Lead Shielded Enclosures for CHESS-U

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Abstract. Shielded enclosures are critical components of radiation safety at scientific, medical, and industrial facilities around the world. As part of the Cornell High Energy Synchrotron Source Upgrade (CHESS-U), ADC has designed, fabricated, and installed highly modular shielded enclosures ("hutches" at synchrotron facilities). ADC utilized expert consultation offered by several facilities including engineers from Advanced Photon Source (APS)[1–3] and Cornell High Energy Synchrotron Source (CHESS); with each facility providing guidance to assure that the design satisfies the rigorous radiation safety requirements. In this paper, ADC will discuss the design of these hutches, particularly the modular design elements which facilitate rapid installation to minimize downtime at the synchrotron.

Keywords: shielding, x-ray, lead, enclosure, hutch, modular

Introduction

The CHESS-U upgrade project requires that a majority of the hutches in the experimental hall be replaced on a short timeline. Modularity of the design has been emphasized in order to meet this requirement by reducing both total design time and installation time. Each hutch is built up from a set of steel frame units covered with lead panels. Similarities between each module allow for efficient use of templates in design, and the modularity allows for rapid disassembly, transport, and reassembly.

Shielding thickness is divided between an inner and outer layer, making seams between lead panels easier to block by staggering the panel joints. Hutches handling the full-spectrum x-ray beam from the undulator ("white beam") carry 1 inch of total lead thickness, while those handling monochromatic beam carry ½ inch of total lead thickness. Seven such hutches are involved in CHESS-U: three with 1" of lead and four with ½" of lead.

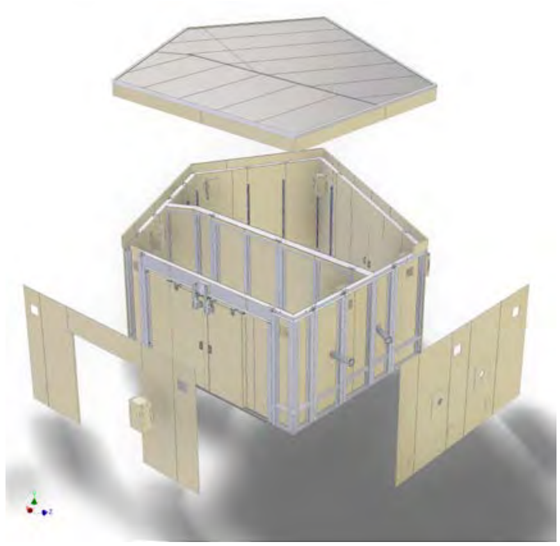

FIGURE 1: Two adjoining hutches with ceiling and exterior lead panels moved to show interior detail.

Frame Modules

The frame of each hutch is an assembly of welded frame modules of four basic types: flat wall panels (the majority of the modules), ceiling modules, corner modules, and one doorway module per hutch. An example of a frame module is shown in FIGURE 2. The design of each basic frame type was approved by a licensed engineer for up to a maximum size, and templates were made in Autodesk Inventor software to enable rapid modeling of any enclosure shape from combinations of the basic modules. Module size is based primarily on maximum weight and size for handling. To make walls of a desired length meeting at a desired angle, the modules can be scaled in length, corner angle, and other parameters. Each of the hutches for the CHESS-U project has a unique footprint shape but uses the same basic modules. FIGURE 4 shows the frame of two of the hutches with an adjoining wall.

Frame modules are bolted together with standardized connections at top and bottom, positioned in such a way that the modules can be easily attached and separated. An example of the top connection is shown in FIGURE 5. While the hutch modules are delivered as frames and lead together, the frames are first assembled complete at ADC, then the lead is hung and the structure is painted. The initial assembly at ADC also confirms fit-up of all components, and allows a survey of the hutch as-built to speed installation.

FIGURE 2: An example of a frame module, a 90° corner.

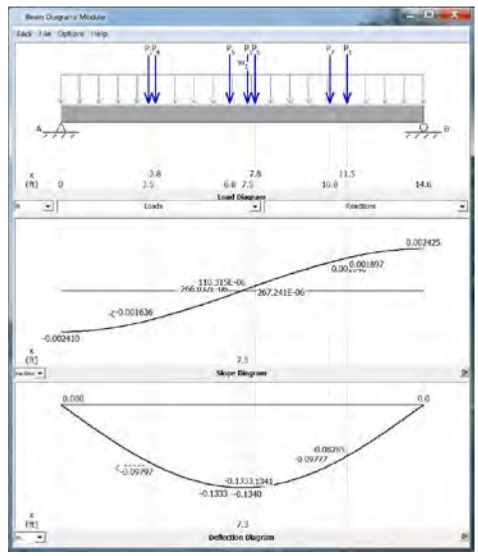

FIGURE 3: Example of calculations used in the framework design.

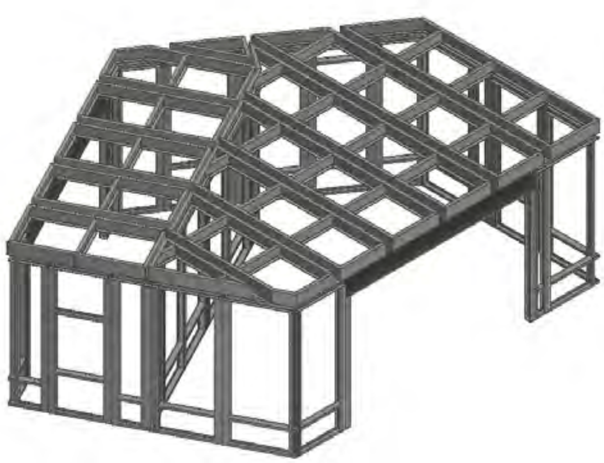

FIGURE 4: Skeleton of two adjoining hutches.

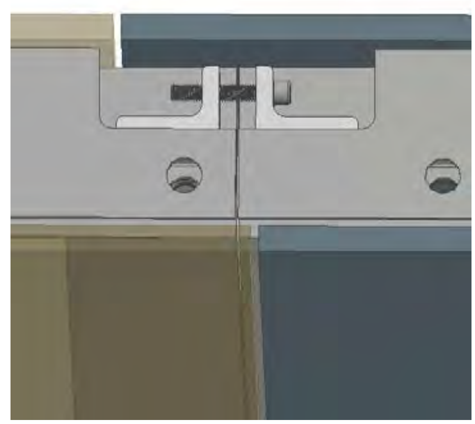

FIGURE 5: Top of wall connection.

Lead Shielding Details

The lead shield panels used on the hutches are laminated structures with a sheet of lead between two sheets of steel. The steel provides structural support and restricts access to the lead, while the lead blocks photons by virtue of its high density. Since the hutch must prevent any line of sight to the x-ray source from outside the hutch, and the shielding material is available only in finite widths, joints between shielding panels are of particular importance to the design. Modularity of the structure also requires joints, and the structural and shielding joints were made to coincide where flat sections of wall connect.

To best block line of sight and facilitate assembly, the exterior shielding panel of one wall segment will extend to cover part of the neighboring segment, while the internal panel will be offset in the other direction to overlap the opposite neighbor and be overlapped by the first neighbor. FIGURE 7 shows a cross section through the joint between two wall segments, with the lead in the shield panels shown in yellow, and additional lead strips shown in lighter gray. Strips of lead back the seams between shielding panels to accommodate tolerance stack-up between the shield panels and frames in an assembled wall.

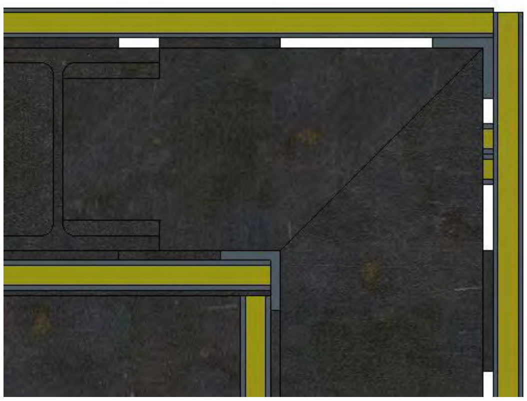

FIGURE 6: Lead detail in a corner segment.

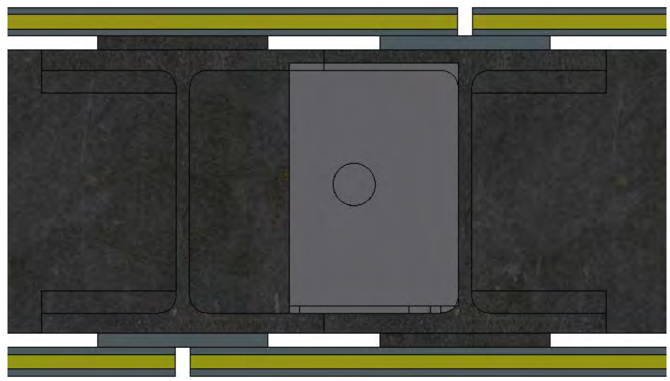

FIGURE 7: Joint between two straight wall segments.

At corner joints, like the one shown in FIGURE 6, the shield panels are overlapped completely, with a lead sheet bent to match the corner blocking any remaining gap. The system is designed such that joints between modules only occur with the type of connection in FIGURE 7. Once assembled, corner joints in the shielding remain assembled through the transportation and installation process.

The equipment used inside of synchrotron hutches requires electrical power and communication and all these cables must be passed through the shielding without allowing x-ray radiation to escape. This is accomplished by the use of "labyrinths" – twisted passageways like the one shown in FIGURE 9. There is no direct path for x-rays to pass through, or even enter, the labyrinth without a reflection from another surface first. A standard box module was used in all locations where labyrinths were required, with one box inside and one outside to block the path through the opening in the wall.

Doors

Doors on hutches allow access for installation and maintenance of equipment, as well as changing of samples in the experimental stations. These hutches were designed with pocket doors (doors which move into pockets in the adjoining walls when opened) to save space and provide a more streamlined exterior with no limitations on placement of work benches and equipment near the walls. Pocket doors also avoid the additional pillars or cantilevered structure required to support the rail of an external sliding door. Details at the edges of the doors ensure that no direct path exists for radiation to exit the hutch when the doors are closed.

Since the hutches both contain the radiation and act as a physical barrier against entry into the irradiated region, an interlock system prevents opening of the hutch while the x-ray beam is active and prevents activation of the x-ray beam when the hutch is open. The bracketry for this system can be seen at the top of the doors in FIGURE 8, which also shows the overhead sliding track for the doors and their hangers. While each door weighs more than 1000 lb, the extra-large bearings selected to carry them allow easy movement. Shock absorbers are used at each end of travel to prevent the doors from slamming open or closed.

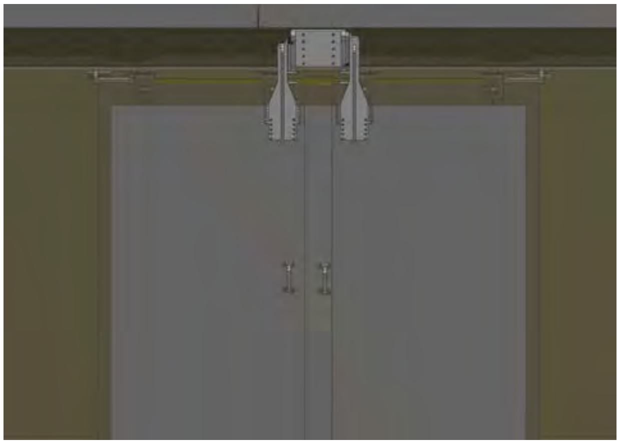

FIGURE 8: Double pocket door with outer shielding shown translucent to reveal hangers and stops.

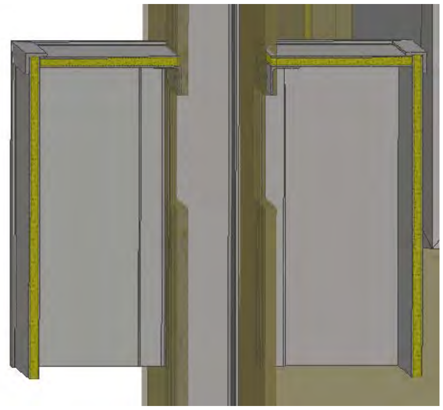

FIGURE 9: Cross section through a labyrinth.

Conclusion

Transportation and installation of the first two hutches was completed over the course of just a few days in September of 2017. Images of the installation are shown in figures below. The hutch received first light in late January of 2018, with successful completion of a full radiation survey shortly thereafter. Following these successes, the remaining hutches are in production and slated for installation in late summer of 2018.

FIGURE 10: Placing a straight section of wall and connecting it to a corner section.

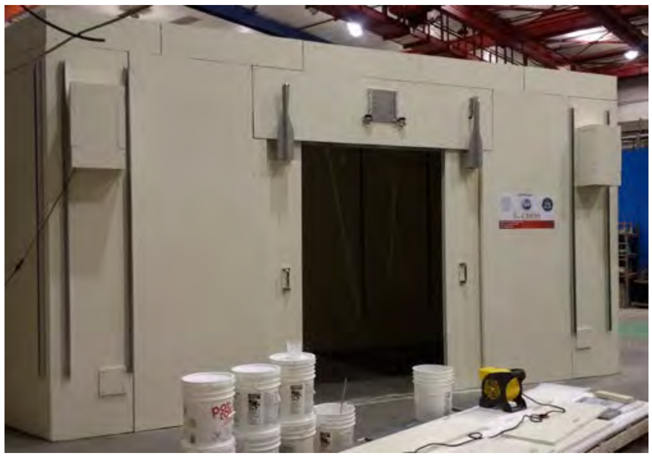

FIGURE 11: Finished hutch installed at CHESS.

Acknowledgements

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References

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