

Title: Design Status of the Post Irradiation Examination (PIE) Hot Cells at McMaster University
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ABSTRACT. The design team for McMaster University's Post Irradiation Examination (PIE) shielded facility was assembled and initiated design work in November 2011. The team consisted of representatives from McMaster University (owner/operator), Merrick & Company (design agent), and Atkinson (architect). Since this time, significant progress on the design has been made and the project is on schedule for start-up in April 2014.

In typical fashion for a facility of this nature, the design effort was initiated with discussions focused on the determining the specific analytical functions that would be housed and performed in the hot cells. Identifying this information would determine the cell configuration and design features. Although elements of the desired analytical functions were known, the details of the specific operations were not completely established. There were many potential users contributing to the discussion, all with good ideas on the analytical mission of the facility. However, resolving the requests from the various individuals and organizations consumed time and a timely path to closure was not expected. This situation confounded equipment identification and selection process, typically a precursor to design of the physical facility configuration.

To advance the design and maintain the start-up target, a new paradigm was proposed. Specifically, focus the design effort on increasing the operational flexibility of the facility rather than on equipment specific configurations. The design team determined that a value engineering study was the appropriate vehicle to document this shift in design strategy. The Value Engineering Study (VES) was completed in early 2012. It established important design criteria, proposed design alternatives to meet the criteria, evaluated the alternatives, and identified the preferred design option. The results of the VES included:

1. Simplified linear layout,
2. Retention of two heavily shielded hot cells for receiving and machining operations,
3. Elimination of separate lightly shielded analytical cells in favor of a single, canyon hot cell,

The design solution improves the usefulness of the available space in the Tandem Accelerator Building, improves the flexibility of the space housed in the hot cells, allows for modification of the hot cell space to accommodate future mission shifts, and reduces the facility costs.

As a result of the VES, key decisions have been made that have allowed the design effort to rapidly advance. To date, the general arrangements and mechanical details of the hot cells have been developed and incorporated into an effective and efficient facility layout solution. The layout provides efficient and user friendly space for operations personnel while maximizing the flexibility of the hot cell volume. The facility will meet present and future mission needs.

1. Introduction

The initial design concept for the McMaster PIE shielded facility was presented at last year's HotLab2011 conference. During the past year, further design decisions have been made which

have been implemented to advance and refine the facility design. This paper presents those design considerations and current status of the project.

2. Initial Conceptual Design

The initial hot cell layout consisted of an “L” shaped configuration with the receiving and machining cells located along one wall in McMaster University’s Tandem Accelerator Building (TAB). The initial concept incorporated various operational needs and requirements. Although these criteria were met, the layout was not efficient and marginally functional. The initial hot cell layout is briefly described below.

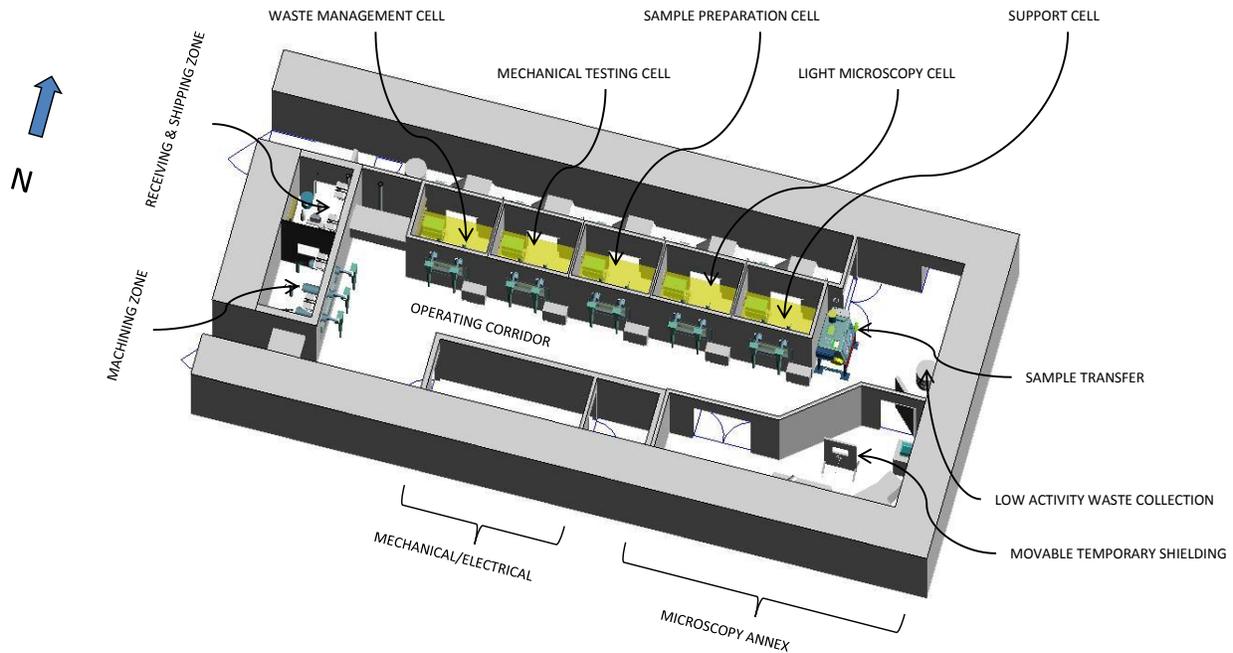


Figure 1. McMaster University PIE Cells, Original Overall Arrangement

2.1 Hot Cell Layout

Since large sections of the CANDU pressure tubes (zircaloy 4, 50 cm long and 104 mm diameter, weighing approximately 10kg each) were handled in these cells, the shield walls were significantly thick, approximately 53 cm. A short, shielded tunnel connected the machining cell to the series of analytical cells oriented in an east-west direction on the northern portion of the room. The tunnel served to transfer samples and waste materials from the machining cell to the waste management and down-stream analytical cells. The cell volume in the corner of the “L,” is difficult to directly access and was of limited use. Since this area could not be accessed directly by an operator, it required remote material handling apparatus with video systems to conduct and monitor operations.

Down-stream of the shielded transfer tunnel, hot cell areas were provided space for waste management, mechanical testing, sample preparation, light microscopy, and miscellaneous support operations, respectively. These cells were separated by interior shield walls creating five separate work volumes. Although small sections of the pressure tube were removed from

the received sample, the shield walls were still on the order of 43 cm thick. This resulted in relatively small working space in each of the separate cell areas. Further, the overall foot-print for the complete hot cell assembly was relatively large, consuming a significant space in the room, and presented a challenge to efficient layout for operations. Further, the design required a significant amount of material for construction of the hot cells, six shielded windows, thirteen master-slave manipulators, a shielded tunnel, large quantities of steel for the shield walls (exterior and interior), multiple exhaust connections and associated filter systems, etc.

2.2 Room layout

The Electron Microscope Annex was located in the south-east corner of the room, and housed a scanning electron microscope/focused ion beam and a transmission electron microscope. The annex also contained a small glovebox for receiving microscopy samples. These samples were transferred from the sample preparation cell via a pneumatic transfer system, also located in the annex.

On the south wall of the room, directly opposite the operator stations for the analytical hot cells, was located two distinct rooms that supported the mission and operations, first, an equipment room housed electrical and ventilation systems for the hot cells, and second, an archive room for storage of previously examined samples. Being located opposite the hot cells, these rooms limit the available operator area and potentially interfere with hot cell operations and maintenance. Additionally, the layout limits the movement and use of the overhead crane currently located in the room.

2.3 Challenges

As the design effort advanced, additional challenges were encountered. Although elements of the desired analytical functions were known, the details of the specific operations were not completely established. There were many potential users contributing to the discussion, all with good ideas on the analytical mission of the facility. However, resolving the requests from the various individuals and organizations consumed time and a timely path to closure was not expected. This situation confounded equipment identification and selection process, typically a precursor to design of the physical facility configuration. Further, a shipping flask, in which the sections of pressure tubes would be delivered to the facility, had not yet been specified and geometries of the interface between the flask and the receiving cell were not available.

3. Advancing the Design Solution

In typical design approach for a facility of this nature, the effort is initiated with discussions focused on the determining the specific analytical functions that would be housed and performed in the hot cells. Identifying this information would determine the cell configuration and design features. Lacking this specific information, a new paradigm was proposed to advance the design and maintain the start-up date target. Specifically, the design team decided to focus the design effort on increasing the operational flexibility of the facility rather than on equipment specific configurations. This approach relieves limitations imposed by designing around specific equipment items and allows the owner/operator to change the analytical mission and upgrade equipment in the future.

3.1 Value Engineering Study (VES)

The design team determined that a VES was the appropriate vehicle to document this shift in design strategy. The VES was completed in early 2012. In the process of developing the VES, the available mission information was evaluated, missing information was considered, and the space available in the room was assessed. The VES established important design criteria and developed various layout options to meet these needs and accommodate the space limitations.

The VES also included a relative comparison of costs for the various design options. Based on the evaluation, a preferred design option was identified. The results of the VES included;

1. Simplified linear layout,
2. Retention of two heavily shielded hot cells for receiving and machining operations,
3. Elimination of separate analytical cells in favor of a single, canyon hot cell.

The preferred design option is described in additional detail below.

3.2 Details of the preferred (revised) hot cell configuration

The arrangement and layout of the hot cells has been changed for the initial "L" shape to a linear configuration and the original seven hot cell volumes have been reduced to three. The operations planned in the hot cells and the spaces themselves have been adjusted to improve the layout, material flow, operational efficiency, and space utilization. The receiving and machining cells are now in-line with the analytical hot cell and the tunnel has been eliminated. Further, the five analytical hot cell spaces have been combined into a single, large hot cell (referred to as a canyon).

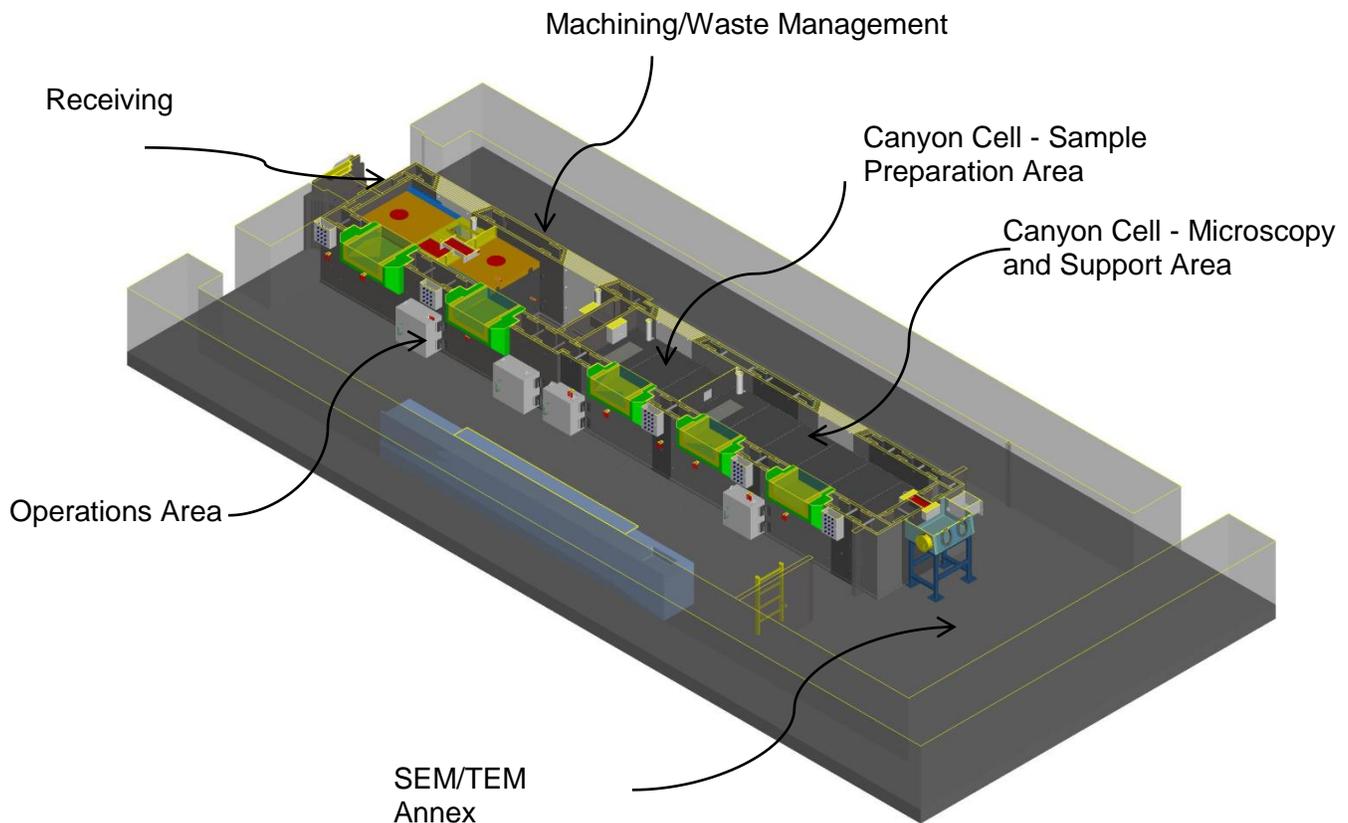


Figure 2. McMaster University PIE Cells, Revised Arrangement

The receiving and machining cells retain a majority of their original design configuration, but have been reoriented from parallel and adjacent the west wall to perpendicular and connected

to the west wall. Since large sections of the received pressure tubes will be handled in these cells, the radiation source term will be significant and the cell walls will be heavily shielded.

The receiving cell is located at the west end of the room, immediately adjacent to the boundary wall for the room. The shipping flask is brought into the transfer position in the hallway outside of the room and is engaged into a transfer penetration located in the wall. The sample pressure tube section is moved into the receiving cell using a manual push-pull apparatus. Shield doors and stepped interface surfaces have been employed to eliminate radiation shine paths during this operation. The receiving cell will be equipped with an overhead hoist for handling the drawer lid from the shipping flask and two CRL Model G manipulators to move the pressure tube.

The machining cell is located immediately to the east of the receiving cell. This cell is separated from the receiving cell by a thin partition wall with a double door pass-through to reduce contamination migration from the machining to receiving. The machining cell will house a lathe and tensile testing apparatus. The full pressure tube section will be moved to this cell where analytical samples will be removed and cut to the appropriate size and shape for testing. This cell will be equipped with CRL Model E-HD manipulators to provide extended reach (to the floor of the cell) and to manage potentially heavier lifts. An overhead crane will also be included in this cell to support maintenance operations and to lift shield plug from the waste drum vestibule.

The waste management function and design features have been incorporated into the machining cell. A large volume of waste from hot cell operations will be generated in the machining area, so incorporating the waste management function into this area provides obvious operations and maintenance benefit. Further, this approach eliminates one of the down-stream cell areas from the original design layout. A shielded vestibule has been incorporated into the rear of the cell into which the waste drum will be moved. To reduce the size of the waste drum vestibule, a 15 gallon waste drum was selected (rather than the typical 55 gallon drum). A shield door on the top of the vestibule will be lifted to access the interior of the waste drum. Once the cell waste is placed into the drum, the shield plug returned to position and the drum can be removed for disposal.

Continuing to the east, a full shield wall with a shielded, double door pass-through separates the machining cell from the analytical cell. The shield wall allows simultaneous operations to occur in the machining and analytical areas. As mentioned above, the interior shield walls that separated the analytical spaces in the original layout have been eliminated. This creates a large, continuous cell space allowing maximum operational flexibility while reducing the amount of shielding material needed for construction. Three work stations, each with a pair of CRL Model G manipulators, are located along the length of the analytical canyon. A removable, configurable work surface is provided to support and allow easy access to the analytical apparatus. Overhead cranes are provided in the analytical canyon to facilitate operations and maintenance.

The first work station has been designated for preparation of microscopy samples. It will house grinding / polishing equipment, which has the potential to generate moist sprays and particulate during operation. To reduce the potential of contaminating the remaining canyon work stations, a thin partition wall has been included in the design. This wall will include a door used to move samples in both directions.

The second work station will be used for in-cell microscopy equipment. The third station will be for miscellaneous support operations. A shielded, double door pass-through will be located at

the east wall of the canyon for transfer of samples to and from the SEM/TEM Annex. A glovebox will be located outside this pass-through to facilitate sample removal and introduction while maintaining radiological dose limits.

These adjustments to the layout have reduced the overall foot-print without sacrificing working volume within the hot cell.

3.3 General cell features

In addition to the adjustments to the hot cell layout described above, several other changes were made to improve the design and reduce construction costs. These features of the facility design are briefly discussed below,

- **Shield wall construction.** The shield walls for the hot cells will be composite design, two inches of steel plate on the interior and exterior surfaces of the wall filled with the appropriate thickness of high density concrete. The steel walls are built as modular sections in the fabricator's shop and are shipped to the McMaster facility in sections. The size of the wall modules is such that they can be easily handled with the overhead crane currently installed in the Room. Once installed, secured, and assembled, the steel walls serves as forms for the concrete which is poured into the walls. This approach to design and installation significantly reduces the amount of steel required for wall construction, which in-turn reduces the capital cost of the facility.
- **Roof access.** The original design included shielded access ports on the roof for use in equipment installation and maintenance operations. As the design has advanced, it was determined that these ports do not provide the level of functionality and benefit originally anticipated. They have been removed from the design, reducing fabrication and installation complexity.
- **Hot cell lighting.** The lighting for the hot cells has been moved inside the cells. The original design included recesses in the roof shielding where lighting windows were located. A light fixture was place on these window out-side the cell to provide area lighting inside the cells. A thick steel panel was then placed over the recess to provide the necessary shielding. The revised concept is to locate the lighting fixtures inside the cells. This provides the ability to focus the lighting more directly on the subject work area while reducing the complexity of the hot cell roof design.
- **In-cell Electrical.** To maximize operational flexibility, generic electrical service will be provided inside the cells. A variety of 110V and 220V outlets will be located periodically around the interior of the hot cells. They are situated for easy access by the manipulators and to allow convenient placement of the connected equipment. A switch panel will be located outside the cells at each of the five operator stations that allowing individual outlets in the cell to be energized as required.
- **Work surfaces.** Removable work surfaces will be installed in the cells to support equipment and facilitate operations. These surfaces are supported by brackets that are attached to the interior perimeters of the cell walls at appropriate heights. Alignment pins will be provided on the work surface at regular locations to interface and position separate equipment mounting plates. As necessary, equipment will be secured to the mounting plates at orientations that are convenient for operations. The mounting plates can be customized for the equipment being installed in the cells providing maximum flexibility in equipment selection and operations interface. The mounting plates can then be installed on the pre-positioned alignment pins and secured to the work surface. If necessary for maintenance or manned access to the hot cells, the mounting plates and sections of the work surface can be moved using the in-cell, overhead hoist.

- Exhaust ventilation. Reducing the number of individual cells reduces the number of exhaust connections and required HEPA filters. This lowers the capital and maintenance costs and relieves congestion in the maintenance corridor at the rear of the hot cells.
- Maintenance Access. To facilitate equipment installation, change out, and periodic maintenance, access doors will be provided in the rear of the cells. Reducing the number of hot cells has eliminated two access doors. Again, this lowers the capital cost of the facility and relieves congestion in the access corridor.
- Source Term. The design team and facility owner continue to scrutinize the source term to understand the impact to operations and shielding requirements. At this time, a decision has been made to locate the tensile testing apparatus in the machining hot cell. Tensile testing requires a relatively large section of the irradiated pressure tube. Locating this operation in the machining cell, which is already heavily shielded, reduces the source term and associated shielding requirements in the down-stream analytical hot cells. Although the shielding analysis for this change has not yet been completed, the design team anticipates a reduction in shielding requirements which will directly lower construction materials and associated capital costs.

3.4 Room 105 features

In addition design changes being implemented for the hot cells, a couple of significant changes have been made to the layout of the room.

First, the acid etching and surface preparation process for the microscopic samples has been moved to a small, shielded glovebox outside the hot cell. This move eliminates the use of hydrofluoric acid in the hot cells which can damage the interior surfaces of the hot cell windows. The hot cell windows are significant contributors to the capital cost for the facility and need to be protected from acid etching.

Second, the location of the SEM/TEM annex has been shifted to the east end of the room. The wall separating the annex from the hot cell operations area aligns with the east end of the hot cell assembly. This relocation provides larger footprint and greater functionality for the annex.

4. Results

The design solution improves the usefulness of the available space in the Tandem Accelerator Building, improves the flexibility of the space housed in the hot cells, allows for modification of the hot cell space to accommodate future mission shifts, and reduces the facility costs. The layout provides efficient and user friendly space for operations personnel while maximizing the flexibility of the hot cell volume.

As a result of the VES, key decisions have been made that have allowed the design effort to rapidly advance. To date, the general arrangements and mechanical details of the hot cells have been developed and incorporated into an elegant facility layout solution. The detailed design has advanced to a level of 60% completion and is being integrated by the architectural contractor into an overall facility modification plan. Potential fabricator firms have been engaged to prepare detailed capital cost estimates and initiate construction planning. Further, McMaster University is ready to initiate discussions with Canadian Permitting and Licensing organizations to secure approval of a modified operating license for the TAB.