Shield Plug-Mounted Hot Cell Manipulator

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PaR Systems provided a standard M3000 Manipulator system to Oak Ridge National Laboratory in 1964.

For use in the Radiochemical Engineering Development Center (REDC) at ORNL:

- One of the missions of REDC is production of radioisotopes for industry and research.
- REDC produces more than 70% of the world’s supply of $^{252}\text{Cf}$.

Radiation levels require that operations and maintenance performed inside the hot cells must be done remotely.
Typical PaR M3000 Manipulator System

▲ Consists of:
  – Bridge (long travel)
  – Trolley (cross travel)
  – Telescoping Mast (vertical travel)
  – Shoulder Rotate
  – Manipulator Arm
  – Interchangeable Grippers
  – Power Center
  – Controller

▲ Hundreds of M3000’s in service in hot cells worldwide
▲ Some in service for 50+ years
▲ Manipulator arm design has remained virtually unchanged since its introduction
Standard bridge and trolley-based system

The system that got installed was designed for hands-on maintenance and not intended for use in a hot cell or maintaining remotely

A drive failure occurred in 2008 which limited the usage of the system

A workable solution (repair or replacement) was not identified in terms of cost, contamination or potential personnel exposure

Significant challenges:
- Installation through shield plug with minimal worker exposure
- Remote connection of cables once new system is in cell
Original Manipulator System in Cell

▲ View of bridge, trolley and mast looking down through the shield plug opening.

▲ Photo taken during hot cell construction in 1964.
Original Manipulator System in Hot Cell

M3000 Arm in hot cell
ORNL asked PaR if we could design a ceiling-mounted system that would not require removal of the existing system.

New system would have equivalent functionality, capacity and in-cell coverage.

The proposed system would mount to a new 6’ x 10’ x 5’ thick shield plug in the cell ceiling.

Installation would be accomplished by simply replacing the original shield plug for a new one with the manipulator attached.

Required ORNL to design a new shield plug with provision for manipulator mounting and cable runs.
Shield Plug From Above the Hot Cell
Collaborative Design Process

▲ ORNL provided PaR with an accurate SolidWorks model of the cell and shield plug

▲ ORNL developed a rough concept of the new system along with system requirements

▲ PaR, with input from ORNL refined the concept and provided detail design, fabrication and testing

▲ Common SolidWorks platform made for effective design evaluation of interfaces
New Shield Plug-Mounted Design

▲ A 360 degree rotating turret attaches to the bottom of the new shield plug

▲ A two-stage horizontally extending boom with 8’6” reach is mounted to the rotating turret
New Shield Plug-Mounted Design

- A telescoping mast with 14’ vertical travel is attached to the boom
- A PaR M3000 manipulator with seven degrees of freedom is attached to the bottom of the mast
New Shield Plug-Mounted Design

Manipulator with joints in position for installation and removal
New ORNL Shield Plug in PaR’s Factory
Completed System in PaR’s Factory

▲ Shield plug was shipped to PaR for fit-up and testing

▲ Successful factory acceptance testing was completed in Fall 2013

▲ System is at ORNL and will be installed at a time convenient to REDC operations and production scheduling
Important System Features

▲ Turret rotate, boom extension, mast and manipulator pivot joints have recovery features to allow positioning of axes for retrieval or maintenance

▲ The shield plug contains access ports long-handed tools to attach to the recovery hex drives

▲ All components radiation hardened to last a minimum of 30 years

▲ Provision for CCTV cameras mounted to the manipulator arm

▲ Remotely detachable grippers
Manipulator Control Console

- Robust, simple and intuitive controls interface
- All axes are variable speed from 0 – maximum speed
- Finger switches are spring return
- Can move one or more axes at a time
- Portable console – can be moved from window to window
Installation at ORNL

- The ORNL/PaR team designed a fixture to support the manipulator system and shield plug.
- Manipulator system will be placed on the stand and jacked up to mate with threaded studs on the shield plug.
Installation Sequence

Manipulator system will be lowered onto the stand plug using a high capacity building crane above the cell.
Installation Sequence

▲ Shield plug is lowered onto the stand

▲ Gap between plug and turret mounting flange will allow for electrical connections to be made between the manipulator and shield plug
Installation Sequence

- Manipulator is raised up to the bottom of the shield plug via hydraulic jacks
- Mechanical connections are made
- Shield plug-manipulator assembly is lowered into the opening
- Out-cell electrical connections are made
Installation Sequence

▲ Site testing to be performed in a cold cell, Cell E

▲ Following complete site testing, system will be installed in Cell G
Summary

- Plug-mounted manipulator system solved a challenging replacement problem for ORNL
- Collaborative effort between ORNL and PaR resulted in no interface issues between shield plug and manipulator mount
- Similar systems could be implemented in other hot cells with shield plugs where enhanced or replacement remote handling systems are required
- Free exchange of SolidWorks models was instrumental in the design process
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Questions