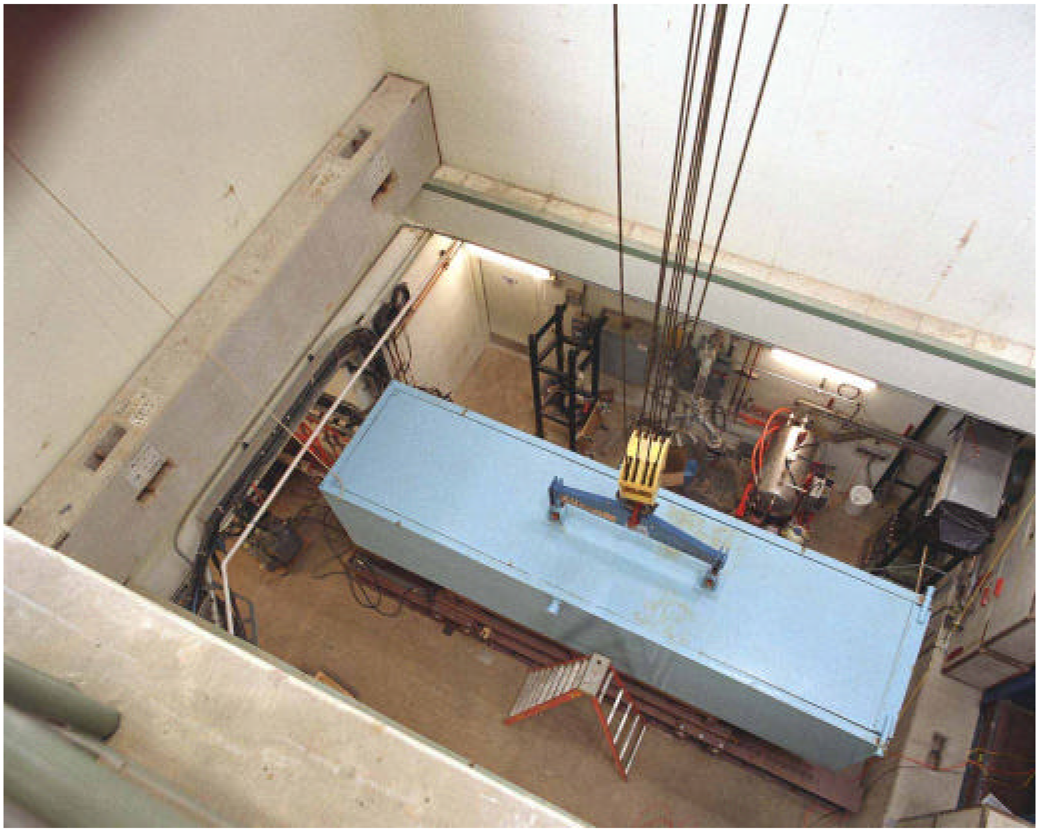


Pulsed Beam Focusing Horn Used in MiniBooNE Experiment

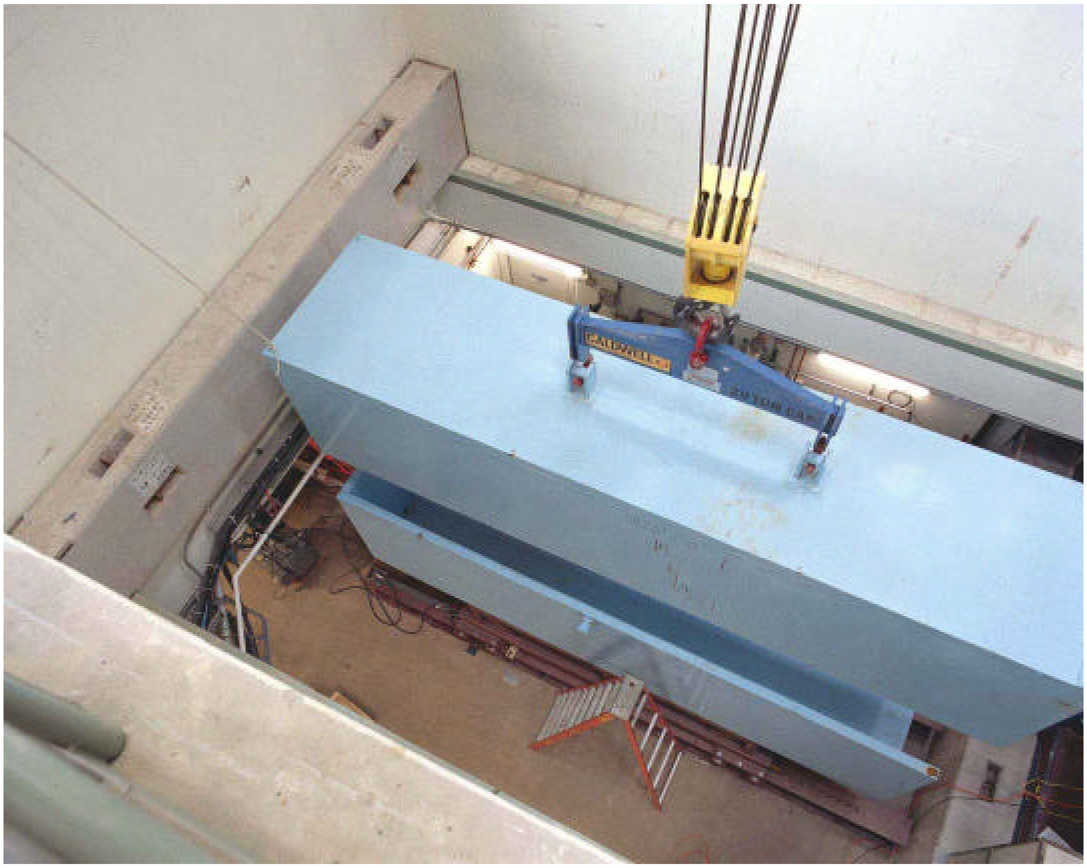


MiniBooNE Focusing Horn Before Removal

Blue Curtain Pulled Down Over Air Barrier in MI-12 B Enclosure Before Horn Removal



Inner and Outer Coffins in MI-12 B Enclosure



Used MiniBooNE Focusing Horn Being Lifted out of MI-12 B Enclosure

Coffin Containing MiniBooNE Horn Being Loaded onto Low Boy Truck

MiniBooNE Horn Contained Inside Wrapped Steel Coffins for Transport to Storage Building