SHIELDING FOR THE MATERIALS TEST STATION

Mahlon T. Wilson (mahlontw@lanl.gov), Guenter Muhrer, Eric J. Pitcher,
Greg E. Mertz, John Eddleman, Kenneth P. Hurtle, Charles T. Kelsey IV

Los Alamos National Laboratory, Los Alamos, NM 87545

Most of the shielding required by the Materials Test Station (MTS) exists onsite in the form of blocks of steel and concrete. The dominant radiation source that drives the shield design are prompt neutrons generated when the proton beam interacts with matter. These neutrons have energies that extend to the incident proton beam energy of 800 MeV.

Approximately 10,000 tons of iron and steel, 3300 tons of concrete block, and 800 tons of magnetite powder will be included in MTS's shielding structure. A tunnel, 25m long, 4m wide, and 3m high houses the proton beam transport components. The walls of the tunnel contain 2m of steel and 1.8m of concrete. Thinner walls extend on each side of a 7m square, 4.2m high, helium tank filled with cast iron slabs that houses the target assembly. The top of the shielding is 7m above the floor.

To create a seismically stable structure, the stacked blocks forming the tall walls will be tied together with trusses. A truss placed on top of each row of block provides a seat for the next layer of block. Beams tie the trusses together. To provide additional protection to the target assembly, the cast iron slabs will be doweled together and tied to steel plates that act as shear diaphragms.

DESCRIPTION OF THE MTS SHIELDING

The Materials Test Station (MTS) is a facility that will be located within the Los Alamos Neutron Science Center's (LANSCE) Area-A to provide intense neutron fluxes of the proper spectrum to irradiate candidate materials that are required for future reactors. The neutrons are produced when the LANSCE 800 MeV proton beam strikes two tungsten targets. Samples are placed between the targets and on the outsides of the targets and they are wrapped with a tungsten and steel neutron reflector. This package is called the Target Assembly (TA). The dimensions of the TA are 76 cm high by 56 cm wide by 71 cm deep, and it weighs 2 tonnes.

The MTS's proton-beam transport system begins within the LANSCE switchyard and extends eastward into Area-A a distance of 27.8 m where the protons impinge upon the TA. The beam height is 1.52 m above the floor. The floor of Area-A is 55 m square, a central stripe of which is 2.4 m thick. The MTS facility rests upon this thick portion and will be designed in accordance with PC-2 seismic requirements. (Fig. 1)

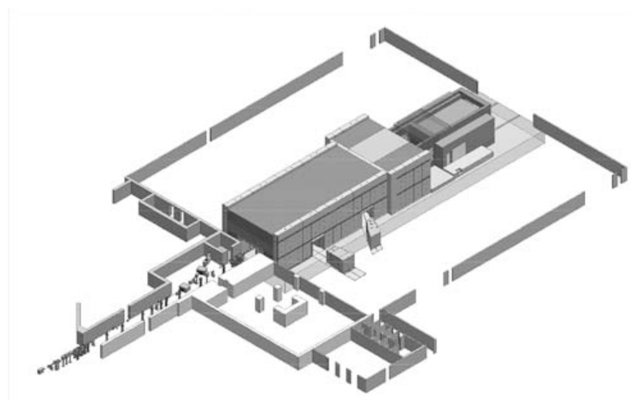

Figure 1. MTS Facility in Area-A. The proton beam enters from the switchyard at the lower left.

Historically, a 1 mA, 800 MeV proton beam interacted with two meson production targets as it traversed Area-A. The building still contains that equipment and the surrounding shielding, which is comparable in mass to that required by the MTS. The shielding was packed tightly around these components and extended the full length of Area-A to a height of 7 m. Shielding was stacked where needed with no consideration given to seismic restraint, as one of the selling points for locating the accelerator at Los Alamos was the historic stability of the site as evidenced by the vertical cliffs, tent rocks, and cobble columns in the vicinity. The fact that Area-A's equipment and shielding are all moveable greatly enhances the cleanout of that area and provides much valuable shielding material for the MTS.

The existing materials that will be reused include counterweights, steel plate, and concrete blocks. Over a hundred counterweights were obtained from the elevators of dismantled Atlas-F missile silos. These are cast iron bars 0.3 m thick, 1 m wide, and 5.8 m long, weighing 12 tonnes. The 1 m-wide surfaces of the bars are machined flat and, when stacked, radiation cannot stream between them. The shielding that will be removed also contains hundreds of tons of off-specification steel plate that was produced during the start-up of a continuous-casting steel mill and over 200 concrete blocks of various sizes.

Stored on site are over 2000, slightly activated, cast-steel ingots from a DOE scrap recovery program. Called "Green Blocks" due to their color, most of them are 1.32 m square by 0.66 m high and weigh 8.6 tonnes, the remainder are one-eighth that size.

Magnetite will be obtained from Phelps Dodge's Hanover Mine in southwestern New Mexico. It has a density of 5, moisture content between 2 and 10%, and is extremely fine; essentially all will pass through 65-mesh screen (0.02 cm dia).

The shielding associated with the MTS is described in the following sequence:

1. Beamline tunnel shield
2. Crossover shield
3. He tank internal and external shields
4. Trolley
5. Service cell
6. Saddle shield

1. Beamline Tunnel

The proton beam line is housed in a tunnel that is 4 m wide by 3 m high and is 25 m long. It is created by bridging walls formed of two rows of B-3 concrete block (3 m high x 0.9 m thick x 1.8 m wide) with the 5.8 m-long counterweights. The counterweights appear to be Class 20 gray iron with yield strength of 110 MPa and tensile strength of 138 MPa, capable of supporting the shielding above the tunnel with a safety factor of 4.5.

The required tunnel shielding, 2 m of steel and 1.8 m of concrete, is obtained by stacking steel block outside and above the tunnel, and surrounding that by concrete. (Fig. 2)

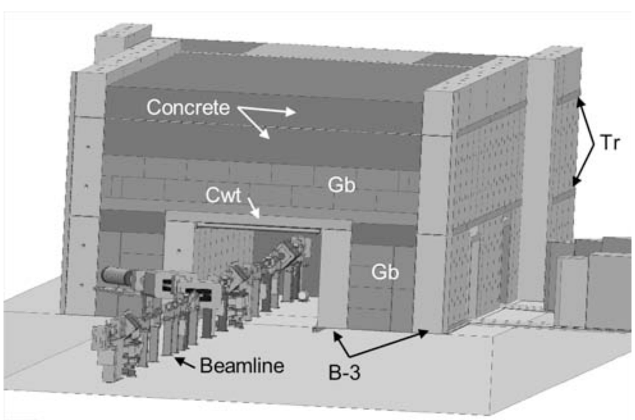

Figure 2. Cross-section of the beam tunnel. Cwt are counterweights, Gb are green blocks, and Tr are trusses.

A seismically stable arrangement is obtained by first erecting and constraining the outside concrete-block walls, and then installing the steel blocks. The outside walls are formed by placing another row of B-3 blocks on either side of the tunnel, leaving 2.06 m wide aisles. The bottoms of the outside and tunnel walls are restrained from separating by placing them on a 1 cm-thick steel floor plate that has edge bars to prevent the bases of the blocks from moving outward and widening the aisle. The floor plates are anchored to the concrete floor.

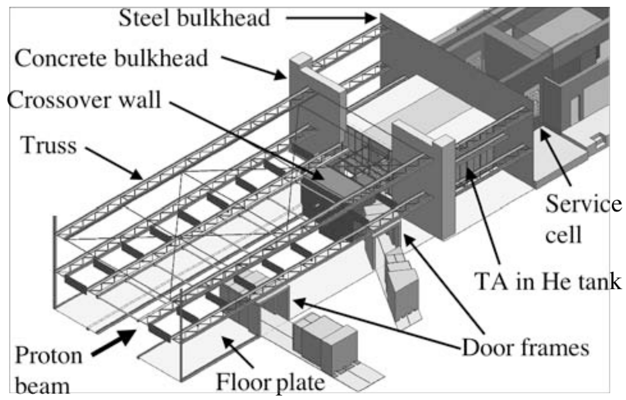

Figure 3. Seismic bracing structure.

A skeleton of steel trusses and beams is employed to stabilize the structure. (Fig. 3) The tops of the outside and tunnel walls are held by four 25 m-long trusses that are laid horizontally on top of the four rows of B-3 blocks. The flanges of the trusses clamp onto the top edges of the blocks, holding the block into four straight rows. Vertical steel plates, 2.5 cm-thick, span the aisle to connect the two trusses that are on top of the tunnel and outer walls, preventing the tops of the walls from moving together or apart. Pipes spanning the tunnel, under the counterweight roof, connect the north two trusses with the south two, restraining all four walls with a steel grid that is 25 m long in the east-west direction and 11.7 m wide in the north-south direction. The trusses are held in place by being attached to the block's lifting inserts, and by the weight of the counterweights on the inner trusses or the 2nd storey of B-3 concrete block that is seated on the outer trusses. The truss webs are filled with grout for shielding and to provide a stable base for the counterweight or block resting upon them (there is no upward flange on the web of the truss under the counterweights).

Two shield doors (boxes filled with magnetite powder) provide access through the south wall of the beam tunnel. The massive, stepped frames for these doors are secured to the two lower-level trusses on the south side of the tunnel and to the floor. All 4 of the lower-level trusses are secured to the 2 m-thick concrete crossover wall (described later).

The 2.06 m-wide aisles between the inner and outer walls on each side of the tunnel are filled with two long rows of Green Block, one with the block flat, the second with blocks on edge as shown in Figure 2. The aisle is 8 cm wider than the space required by the two rows of Green Blocks to facilitate their placement. As the Green Blocks are placed, gaps around them are filled with magnetite powder, and additional powder is spread over the blocks to fill their uneven surfaces. In addition to blocking radiation-leakage gaps, the magnetite also locks the Green Blocks in place between the B-3 block walls, causing the shield wall to act as a unit 3.89 m wide by 3 m high, greatly enhancing its seismic rigidity. All gaps and joints are sealed with tape to prevent magnetite leakage.

Two more trusses, the fifth and sixth, are placed on top of the rows of B-3 block that form the 2nd storey of the outer wall. The 3rd storey is B-2 concrete block, 0.9 m thick by 1.4 m high by 5.5 m long (3' x 4.5' x 18'), placed on top these two trusses, raising the top of the outer walls to a height of 7.5 meters. This provides a 50 cm-high curb along the outer sides of the top of the shielding.

Two layers of Green Block and 30 cm of reject steel, providing a total iron thickness of 1.9 m, are placed on top of the tunnel's counterweight roof and the Green Blocks filling the aisles. The iron is topped with 2.1 m of concrete in the form of two layers of existing block in a patch-work-quilt pattern. Between the concrete layers will be placed horizontal steel members that tie together the two upper trusses. Buttresses rising from these members will brace the B-2 blocks at the top of the walls. The top of the shielding provides a level roadway that matches an existing balcony and access road (7 m above the floor) at the west end of Area-A.

All voids that result because the existing blocks do not adequately occupy the volume of the required shielding will be filled with poured concrete or fabricated steel pieces.

The dimensions of the outside of the tunnel shield are 25 m long x 7 m high x 11.7 m wide. The role of the trusses, the ties between the trusses, and the anchors at the ends and mid-span of the trusses, is to carry horizontal seismic forces diagonally downward to the building floor. The plates beneath the two shield walls prevent sliding on the floor. The tied-together structure is now short compared to its width and length, so it is resistive to being tipped over.

2. Crossover Shield

It is necessary to protect the beam transport equipment from neutrons streaming back from the TA. The proton beam is designed for a size minimum at 20.4 m into Area-A. A collimator at this location is embedded in a 2 m-thick poured-concrete shield wall (crossover shield) that blocks the tunnel. The crossover wall is shown in Figure 3. After emerging from the crossover shield, the beam drifts 3.9 m (passing an optical diagnostic) before the beamline vacuum pipe enters a He tank. This portion of the beam line will become activated to few-tenths Sv (10s of rem/h) levels, requiring a shadow-shield wall and thru-wall tooling for maintenance.

3. He Tank and its External Shield

The TA resides in a 7.3 m-long steel vacuum pipe (called the scabbard), the west end of which is 20 cm diameter to match the beam pipe and the east end is 86 cm diameter to house the TA and its supporting structure. Seven stacks of counterweights are placed (long direction oriented east-west) in a 7.3 m square He tank to surround the scabbard. An eighth stack and a 15 cm-thick vertical plate are placed in a north-south direction across the ends of the seven stacks. The tank's 2.5 cm-thick steel floor is secured to the building's floor, and the lowest layer of counterweights is keyed to the tank floor. A 2.5 cm thick steel seismic diaphragm is placed between the first and second layers of counterweights. Posts extending up and down from this diaphragm secure it to the first layer (and floor) and restrain the 11 layers of counterweighs stacked above. A second diaphragm is bolted to the top of the counterweights and to the posts, thereby tying the stacks together. One-meter square concrete columns occupy the two corners of the eastern wall for neutron absorption. The tank walls are formed with steel structural sections covered with a sheet-steel skin. The roof is steel sheet pieces. The tank is made He tight with the use of neoprene gaskets at all joints. (Fig. 4)

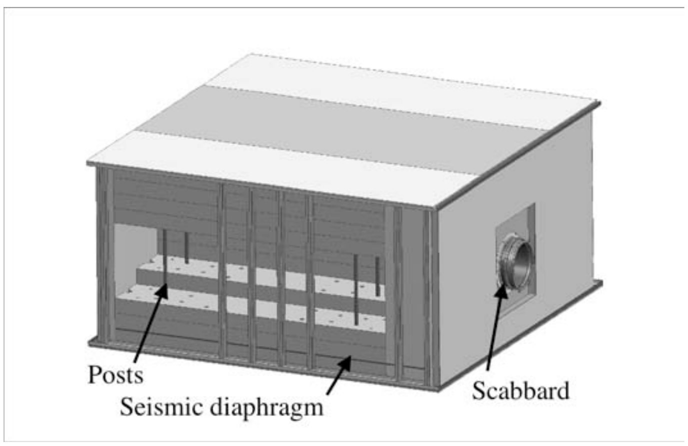

Figure 4. View inside He tank showing seismic restraint posts threaded through the holes in the stacked counterweights.

Additional shielding is required outside and above the helium tank for personnel protection. The side shielding is provided by jogging the tunnel shield walls outward, at the poured concrete bulkhead, to accommodate the wider He tank and access aisles alongside it. Because of the large amount of cast iron in the He tank, the side shielding walls are thinner, the inner B-3 block is replaced with the half-thick B-9 block and only one layer of Green Block is placed flat in the aisle. The west ends of the trusses are anchored in the poured concrete bulkhead, the other ends attach to a vertical steel plate that covers the east end of the shielding.

The upper shielding consists of 2.7 m of steel block, topped with 0.9 m of concrete block resting on the He tank and its sidewalls. This locates the top of the He tank shielding 7.1 m above the floor. Hand-stacked concrete block is used to fill the east end of the access aisles between the He tank and its external shield.

The shielding is arranged so that it is possible to remove the scabbard for replacement. The shield blocks above the He tank will have additional bracing so that a canyon can be excavated over the centerline of the tank. The central portion of the tank roof is removable, exposing the top horizontal seismic shear plate. Unbolting the central section of this plate from the top of the counterweights and posts allows removal of the upper layers of the three stacks of counterweights that cover the scabbard.

The east end of the scabbard and the nose penetrate the east wall of the He tank and are sealed to it (and to each other) with squeezed neoprene gaskets. The east wall of the He tank is also the west wall of the service cell.

4. Trolley

The TA is attached to the west end of a horizontal cylindrical assemblage (called the nose), 0.86 m diameter and 4.6 m long that is slid into the scabbard for irradiation (Fig. 5). The nose contains a liquid metal pumping section located between two shielding sections.

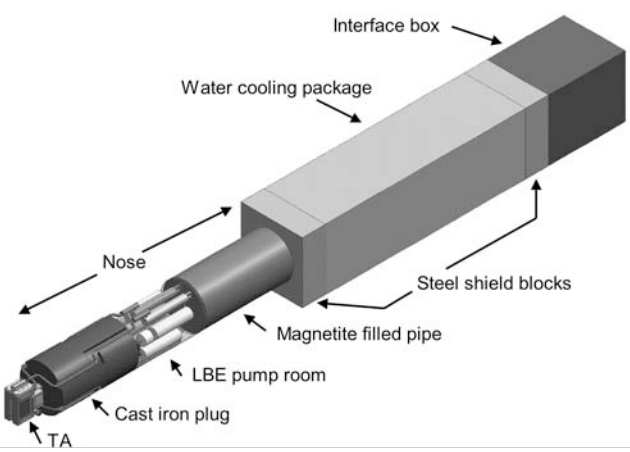

Figure 5. The trolley, shown with the reflector removed from the TA on the left.

A steel framework approximately 1.2 m square and 4.9 m long, that resides within the service cell is connected to the east end of the nose. Each end of the framework consists of a 46 cm-thick steel shield block. The 4 m-long central portion of this framework contains four water-cooling systems whose piping traverses the nose to remove heat from the TA systems. The cooling package with its shield blocks, and the nose connected to it, are collectively named the trolley. An interface box is mounted on the east end of the trolley that contains all utility and instrumentation connections to the building. The trolley can be moved to the east about 7 m to position the TA and the liquid metal pumping system at convenient locations within the service cell for maintenance.

5. Service Cell

The service cell is a shielded structure that surrounds the cooling package. Every item that is activated and requires maintenance during normal operations is viewable and remotely maintainable within the service cell. During operation the TA contains radionuclide activities of the order of 10^{17} Bq (3 MCi), of which about one-quarter remains 30 days after irradiation. The maximum component radiation dose rates at 1 m at beam shut-off are in the 10^{3} Sv/h (100 kilorem/hour) range. After one day of decay these are an order of magnitude lower.

Both the north and south walls of the service cell contain 2 viewing windows and 4 manipulators. The cell is provided with a hoist, lights, rolling roof and doors, and other support equipment. Its interior north-south dimension is 4.6 m to provide complete and overlapping coverage with extended-reach manipulators. The interior of the service cell is at least 4.9 m in the E-W length, and 4.6 m in height. The final dimensions will be determined when the space requirements of the cooling systems, contamination control, and material transfer systems have matured.

The service cell walls will be poured magnetite concrete to absorb the low energy neutrons emanating from the He tank. The windows and wall penetrations may be housed in magnetite-filled boxes that are inserted in openings in the concrete walls. The existing Area-A hot cells were constructed in this fashion[1] and it is possible to move those window boxes to the MTS service cell. Rolling roof and horizontal access doors will be steel.

Attached to the east face of the service cell is an airlock building to resist the spread of contamination. All connections to the movable trolley occur in this building. Horizontal material transfers from the service cell are through this room. This is a light steel structure about 10 m square and 3.7 m high, with removable roof hatches.

6. Saddle Shield

A steel saddle shield, 30 cm thick, covers the sides and top of the cooling package, its shield blocks, and the interface box. The saddle shield protects these items during a seismic event, and shields the service cell components and personnel from activity in the cooling systems. The mass of the saddle shield, the two shields on each end of the cooling package, and the walls of the service cell and transfer locks, are required to supplement the shielding in the He tank and the nose's shield sections to provide adequate shielding from the TA in the eastern direction.

The saddle shield can be moved eastward into the airlock building about 75 cm to expose the nose's vacuum seal for hands-on maintenance. It can be rolled further eastward, exposing the cooling package for maintenance within the service cell. (Fig. 6) When both the trolley and the saddle shield are moved to the east, the saddle shield blocks the TA's radiation from streaming eastward. To protect the service cell equipment and windows from the intense radiation of the TA when it is in the cell, but not being worked on, 1.5 m of the western end of the saddle shield can be independently moved westward to cover the TA. (Fig. 7) The eastern end of the saddle shield can be independently moved eastward to provide access to the sides of the interface box.

The moveable saddle shield essentially extends the size of the service cell during maintenance.

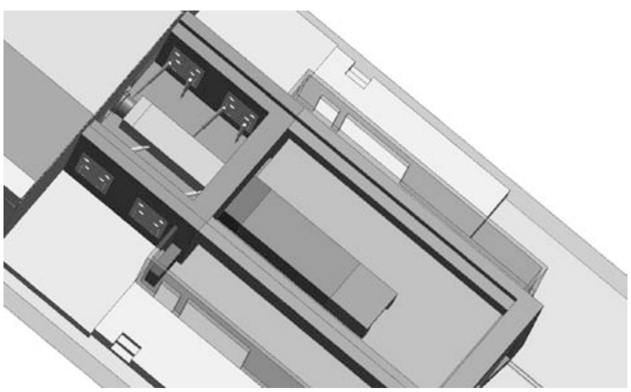

Figure 6. Saddle shield moved eastward into the airlock building for cooling water system maintenance.

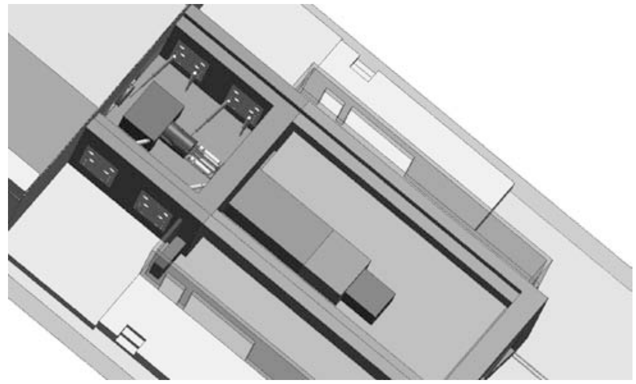

Figure 7. Shielding the TA with the west end of the saddle shield to reduce radiation levels in the cell.

CONCLUSION

We have shown in this paper that even though we are planning on using a significant amount of used materials for the construction of the Materials Test Station, that we have a solid concept that will not only fulfill the radiological requirements but also the seismic ones. The presented concept also is a great example how the utilization of used materials not only reduces the construction cost of a new facility, but also helps the environment by recycling materials and reducing waste. This concept also results in a facility that will be relatively easy to dismantle or reconfigure for future programs.

ACKNOWLEDGMENT

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REFERENCE

1. MAHLON T. WILSON, "Los Alamos Meson Physics Facility Hot Cell Complex," *Proc. of the 17th Conference on Remote Systems Technology*, p. 105-109, American Nuclear Society (1969)