DEVELOPMENT OF A FUEL TRANSFER CASK AT THE UNIVERSITY OF TEXAS TRIGA REACTOR

Replacement of a beam port bellows at the University of Texas TRIGA reactor in 2015 required removal of all fuel from the reactor pool. Fuel transfer at the facility historically used a TRIGA transfer cask built for BMI shipping cask operations. The transfer cask has minimal shielding, and cannot be approached when loaded. Controlling personnel exposure during fuel element transfer to and from the pool requires that people seek shadow shielding (like structural columns), install temporary block walls, and work from scaffolding. The transfer cask configuration requires elements be suspended in air during transit to and from the cask. Interference between the fuel tool and rigging requires the rigging be partially detached from the crane, providing multiple chances for equipment damage. A large staff is required. A strategy was initiated for development of a better cask integrated in bellows replacement scheduling to address these issues:

1. General Design Objectives
2. Conceptual and Engineering design
3. Contracting and Fabrication
4. Final Assembly
5. Testing
6. Implementation

GENERAL DESIGN OBJECTIVES

Integration in the bellows repair schedule was the fundamental criterion; if the program could not be completed prior to reload, then a new cask was not viable. Radiation levels from the new cask must permit extended time near the cask. Rigging clearances should allow operating the fuel tool with the cask suspended. The cask should be capable of top and bottom transfers. Cask weight limit was set at 5000 lbs., within normal capacity of available pallet jacks.

CONCEPTUAL AND ENGINEERING DESIGN

The use of commercial off the shelf materials was important for the timeline. Initial concepts used plate steel, assuming large bore pipe requires manufacturing. However, pipe up to about 4 ft diameter can be provided on demand. A cylindrical design with bottom load/unload capability was completed using Solidworks, with a 302% safety factor based on the weight of solid lead.

CONTRACTING AND FABRICATION

The design for the basic cask structure was provided to Domatex, Inc., (a Houston based recycling design and fabrication shop) for time and cost estimates. Domatex and staff collaborated on minor design changes resulting in an estimated delivery on site less than 7 days at acceptable cost. The designs for top shield plugs and bottom “drawers” (fabricated as stainless steel shells) were contracted locally.

Final Assembly

The cask shell was acquired. Fuel transfer cask assembly required finishing drawers, top plugs, and liner and also evaluation of potential shielding material. After installation of shielding, lead surfaces were sealed.

Shielding

A source term was developed in SCALE by depletion calculations for TRIGA fuel element at 10 MWD (approximately 25% reduction in ^{235}U) and 1-week decay. The source term was used in MCNP to evaluate shielding effectiveness. Solid lead, lead shot and a "nuclear grade" concrete mix were evaluated.

Lead was the most effective shielding. Lead foundries have been phased out, but specialty vendors can process lead for shielding in a difficult and hazardous process. Cost is high and scheduling not within acceptable range. Lead shot has about 70% of lead density, and lead reclamation is an active industry. High density concrete used for reactor shielding was considered. Radiation levels were acceptable but high, and processing requirements challenged the schedule. Therefore lead shot was chosen.

Top Plugs, Drawers, and Liner

Bottom drawer and top plug shield containers were manufactured locally. Stainless steel tubing was acquired to line fuel spaces so that the fuel elements would not contact and potentially chip the coating. The top of the stainless steel liners were expanded to accommodate top shield plugs. Mechanisms were installed to constrain the drawers and prevent accidental removal.

Machining/Processing for Fit

Drawers were designed for a fit tolerance of approximately 1/8 in., and suffered distortion from welding processes. Surface straightness was not specified for internal surfaces of the aperture. The drawers did not fit within the cask structure as built, and surfaces were ground to acceptable fit.

Lead shot was poured into the containers and heated to melt. Processing was located outside, using oxy-acetylene. Temperature was monitored with a thermal camera to assure adequate margin to prevent vaporization.

Fuel element bottom fins rest on a chamfered hole and depression in the shielding of the bottom drawer. This chamfer was machined on site after the lead melt was accomplished. Melting the lead distorted the container, requiring milling surfaces to fit.

Seal

The space between the reactor pool wall and surrounding concrete is sealed with a commercial polymeric material. The same type of material was used to seal all lead surfaces and stabilize bulk shielding in the cask.

TESTING

Testing was conducted in two phases, starting with trials with the cask shell as a feasibility test and sanity check prior to ordering lead shot. Tests demonstrated handling and camera-guided manipulation was possible. After shielding was installed, field testing was performed with irradiated fuel using the assembled cask with camera support. This proved frustrating, and two additional process modifications created a relatively seamless process. A guide tube was developed to select specific elements, and a centering-guide was fabricated to assist tool movement into the cask.

IMPLEMENTATION

Defueling operations required three people pool-side (two using the fuel tool, one for rigging), two on scaffolding, one on the reactor bay floor and radiation protection personnel (because of high dose rates). Outside dose rates were monitored by the national defense 6th Civil Support Team (CST6) during defueling and refueling. The average dose rate at a monitoring point adjacent to the reactor bay during defueling on 8/20/2015 was 663 μR/h.

On Oct. 22 field testing using the new cask began, with completion of refueling Nov 11, 2015. Based on reduced manpower requirements for the new transfer cask, refueling was removed from the critical path to restored operability and coordinated around other tasks. Scaffolding was not used. With the cask was suspended in the pool, vulnerabilities associated with tensioning rigging near the core was avoided and there was no potential for tipping the transfer cask both in and out of the pool. Bottom loading reduced dose rates in the reactor bay and minimized potential for a dropped element. Dose rates at the CST6 monitoring point were indistinguishable from background during refueling operations. About 20% of the dose commitment with the new cask was accumulated during field testing. A comparison of important data for defueling and refueling operations is provided in Table 1.

Table 1: Comparison Fuel Transfer to Storage and Core Reload

Category	Units	BTB[1]	BOT-C[2]
Radiation Protection			
Total exposure	mrem	669	186
Maximally exposed worker	mrem	219	72
Dose rates (cask surface)	mrem/h	Est 500K	3.6-135
Dose Rates (bay)	mrem/h	35 (20’)	4-40 (6”)
Max Dose Rate (outside)	mrem/h	8.7	Bkg
Process			
Required Staffing	Persons	7	2
Required fuel tools	No.	2	1
Time per element	Minutes	8.3	<2.5

SUMMARY, CONCLUSION, AND LESSONS LEARNED

The process improvement reduced personnel exposure, personnel hazard, and equipment damage. Coordination with the bellows replacement schedule provided opportunities to secure the program if it interfered with the master schedule or exceeded cost expectations. Unanticipated difficulties and problems were overcome by creative approaches. Aspects that might benefit from experience:

Drawer Issues

- A design revision during fabrication removed a drawer stop, not identified in review and required compensation.

[1] BMI Transfer Cask/Basket
[2] Bevo Orange Transfer Cask

- If the top and bottom shield/containers had the same fabricator, fit could have been assured with less on site effort.
- Solid stainless steel plugs and drawers would probably have been more cost effective an required less on site effort

Cask Storage Well Issues

- Tubing used to make fuel spaces was not seamless, and had to be ground. The stainless steel liners were very difficult to expand. The need for the liners was identified after the design had been commissioned,
- The use of seamless stainless steel tubing for the wells would have mitigated problems.
- Pitch was set before rigging was specified; acceptable commercial rigging required less clearance and pitch could have been optimized for shielding.

Drain Issues

- There was not enough lead shot to raise the sealant surface to the top of the stainless steel liner, and drains had to be cut.
- The volume of trapped water in the drawer depression is low, but there are no drains.

Long Term

- The lead shot may settle (causing the polymer seal to dimple) and may require more shot.

Finish

- Expensive finish
- Tore it up multiple times
- Should have put a primer on it

Overall Issues

- Crane access to one set of wells
- Pool access/clearance
- The Safety analysis report does not contain any information about the fuel handling cask
- Facility procedures do not reference fuel handling cask