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Feasibility Study for Use of Commercial Cask Vendor Dry Transfer Systems to Unload Used Fuel Assemblies in L-Area

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EXECUTIVE SUMMARY

The purpose of this study is to determine whether a commercial dry transfer system (DTS) could be used for loading or unloading used nuclear fuel (UNF) in L-Basin and to determine if a DTS pool adapter could be made for L-Basin Transfer Pit #2 that could accommodate a variety of DTS casks and fuel baskets or canisters up to 24" diameter.[1, 2] This study outlines the technical feasibility of accommodating different vendor dry transfer systems in the L-Basin Transfer Bay with a general work scope. It identifies equipment needing development, facility modifications, and describes the needed analyses and calculations.

After reviewing the L-Basin Transfer Bay area layout and information on the only DTS system currently in use for the Nuclear Assurance Corporation Legal Weight Truck cask (NAC LWT), the authors conclude that use of a dry transfer cask is feasible. AREVA was contacted and acknowledged that they currently do not have a design for a dry transfer cask for their new Transnuclear Long Cask (TN-LC) cask. Nonetheless, this study accounted for a potential future DTS from AREVA to handle fuel baskets up to 18" in diameter. Due to the layout of the Transfer Bay, it was determined that a DTS cask pool adapter designed specifically for spanning Pit #2 and placed just north of the 70 Ton Cask lid lifting superstructure would be needed. The proposed pool adapter could be used to transition a fuel basket up to 24" in diameter and ~11 feet long from a dry transfer cask to the basin. The 18" and 24" applications of the pool adapter are pending vendor development of dry transfer casks that accommodate these diameters. Once a fuel basket has been lowered into Pit #2 through a pool adapter, a basket cart could be used to move the basket out from under the pool adapter for access by the 5 Ton Crane.

The cost to install a dry transfer cask handling system in L-Area capable of handling multiple vendor provided transport and dry transfer casks and baskets with different diameters and lengths would likely be on the same order of magnitude as the Basin Modifications project. The cost of a DTS capability is affected by the number of design variations of different vendor transport and dry transfer casks to be considered for design input. Some costs would be incurred for each vendor DTS to be handled. For example, separate analyses would be needed for each dry transfer cask type such as criticality, shielding, dropping a dry transfer cask and basket, handling and auxiliary equipment, procedures, operator training, readiness assessments, and operational readiness reviews.

A DTS handling capability in L-Area could serve as a backup to the Shielded Transfer System (STS) for unloading long casks and could support potential future missions such as the Idaho National Laboratory (INL) Exchange or transferring UNF from wet to dry storage.

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ARMS	Area Radiation Monitor System
BTH	Below the Hook
CHA	Consolidated Hazards Analysis
CHAP	Consolidated Hazards Analysis Process
DCA	Double Contingency Analysis
DOT	Department of Transportation
DSA	Documented Safety Analysis
DTS	Dry Transfer System
ID	Inner Diameter
INL	Idaho National Laboratory
ISO	International Standards Organization
LWT	Legal Weight Truck cask
NAC	Nuclear Assurance Corporation
NCSE	Nuclear Criticality Safety Evaluation
NIM	Nuclear Incident Monitor
NRU	National Research Universal Nuclear Reactor
NRX	National Research Experimental Nuclear Reactor
ORR	Operational Readiness Review
RA	Readiness Assessment
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
STS	Shielded Transfer System
TN-LC	Transnuclear Long Cask
TSR	Technical Safety Requirement
UNF	Used Nuclear Fuel

1.0 INTRODUCTION

This report was prepared by the Savannah River National Laboratory (SRNL) and Savannah River Nuclear Solutions (SRNS) at the request of the National Nuclear Security Administration. This feasibility study identifies the scope of work necessary to install and operate a Dry Transfer System (DTS) in the L-Area transfer bay capable of handling different vendor DTS designs. The approach taken was that the DTS capability would not interfere or require modification to other operating cask handling structures or equipment like the 70 Ton Cask lid lifting superstructure, 5 Ton Crane, or the Shielded Transfer System (STS). The system would be capable of handling a range of vendor dry transfer casks with fuel baskets and/or canisters ranging from ~13” to 24” diameter. The fuel basket length evaluated in this study is 10.5’ (e.g. NRU/NRX basket). It may be possible to handle longer baskets, but shielding calculations must be performed for the specific fuel to determine the maximum length that could be unloaded into the basin and still maintain enough submerged depth for adequate shielding. This study considered making the fuel transfer from the transport cask to the dry transfer cask both inside and outside of the 105-L structure. The transfer can be done in either location; however, doing so inside the robust structure of the transfer bay offers specific Safety Basis advantages. Performing dry transfers outside the building structure has advantages if the L-basin UNF inventory needed to be transferred from wet to dry storage. In this case, a dry transfer cask could be used to move fuel canisters out of the building for placement into a very large dry storage package that is on a pad outside the building. A significant amount of analysis was completed on this subject by SRNL in 2012 as part of the *Back End Fuel Cycle Demonstration* [7]. Use of a DTS outside of 105-L is discussed in section 9.0 of this study; however, because of the aforementioned report, this study focused on performing DTS operations inside the transfer bay.

The scope of this study will include assessment of Dry Transfer Systems to:

1. Provide for the use of a DTS inside 105-L.
2. Identify DTS safety basis requirements.
3. Identify facility equipment limits and physical layout for consideration in the handling and placement of a DTS and support equipment.
4. Identify potential facility modifications needed to support DTS operations.
5. Provide for a pool adapter capable of handling a DTS with baskets or canisters ranging from ~13” to 24” diameter and 10.5’ in length (with potential for handling of longer fuel with additional shielding calculations).
6. Provide cost considerations for adding a DTS capability to L-Area

Background: Irradiated Used Nuclear Fuel (UNF) is managed by the Savannah River Site (SRS) Spent Fuel Project. These items are stored in a water-filled basin located in L-Area. The Project provides receipt and storage capabilities to support United States nuclear nonproliferation objectives, including the management of used domestic and foreign research reactor fuels that contain fissile isotopes or other radioactive species that must be protected from diversion.

At present, L-Basin has two primary means of unloading irradiated UNF from a Type B transport cask, one is by placing a cask directly into the transfer bay Pit #2 for unloading underwater, and the other is to use the Shielded Transfer System (STS) for dry unloading of casks that are too tall to be unloaded underwater. The STS is a permanently installed Dry Transfer System (DTS). The STS is currently in use but limited to unloading NAC LWT fuel baskets that are < 13.375” in diameter and up to 44” tall. Modifications are currently in progress to make the system capable of handling a basket ~ 125.5” in length. The addition of a DTS capability would provide additional future operational flexibility to support unloading of more than one type of long cask, (i.e., the NAC-LWT and the new TN-LC); Figure 1-1 illustrates two long fuel casks. The DTS would have the same Safety Significant functions as the STS. The DTS could also support transfers of SRS non-Al fuel to INL by providing a capability to load long canisters that are > 13” in diameter containing damaged non-Al fuel into a transportation cask. A DTS may also be capable of removing loaded UNF baskets or canisters up to 24” in diameter from the basin should the L-Basin UNF inventory need to be transferred from wet to dry storage in the future.

- LWT Dimensions
  - Cask Body
    - 43,412 lbs
    - 199” (16.5’) long
    - 44.24” max diameter
  - Cask Cavity
    - 178” (14.75’) long (usable)
    - 13.375” diameter
- TN-LC Dimensions
  - Cask Body
    - 51,000 lbs
    - 197.5” (16.45’) long
    - 44.24” max diameter
  - Cask Cavity
    - 182.5” (15.2’) long (usable)
    - 18.0” diameter

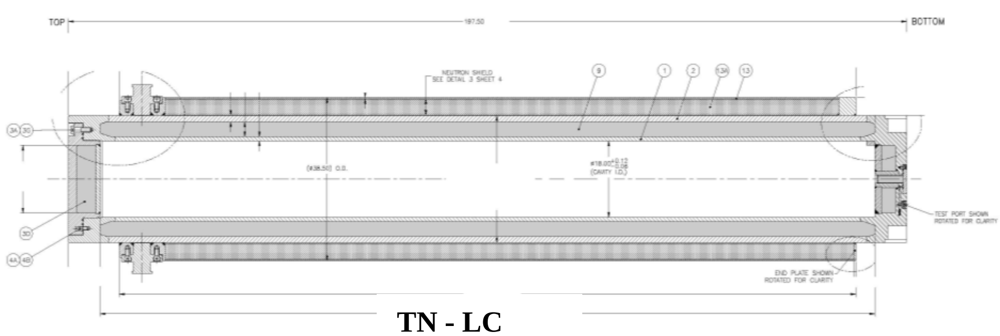

Figure 1-1: Long Fuel Shipping Cask Examples

2.0 FACILITY AND OPERATIONAL DESCRIPTION

Building 105-L in the L-Area at the Savannah River Site contained one of the five operating production reactors at the Savannah River Site. Reactor operations were shut down in the late 1980s. Since that time the used fuel basin in Building 105-L has been used to store legacy used fuel from past onsite reactor operations. In recent years, it began to receive and store used nuclear fuel from offsite research reactors, both domestic and foreign.

L-Area personnel have extensive experience in safely receiving and storing a wide variety of used nuclear fuel assemblies shipped within a wide variety of casks. Since 1996, the L-Area facility has received over 10,000 used fuel assemblies shipped in over 500 casks from offsite sources and has stored the used fuel assemblies underwater in L-Basin. Both high and low enriched uranium fuels have been received in L-Area. Of the hundreds of shipments and transfers received at the L-Area facility, there have been primarily ten different transportation cask types or designs that have been unloaded in the Transfer Bay. Concurrent to the offsite receipts in L-Area, about 360 onsite used fuel cask transfers have been made.

Several photos of the 105-L Transfer Bay Area, where a DTS would be deployed, are shown below. Figure 2-1 shows the above grade portion of the Shielded Transfer System (STS). In the proposed concept, a long shipping cask such as a NAC-LWT or TN-LC cask would be inserted into the dry well of Pit #1, which is below the area in the foreground of Figure 2-1. The dry well is designed to receive a NAC-LWT cask, but a spacer for insertion into the dry well would be designed and constructed for a NAC-LWT or AREVA TN-LC cask in order to raise the top of the cask to a height accessible to a DTS cask adapter.

Figure 2-1: Shielded Transfer System (Over Transfer Pit #1)

Figure 2-2 is a photo of the work area around Transfer Pit #2. Notable in this photo is the crowded nature of the area. There are numerous potential obstructions such as the frame of the 5 Ton Crane, structural steel supporting the monorail, and hand rails surrounding the pit. There is also a 12" tall curb on the east side of Pit #2 making the east pit wall (foreground) higher than the west side floor elevation.

Figure 2-2: View From the East of 105-L Disassembly Area Pit #2 (STS Shield Tube Shown Upper Left)

In addition to the surrounding obstructions, the superstructure that supports the 70 Ton Cask lid is located in the middle of Pit #2 (see Figure 2-3). The 70 Ton Cask is used to transfer used fuel onsite at the SRS. The canal where fuel removed from the DTS carriage would exit Transfer Pit #2 can also be seen and cannot be blocked by the proposed pool adapter.

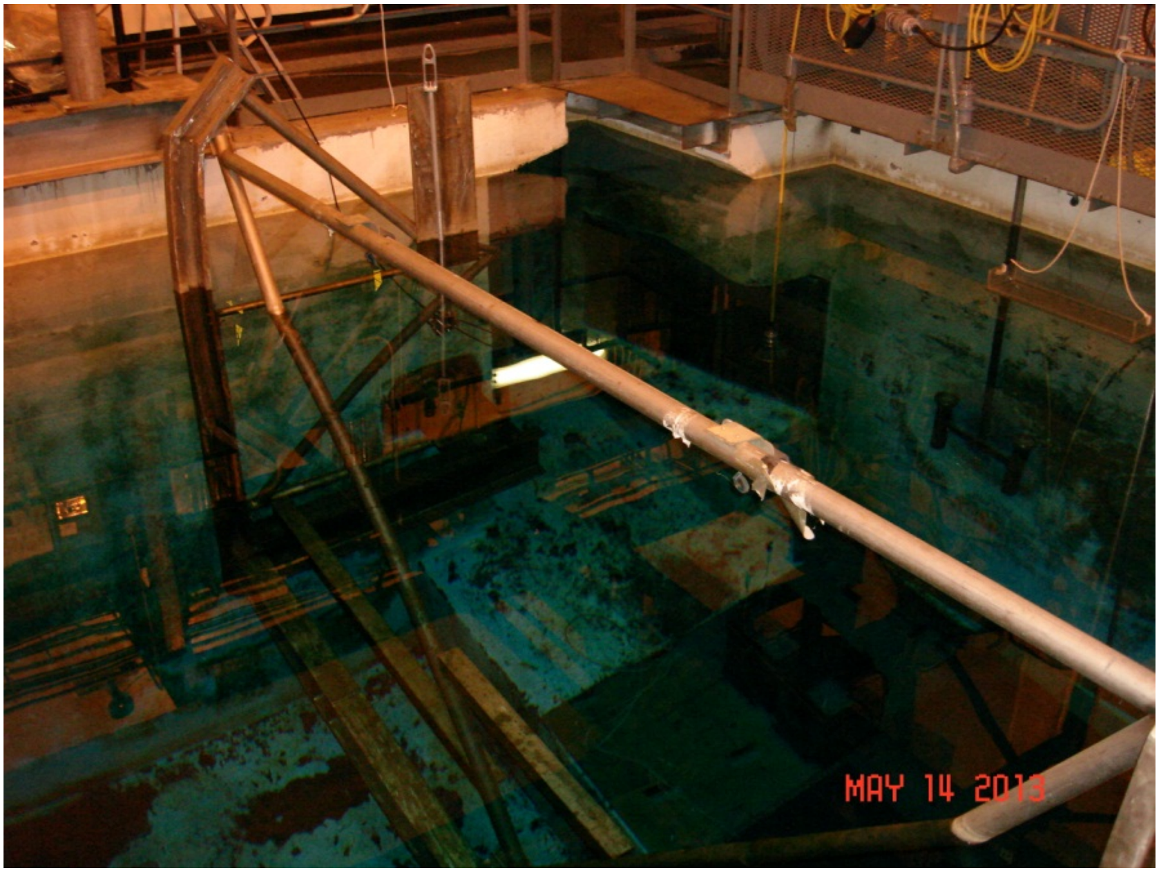

Figure 2-3: Superstructure in Pit #2

3.0 ASSESSMENT OF DRY TRANSFER SYSTEMS

The purpose of this study is to assess the feasibility of using commercially provided Dry Transfer Systems (DTS) in L-Area at the Savannah River Site with the following capabilities:

1. Receive used nuclear fuel in a tall transport cask such as the NAC-LWT or AREVA TN-LC casks.
2. Unload a fuel basket from the transport cask using a DTS cask inside the 105-L building
3. Move the DTS cask with the 85 Ton Crane to a transfer pit pool adapter
4. Transition the fuel basket from the DTS cask to the basin via the pool adapter
5. Access the fuel basket for fuel processing without removing the pool adapter (supports unloading of multiple casks without having to remove the pool adapter to gain access to the fuel basket).

The concept proposed for a pool adapter would include the capability of handling dry transfer casks containing fuel baskets or canisters up to 24” diameter for potential transition of fuel from L-Basin to dry storage or an offsite facility. The different cask designs need to be included as an initial design input.

Typical DTS components used for research reactor Used Nuclear Fuel (UNF) include the following:

1. Dry transfer cask – used to transfer UNF from the spent fuel basin to the transportation cask, see Figure 3-1: NAC DTS on LWT Cask. A dry transfer cask is typically needed because the research reactor facility does not have the physical space or lifting capacity to handle the transportation cask. The dry transfer cask is not licensed for transportation.
2. Transport cask baseplate – the transport cask is removed from its ISO container and mounted in the vertical position on a baseplate outside the facility. The baseplate is on a level surface and the cask is tied down to it for stability during the dry transfer operation.
3. Dry transfer cask basket grapple – the dry transfer cask has an internal grapple that is customized for the particular fuel basket being used. It typically requires a compressed air supply to operate and is attached to the hoist. For transportation cask loading, engagement of the grapple to

Figure 3-1: NAC DTS on LWT Cask

the basket is done visually in the facility fuel pool. For transportation cask unloading, a means of verifying positive engagement of the basket to the DTS grapple inside the cask has not been discussed with the cask vendors.

4. Transport cask shield gate – this shield gate is attached to the transport cask and allows removal of the cask lid and is opened and closed to provide radiation shielding during DTS operations.
5. Dry transfer cask shield gate – this shield gate is built into the DTS and can be opened and closed to allow the loaded fuel basket to transition from the pool into the cask then it is closed to provide radiation shielding while the dry transfer cask is being moved to the transport cask. Once placed on the transport cask, the dry transfer cask shield gate is opened (along with the transport cask shield gate) to allow the loaded fuel basket to be placed into the transport cask.
6. Dry transfer cask dolly or lifting frame – this is used to transition the dry transfer cask in and out of the reactor facility.
7. Reactor pool adapter – the adapter is temporarily installed over the reactor pool and provides radiation shielding for transition of the loaded fuel basket from the water up into the dry transfer cask. The adapter is also a personnel work platform for operation of the dry transfer cask shield gate.

The above list of DTS components describes how these components are used to load fuel baskets from a research reactor spent fuel basin. The next section of this report describes how these same components can be used to unload a shipping cask and transfer fuel baskets to L-Basin. In addition, existing L-Area Transfer Bay structures such as the STS dry well are utilized as much as possible in the proposed approach to minimize modifications to the existing L-Area facility.

4.0 USING A DRY TRANSFER SYSTEM TO TRANSFER FUEL TO 105-L

To assist in evaluating the feasibility of using a DTS for transferring fuel in and out of L-Basin, a 3D model of the L-Basin Transfer Bay was made (see Figure 4-1). NAC is presently developing a longer version of their DTS called a DTS-XL for handling NRU/NRX fuel. A NAC DTS-XL system was included in this model as a “generic” system because it is the only commercial system available for evaluation of the details of loading/ unloading long fuel from a DTS system. This study assumed the DTS-XL would have the same operational features as the current smaller NAC DTS. At the time of this report, NAC had not completed the design of the DTS-XL and only provided overall weight and length information. It was assumed that other vendor dry transfer systems would have the same generic components. Any significant differences between vendor dry transfer systems will likely affect the assumptions and conclusions in this report.

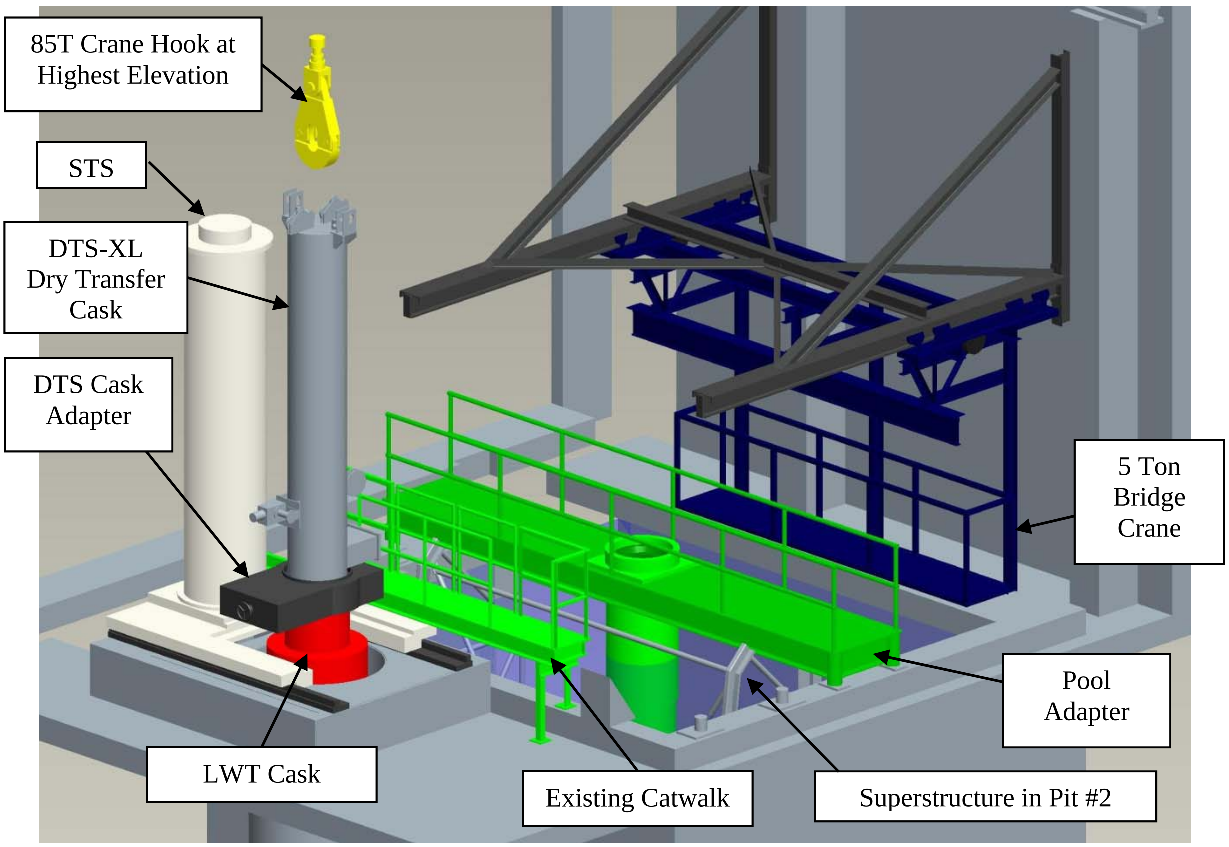

Figure 4-1: 3D Model of Transfer Pit #1 (Under STS Structure) and Pit #2 (Under Pool Adapter)

Use of a Dry Transfer Cask Loading/Unloading System in the primary pit (Pit #2) of the L-Area transfer bay requires an examination of several interferences. The first consideration is the wall mounted cantilever style bridge crane referred to as the 5 Ton Crane. This crane interfaces with the basin monorail system for transporting fuel to the storage basin. The 5 Ton Crane covers a little over half the surface area of Pit #2. The second major consideration is the steel 70 Ton Cask guide/lid frame commonly referred to as the superstructure. The superstructure retains the 70 Ton Cask lid as the cask is lowered along the south wall of Pit #2. It then allows the cask to be positioned in the superstructure open bay near the -17 foot shelf for unloading while the cask remains on the 85 Ton Crane hooks.

The 5 Ton Crane travels in the north/south direction from the north wall of Pit #2 to the open bay area of the superstructure. Past studies have looked at modifying the 5 Ton Crane including changing the orientation of crane travel as well as changing its support structure to cover the entire Pit #2 surface area [3].Each of the proposed changes in the referenced report would require costly modifications to systems in a radioactive contamination area and are considered outside the scope of this study. While a DTS-type system can be used in Pit #2 without any modifications to the 5 Ton Crane structure, the pool adapter bridge must be oriented in an east-west direction to avoid interference with 5 Ton Crane bridge operation.

The presence of the superstructure limits the placement of the pool adapter bridge and access below the adapter. Removing the superstructure would ease the use of a DTS system in the -20 ft section of Pit #2 but has many negative consequences. While the 70 Ton Cask has previously been operated without the superstructure in other SRS facilities, the frequency and consequences of an accident are dramatically increased without the superstructure because such operation requires heavy lifts over fuel. Additionally, such operation requires the 70 Ton Cask to be released from the 85 Ton Crane hooks during fuel handling and then re-engaged by the crane hooks underwater for removal from the basin. This would significantly increase operation time and introduce new risks to be addressed within the safety analyses. The removal of the superstructure itself is a costly endeavor. A design change to remove and reinstall the superstructure as needed to support DTS operation is not practical.

With the superstructure in place, it is not desirable to install the pool adapter bridge south of the superstructure, because the fuel must be rotated out of the vertical orientation to pass under the superstructure and then rotated back to vertical to be accessed by the 5 Ton Crane. The pool adapter bridge cannot be placed over the -17ft level since there are only 51 inches from the shelf edge to the monorail centerline, preventing access below the pool adapter. Moreover, the wall that separates Pit #2 from the canal has an opening in this area, so there is not adequate support for a pool adapter bridge at this location. Therefore, the pool adapter location that provides adequate support for the bridge, minimal facility modifications, and easy access to the fuel by the 5 Ton Crane is spanning Pit #2 in an east-west orientation over the open bay of the superstructure. This is the DTS configuration that is modeled in detail in the remainder of the report.

As part of the determination of the optimal location of a DTS pool adapter, the SRS Structural Engineering organization was consulted concerning the structural stability of the east and west walls of Pit #2 when subjected to the load of the pool adapter with a shield tube. While it is expected that the DTS would be supported by the 85 Ton Crane during a fuel transfer evolution, the weight of the DTS was also considered as a conservative condition. Because both ends of the pool adapter bridge are supported by the walls, the gravity load from the bridge is the only load that must be considered. Per ACI 349-06, the bearing capacity of the concrete would be at least 0.6 x 0.85 x 2,500 psi = 1,275 psi. The bridge that is shown in Figure 4-1 has four feet each with 100 in^2 bearing area. If the most conservative case of a 24" inner diameter (ID) pool adapter with the same submerged depth and thickness as the STS shield is used, the pool adapter would weigh approximately 37,000 lb. NAC has estimated the weight of a DTS-XL to be approximately 27,000 lb. This results in a bearing stress (37,000 lb + 27,000 lb)/(4 x 100 in^2) = 160 psi, which is much less than the allowable bearing stress of 1,275 psi. A more detailed calculation including column loading would be required if a pool adapter is designed, but it is expected that the 16” wide wall will be more than adequate.

In addition to the shield tube that must be designed and fabricated as part of the pool adapter, the shielding must be evaluated at the interface between the dry transfer cask and shipping cask and the interface between the dry transfer cask and the pool adapter. Additional shielding may also have to be designed and fabricated address these situations, especially considering the possibility of reflected shine.

Evaluation of the existing NAC pool adapter for this application resulted in the conclusion that it does not have adequate span or structural strength to support this application. The current NAC pool adapter cannot accommodate the difference in floor elevation on the east and west sides of transfer Pit #2 due to the 12” curb on the east side. It is assumed that other vendor’s pool adapters would have the same issues. Attempting to model several yet to be developed vendor provided pool adapters was not possible without design information. A concept of a pool adapter that could handle multiple vendor dry transfer casks for use in this application is shown in Figure 4-1. Pool adapter mounts that are similar in design to those installed for the TN-7 pool adapter must be installed over the east and west basin walls to receive the pool adapter. Following this concept, the operational sequence could be used to introduce long fuel such as NRU/NRX fuel baskets into L-Basin. While SRNL thinks the proposed location for DTS deployment is the most ideal, the designs/figures of the pool adapter, basket cart base, and basket cart carriage are conceptual only. There are details such as compliance mechanisms between the pool adapter and the basket cart that are not included in the model. There are other options for suspending the pool adapter, aligning the pool adapter to the basket cart and making the fuel accessible to the 5 Ton Crane after it is submerged in Pit #2. These options are discussed in the Modifications/Equipment section of this report. This sequence also assumes that the shipping cask and DTS are already located in the transfer bay and are accessible to the 85 Ton Crane. All lifting steps of this process would be performed using the L-Basin 85 Ton Crane unless otherwise specified. There are multiple notes embedded in the procedure that describe either the complexity of the task or the need for further evaluation to determine if more engineering controls are required for safe and effective performance of the task.

4.1 Operational Sequence for Use of a DTS to Unload Fuel into L-Basin

1. Install a basket cart on the floor of Pit #2.
    a. **NOTE:** In order to maneuver the fuel basket from under the pool adapter, the basket cart must be lowered into Pit #2 directly north of the superstructure. The cart will sit on the floor of the basin, straddling the -20 ft depth and -17 ft depth areas of the pool.
    b. **NOTE:** A spacer placed on -17 ft shelf (not shown in the figures) or some other method must be used to ensure proper east-west position of basket cart relative to the pool adapter.
        i. Movement of basket cart from under pool adapter to be performed by a water driven hydraulic cylinder or other linear actuation device. Hydraulic hose/ cable management between linear actuator and power source must be considered for proper operation.

2. Install pool adapter over Pit #2 (see Figure 4-2)
    a. Lower pool adapter bridge onto pool adapter mounts.
    b. Lower pool adapter shield tube into pool adapter bridge.
    c. Lower pool adapter sleeve into shield tube to accommodate specific fuel diameter (if needed).

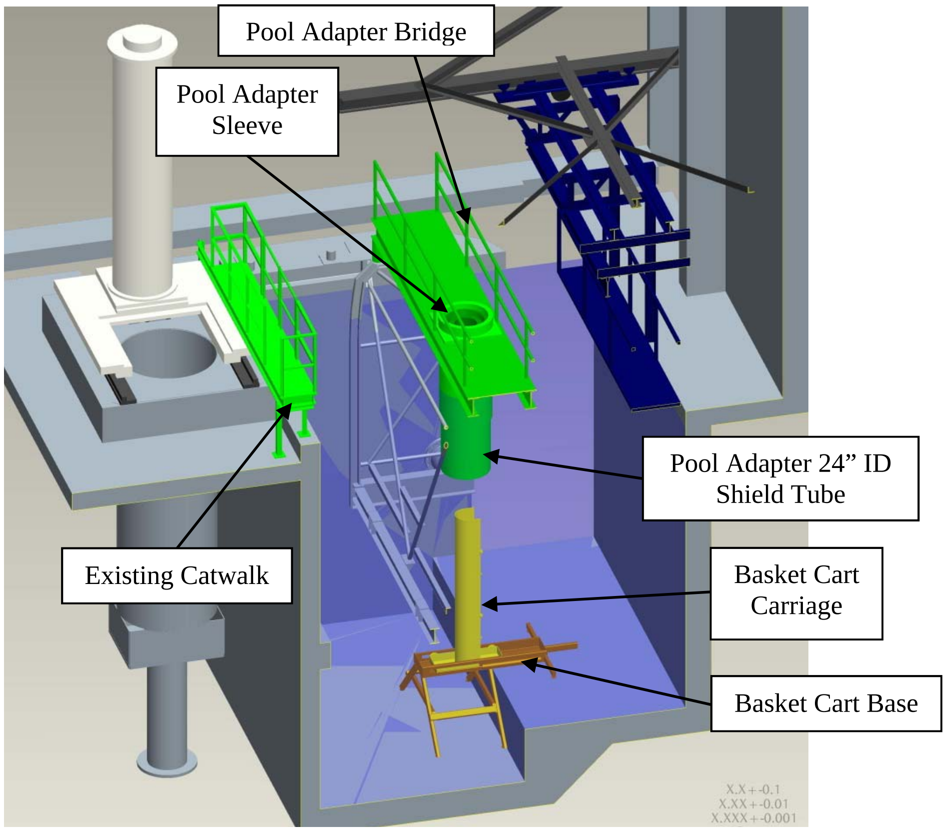

Figure 4-2: L-Basin Disassembly Area after Staging of Pool Adapter

3. Install shipping cask shim in STS dry well. Shim will provide alignment function and allow access to cask trunnions for attachment of cask adapter.
4. Place the transport cask in STS drywell per SOP-DHS-036-L.
5. Install modified dry well cover plate.
6. Install cask adapter onto transport cask trunnions (see Figure 4-3).
    a. Orient the cask adapter gate actuator southward to avoid interference with the existing STS cask assembly.
7. Remove cask lid.
    a. Install swivel hoist rings and sling.
    b. Remove cask lid using chain hoist attached to 3 Ton Hoist.
    c. Close cask adapter gate before lid clears adapter.
        i. **NOTE:** A shielding study is needed to determine if there is adequate shielding during this operation. An additional removable shield tube may be necessary to protect workers from radiation streaming and to avoid Area Radiation Monitor System (ARMS) alarm activation.
8. Install shield ring/plug assembly.

9. Remove shield plug and plate.
10. Install adapter ring.
11. Place the dry transfer cask in the transfer bay per new SOP-DHS-XXX-L

    a. Assemble and check out the dry transfer cask as necessary (may have a Technical Safety Requirements (TSR) required surveillance prior to use).
    b. Engage dry transfer cask and install on transport cask (see Figure 4-3).
    c. Maintain dry transfer cask engagement to the 85 Ton Crane west hoist.
    d. **NOTE:** Current STS dry well alignment allows for dry transfer cask gate actuator oriented north (operate from catwalk).

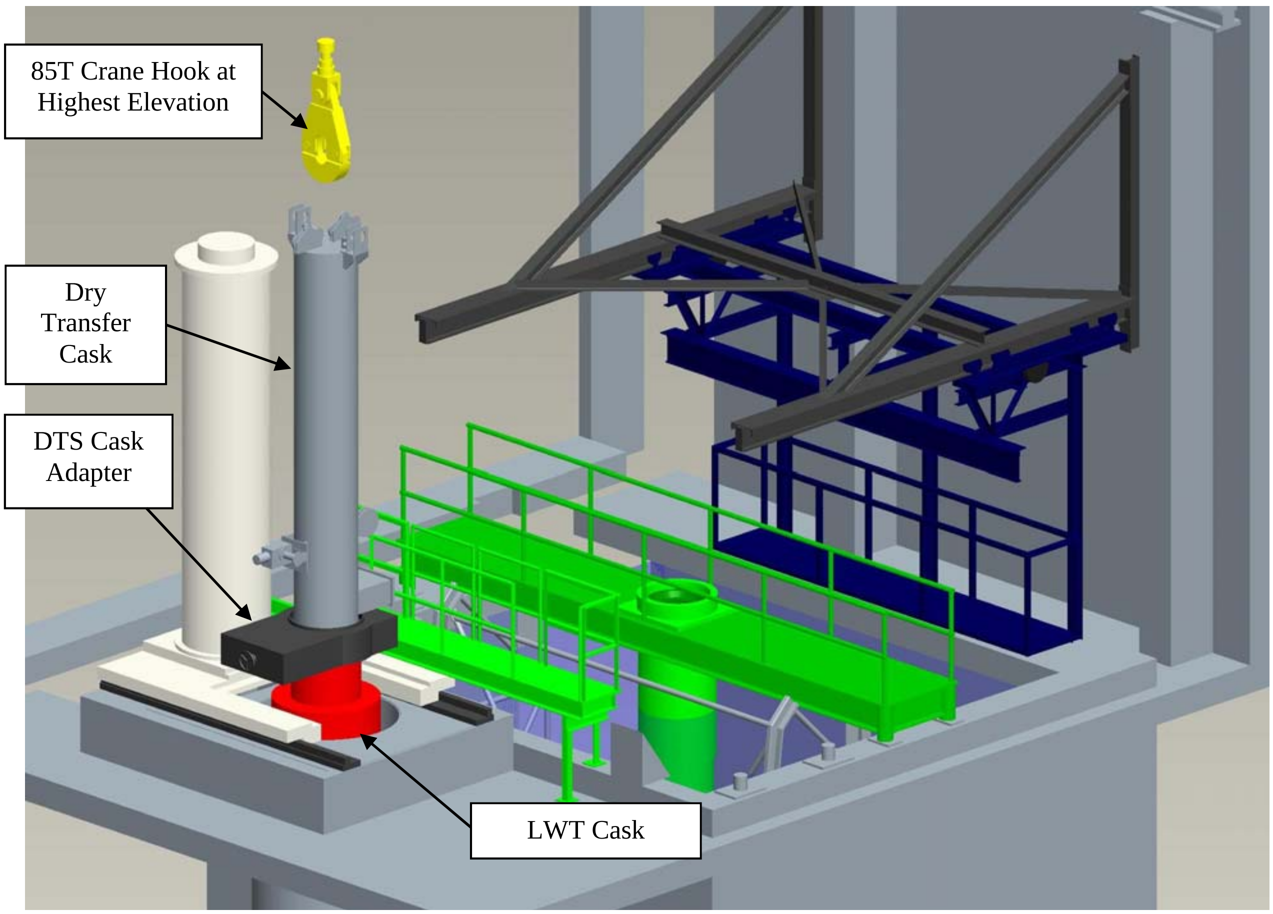

Figure 4-3: L-Basin Disassembly Area During Transfer of Fuel from Shipping Cask to Dry Transfer Cask

12. Connect air supply (80-90 psi) to dry transfer cask.
13. Lower dry transfer cask grapple and engage fuel basket.
    a. **NOTE:** Method of engagement verification must be determined (may require modification to the NAC DTS-XL or TN-LC DTS design)
        i. Load cell
        ii. Camera
14. Remove basket from transport cask into dry transfer cask.

   a. **NOTE:** Need shielding study, same as steps 7c and 20a.
   b. **NOTE:** Need cask basket deformation study.
15. Close dry transfer cask shield gate.
    a. **NOTE:** Determine method to verify gate closed/basket all the way up.
    b. **NOTE:** Possibility of basket/fuel damage if not fully into dry transfer cask.
16. Disconnect air supply.
17. Transfer dry transfer cask to pool adapter (see Figure 4-4).
    a. **NOTE:** Requires confirmation that there is enough head room over the dry well to rig the dry transfer cask to the 85 Ton Crane hook with shackles and sling, but removal of the hook may be required.
    b. **NOTE:** Circuitous crane flight path necessary to avoid catwalk.
    c. **NOTE:** Dry transfer cask remains engaged to 85 Ton Crane west hoist
       i. Hand rails or fall protection required for pool adapter access.
       ii. May need gate in pool adapter hand rails for adequate crane head room to install over pool adapter.
       iii. Preliminary load evaluation indicates basin walls can handle weight of pool adapter and dry transfer cask, but the dry transfer cask will remain engaged to credit the seismically qualified 85 Ton Crane structure.
       iv. This avoids having to add complexity and weight to the pool adapter design to stabilize the dry transfer cask should it be disengaged from the crane.

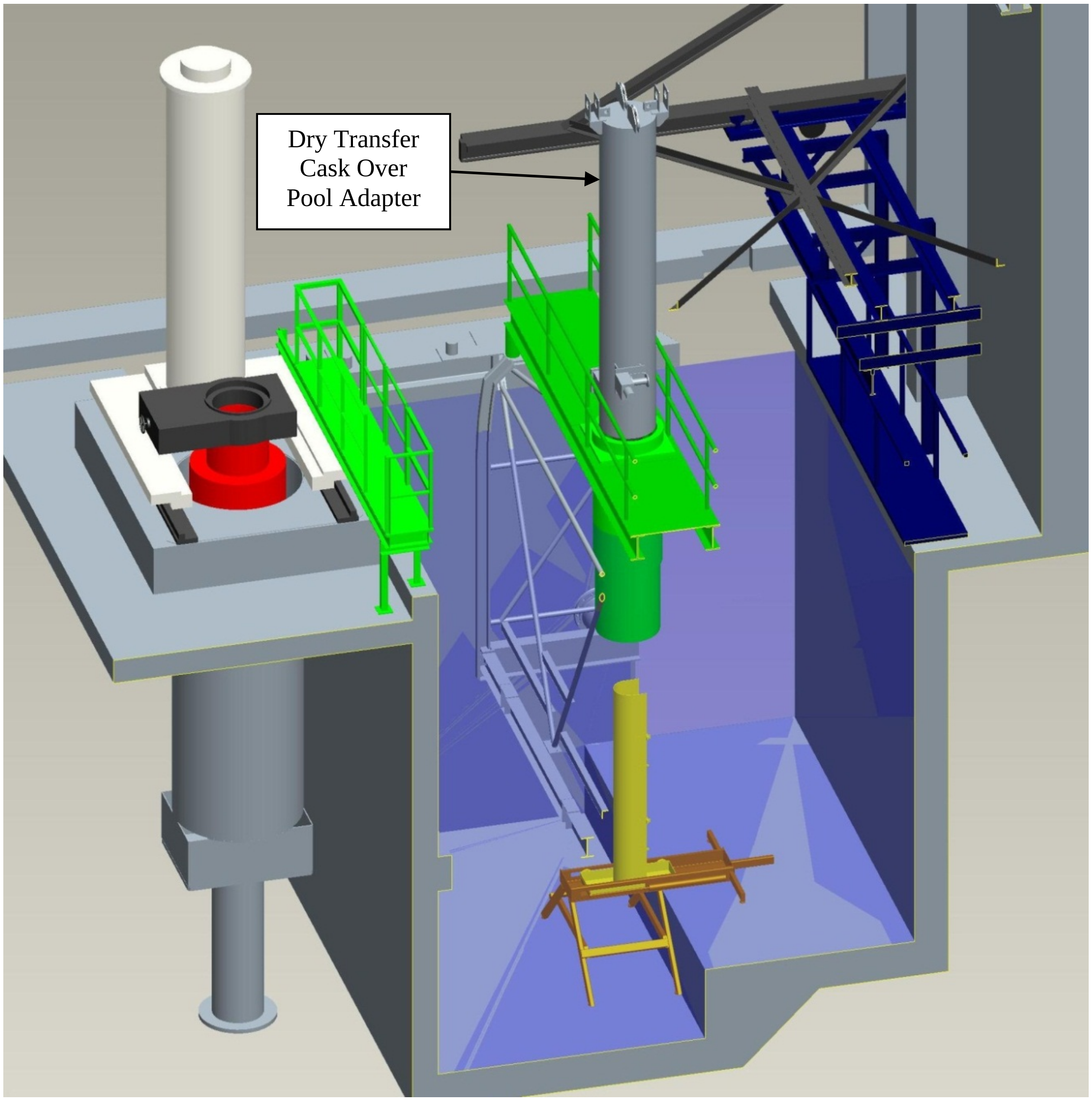

Figure 4-4: L-Basin Disassembly Area with Dry Transfer Cask in Position to Lower Fuel into Pit #2

18. Connect air supply to dry transfer cask.
    a. **NOTE:** Evaluation of a possible basket drop onto the closed DTS shield gate is needed.
19. Open dry transfer cask shield gate.
    a. **NOTE:** Evaluation of a possible basket drop onto the basket cart is needed.
20. Lower fuel basket into basket cart carriage (see Figure 4-5).
    a. **NOTE:** Shielding study is needed, same as steps 7c and 14a.
    b. **NOTE:** Need cask basket deformation study.

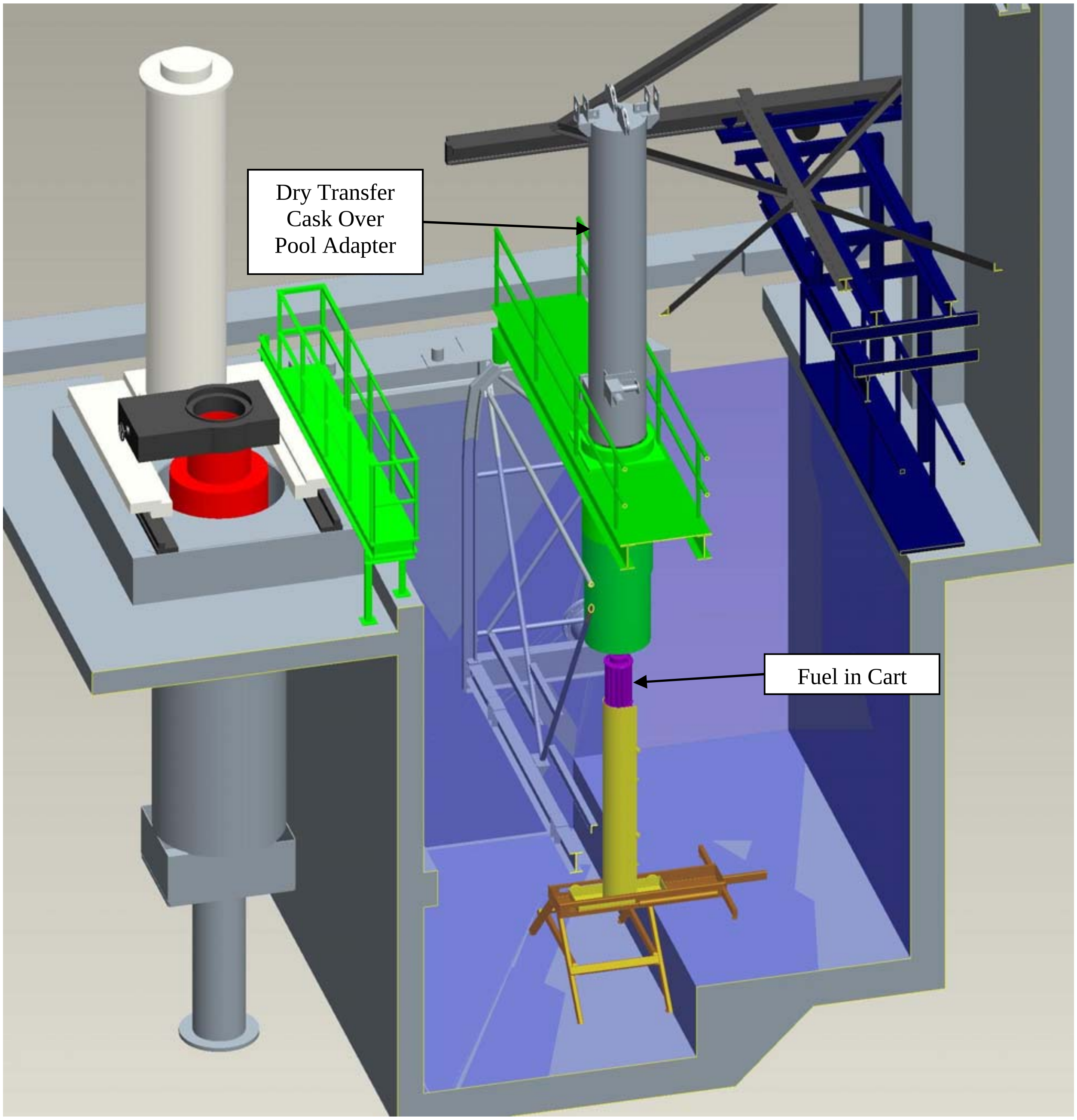

Figure 4-5: L-Basin Disassembly Area After Fuel Lowered into Basket Cart Carriage

21. Disengage fuel basket from dry transfer cask grapple and withdraw the grapple back inside the DTS.
22. Operate linear actuator to slide fuel basket from under pool adapter (see Figure 4-6).

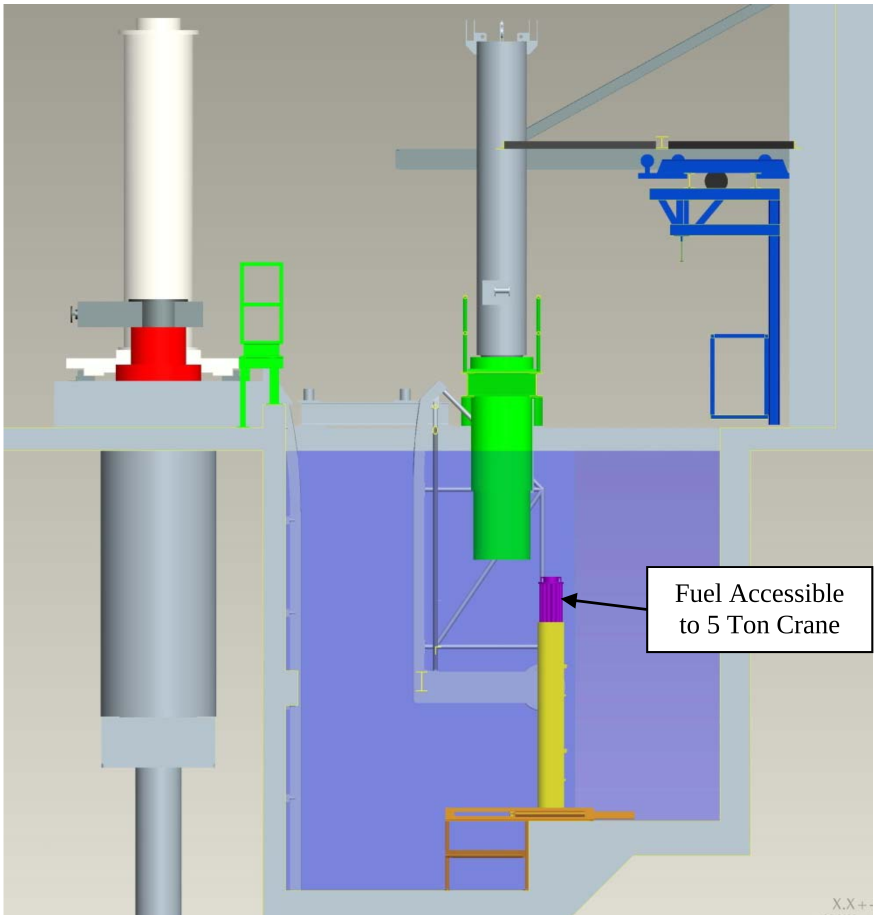

Figure 4-6: : L-Basin Disassembly Area After Fuel is Made Accessible to 5 Ton Crane

23. Attach to the top of the fuel basket with the 5 Ton Crane (see Figure 4-7).
24. Rotate the basket carriage arms to allow removal of fuel basket from carriage.
25. Transport fuel basket to monorail track where it can be transferred to the area of L-Basin where the fuel is removed from the basket and repackaged into its storage configuration.

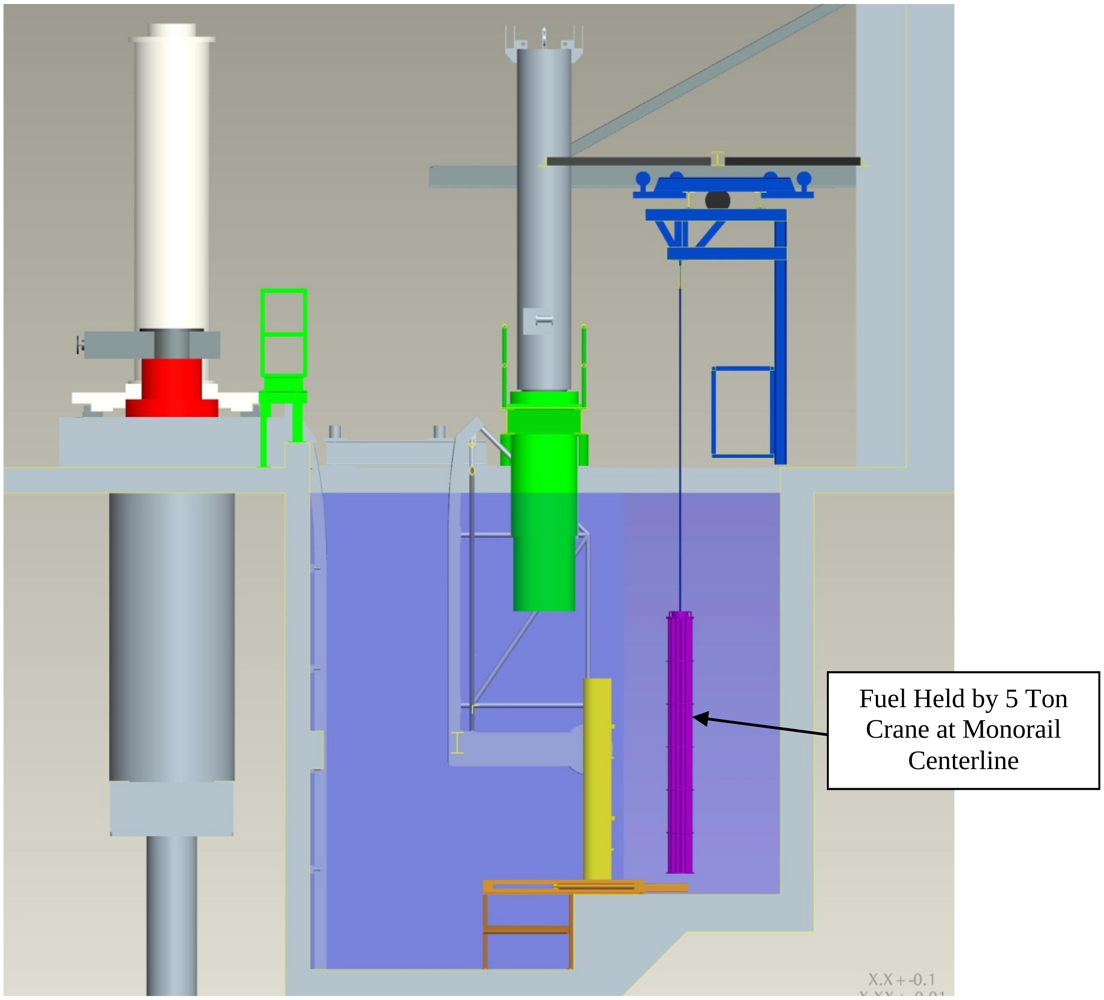

Figure 4-7: L-Basin Disassembly Area with Fuel Held by 5 Ton Crane

26. Return basket carriage to loading position directly under the pool adapter shield tube.
27. Disconnect air supply from DTS.

This operational sequence lists only the steps required to unload a single fuel basket from one shipping cask. The dry transfer cask must be removed from 105-L to allow adequate space within the transfer bay to remove the shipping cask from the building and insert another shipping cask in the dry well. Section 6 discusses the supporting tasks required and the number of shifts to use a DTS to transfer fuel baskets into L-Basin from two shipping casks consecutively.

5.0 MODIFICATIONS/ EQUIPMENT

5.1 Pool Adapter

The existing NAC pool adapter was evaluated to determine if it could be used for this application and it was determined that it does not have adequate span or structural strength to support this application. The current NAC pool adapter cannot accommodate the difference in floor elevation on the east and west sides of transfer Pit #2 due to the 12" curb on the east side. It is assumed that other vendors pool adapters would have the same issues. Attempting to model several yet to be developed vendor provided pool adapters is not possible without design information. To make a pool adapter designed for transfer Pit #2 as useful as possible, it could be made to accommodate the 13.25" NAC basket, 18" TN-LC basket, and up to a 24" diameter fuel container. It has been determined that directly north of the existing superstructure there is adequate room to install a pool adapter bridge wide enough to accommodate transfer of up to a 24" diameter fuel canister or basket. This will allow access to the fuel by the 5 Ton Crane. Supports similar to the TN-7 pool adapter supports could be designed, fabricated, and permanently installed on the east and west Pit #2 walls to accommodate the pool adapter. In addition, the permanent hand rails that currently surround the transfer pit in this location must be replaced with removable hand rails. The pool adapter concept described in the operational sequence assumes installation of the pool adapter in several steps:

1. The pool adapter bridge is installed, engaging permanent supports installed east and west of the transfer pit for this application.
2. The 24" ID pool adapter shield is installed.
3. A pool adapter shield sleeve that is sized for the fuel basket to be transferred is installed inside the pool adapter shield.

The pool adapter shield tube (or sleeve, if used) must incorporate a rotational alignment bar to ensure that the fuel basket is oriented correctly to be received by the grapple of the dry transfer cask.

If only one application for the pool adapter is known (such as receipt of NRU/NRX fuel), the shield tube could be sized for the specific fuel and modularity could be accomplished by a spacer between the bridge and the shield tube. Calculations will be required to properly size the pool adapter shield tube to suit the transfer pit depth and SRS shielding requirements [4]. Access to the pool adapter will require installation of removable hand rails on the bridge east and west of the pool adapter opening. To provide maximum flexibility for handling long fuel baskets, a hand rail gate directly south of the shield tube would likely be needed to allow adequate headroom to maneuver a dry transfer cask between the pool adapter and the 85 Ton Crane.

In addition to a pool adapter bridge discussed in the section above, other pool adapter options were considered. One option is a pool adapter that rests on the floor of the transfer pit. The pool adapter lower base would have a heavy structure with a wide footprint for the stability needed to support the shield tube, whose top would be more than 20 feet above the floor of the transfer pit. The base would incorporate trunnions allowing it to be installed under the superstructure using the 85 Ton Crane lifting attachment used for the 70 Ton Cask. The basket stand/carriage would be lowered onto the lower base from above by the 3 Ton Hoist. An upper base would then be lowered into position on the lower base by the 3 Ton Hoist. The shield tube would then be lowered into a receiver in the upper base by the 85 Ton Crane. Once all of the components of the pool adapter are assembled and the dry transfer cask is in place, the fuel basket would be raised and lowered by personnel stationed on the 5 Ton Crane. The advantage of this arrangement is ease of alignment between the shield tube and the basket stand/carriage. The disadvantage is that multiple large pieces of the equipment would need to be decontaminated and stored after each use.

5.2 Drywell Shim

In the existing use of the STS, the shipping cask is lowered entirely into the STS dry well. To be able to use the NAC DTS to remove fuel baskets from the LWT, the LWT must be raised so that the DTS cask adapter can access the trunnions on the top end of the LWT. Design, fabrication, and installation of an LWT cask shim in the STS drywell would be required provide this access. The shim must be designed to be removable and must be compatible with cask rotational alignment components in the drywell.

5.3 Drywell Cover Plate

To accommodate use of the STS dry well with the DTS system, a new dry well cover plate must be designed and fabricated. The cover plate must stabilize the LWT. Some design effort and calculations will be required to ensure the cover plate incorporates adequate shielding, because the top of the LWT will be at a higher elevation than the STS dry well shielding.

5.4 Dry Transfer Cask

As the NAC DTS is designed today, verification of fuel basket engagement and verification that the fuel basket is fully withdrawn in the dry transfer cask are performed by operator “feel”. Modifications of the dry transfer cask or its internal grapple will likely be required to provide a method of fuel basket engagement verification. The verification method could be provided by installation of a camera/lighting system or a load cell with an indicator at working height.

5.5 Basket Stand/Carriage

Design and fabrication of a basket stand/carriage will be required for stabilizing the fuel basket and for removal of the fuel basket from under the pool adapter. The stand/carriage must be portable such that it can be relocated to allow for 70 Ton Cask handling in the transfer pit. The basket stand described in the operational sequence would be lowered by the 3 Ton Hoist and would straddle the transition between -20 feet and -17 feet in the transfer pit. The transition between the -20 foot and -17 foot levels would provide north-south alignment with the pool adapter. To ensure that the stand is level, the stand would have feet that could be adjusted by an operator in the 5 Ton Crane during setup the first time the stand is used. Prior to lowering the basket stand, a spacer would be lowered to lie on the floor of the -17 foot level and rest against the west wall of the transfer pit. When the basket stand is lowered into the pool, it would be maneuvered to rest against the spacer for east-west alignment with the pool adapter.

Another option for translational alignment of the basket stand is installation of holes into the floor of the basin to be used as receivers for the basket stand feet. Evaluation of the existing concrete pad would be required to determine whether holes could be drilled without damaging the existing structure. Drilling of the holes would require underwater divers.

The carriage borrows many of the features of the STS carriage and could be lowered with the stand or as a separate component. Rigging and connection ease and structural integrity of the carriage linear actuator would be among the considerations in determining whether the carriage would be lowered with the stand.

In order to access the fuel basket after it is lowered into the carriage, the carriage would be translated horizontally to move the fuel out from under the pool adapter. The carriage would travel on wheels or slides captured above, below and on the outsides to prevent tipping of the carriage and fuel. The slides would be driven by a linear actuator. If the linear actuator is powered by a hydraulic cylinder (filled with water to prevent cross-contamination of the basin) or a pneumatically driven motor, management of the hoses to operate the actuator would be an operational challenge. An alternative is use of a pole by personnel on the 5 Ton Crane to operate a gear or belt driven actuator. It is expected that a pole driven device would be difficult to use through the water from 20+ feet above.

As described in the section above, alignment of the pool adapter to the basket carriage would likely be operationally complex and/or require additional engineered features to ensure proper alignment. Due to these complexities, below are two other options that could possibly be employed:

1. The track for the basket carriage is permanently attached to the north wall of the transfer pit and can be rotated from horizontal to vertical for storage against the wall. This option would require significant work by underwater divers for installation of anchor points and assembly of the device. Initial alignment could be a challenge, but this option would be simpler for operations.
2. An option that eliminates the bridge and integrates the shield tube with the basket stand/carriage in a multi-component assembly as described in the *Other Pool Adapter Options* section of this study.

6.0 FACILITY OPERATIONAL CONSIDERATIONS

6.1 Operations DTS Handling Procedures

As discussed in the previous sections, use of a DTS will require setup of multiple items in and over the transfer pit. Proper relative alignment of the various components of the dry transfer cask, pool adapter shield tube, pool adapter bridge, and basket cart carriage is critical to proper operation of the system. Operating space limitations in the Transfer Bay prevent co-location of the ISO containers that are used to transport the shipping casks and DTS equipment containers. Each vendor DTS cask will need its own procedure on how to operate it and its support equipment. Operating procedures will be required to ensure the various components are installed, aligned and tested so the DTS will be safe and efficient to operate.

6.2 DTS Operations Task Analysis

There are multiple operational steps that must be performed before and after the operational sequence described in section 4 of this report. An operations task analysis was done on the potential use of a NAC-DTS-XL to unload two LWT casks containing NRU fuel. Table 6-1 shows 21 shifts are required for the entire two NRU LWT cask unloading evolution, including preparation, use and removal of a DTS in the L-Area transfer bay. Unloading one DTS cask would take 12.5 shifts.

The following assumptions were used in preparing this schedule:

1. One shift crew performing sequential tasks.
2. The DTS must be supported by the 85 Ton Crane while in use.
3. The DTS must be removed from the transfer bay during removal/installation of a LWT from/into an ISO (not adequate room for all of the equipment at the same time).
4. One ISO dolly is used (a second ISO dolly may be needed).
5. Two LWTs will be shipped at a time as is expected for the NRU/NRX campaign. Both LWTs will be unloaded prior to starting another cask type (limits flexibility for Canyon support for shipping 70 Ton Cask).

Table 6-1: Shifts Required for Preparation, Use and Removal of a DTS in L-Area

Task	**Number of Shifts**
Install basket cart/carriage & pool adaptor (includes checkout of cart/carriage operation)	2
Install cask shim and place LWT in dry well	1
Install cover plate, install cask adapter, remove cask lid and install shield ring	1/2
Close and clear empty ISO to allow DTS ISO installation in transfer bay	1/2
Place DTS ISO in transfer bay, remove DTS from ISO, checkout and attach to cask	1-1/2
Unload one basket, place on pool adapter, lower into cart/carriage and disengage	1/2
UNLOAD fuel	2
Place DTS in ISO and remove from transfer bay	1
Remove cover plate, remove cask adapter, remove cask lid, and remove shield ring	1/2
Place empty LWT ISO in transfer bay, load with empty cask and remove from transfer bay	1
Place second LWT in dry well to be unloaded	1
Install cover plate, install cask adapter, remove cask lid, and install shield ring	1/2
Close and clear empty ISO to allow DTS ISO installation in transfer bay	1/2
Place DTS ISO in transfer bay, remove DTS from ISO, checkout and attach to cask	1-1/2
Unload one basket, place on pool adapter, lower into cart/carriage and disengage	1/2
UNLOAD fuel	2
Place DTS in ISO and remove from transfer bay	1
Remove cover plate, remove cask adapter, remove cask lid, and install shield ring	1/2
Place empty LWT ISO in transfer bay, load with empty cask, and remove from transfer bay	1
Remove from L-Basin and decontaminate basket cart/carriage & pool adapter and transport to storage location outside of 105-L	2
Total	**21**

6.3 Storage of Equipment

Another consideration for use of a DTS at L-Area is storage of equipment. There are multiple large items that are part of the pool adapter that will need a storage location. Decontamination of the pool adapter shield tube and sleeves for storage in a clean area may be possible. However, the basket cart/carriage will require extensive decontamination and will need to be bagged or otherwise contained for transport to and storage in a contaminated laydown area.

7.0 SHIELDING/ DOSE CONSIDERATIONS

7.1 Radiological Protection

The design of the STS or DTS process must provide sufficient shielding during normal cask unloading activities to ensure that the direct radiation dose is within the allowable SRS limits [4, 5] and kept As Low As Reasonably Achievable (ALARA). Per the Fuel Receipt and Shipping Program, each cask receipt is evaluated against a bounding source to ensure operation within the equipment design basis. The installed STS has bulky integrated shielding at the cask lid lifting unit and the transition between the top of the shipping cask and bottom of the shielded transfer tube. For the DTS process, specialized cask adapter equipment must be installed on the top of the shipping cask to provide the shielded interface with the DTS cask. At a critical point in the adaptation process, personnel are potentially directly exposed to unshielded fuel.

Completion of a dose/shielding study for the DTS process will be required to determine if modification to the DTS shielding and/or design, fabrication, and installation of additional shielding is required at the interface points between the shipping cask and DTS. This is particularly significant for the case of indoor unloading of a shipping cask to a DTS cask where operating personnel are located above the top of the shipping cask and proximity to other equipment increases potential for radiation scattering. A similar situation exists at the transition from the DTS cask into the pool adapter. The dose/shielding studies also have to determine effects on installed Area Radiation Monitors (ARMs).

Preliminary dose calculations by NAC estimate a dose of 1-2 mrem/hr at 1 meter from NRU/NRX fuel when using the NAC DTS-XL, so the custom pool adapter in this study uses the same shielding thickness as the NAC DTS pool adapter. The DTS-XL can only handle fuel baskets up to 13-3/8” diameter, but it was determined that fuel baskets up to 24” diameter and 11 ft long could be loaded/ unloaded in the north side of Pit #2, assuming the same depth of shielding used for the existing STS. Scenario specific shielding calculations must be performed to determine whether a shorter shield tube could be used, thus permitting longer fuel to be handled.

8.0 SAFETY BASIS CONSIDERATIONS [5, 6]

8.1 DTS Cask Evaluation

The L-Area Facility Fuel Receipt and Shipping Program ensures that all spent fuel casks for offsite shipments of domestic and foreign research reactor fuel are designed, built, and tested to meet the requirements of 10 CFR 71; i.e., spent fuel casks handled in the facility are certified Department of Transportation (DOT) Type B casks. As a result, the L-Area Facility safety basis often credits the use of qualified casks in the prevention and mitigation of many types to events including design basis fires, explosions, cask drops, and cask impacts. The qualified casks also provide containment of radionuclides and personnel protection from direct radiation. The Dry Transfer System (DTS) casks are not evaluated or certified as DOT Type B casks. As a result, safety functions currently assigned to spent fuel casks cannot be assumed for the DTS cask. Each type of DTS cask will need to be evaluated for the credible events specific to L-Area.

8.2 In-Air Nuclear Criticality

L-Area does not have a Nuclear Incident Monitor (NIM) system to alert personnel of an inadvertent criticality accident. As a result, the combined frequency for all in-air nuclear criticality scenarios in a given Process Area must be Beyond Extremely Unlikely (i.e., less than 1×10^{-6} events per year). Controls to achieve these results may be engineered features, administrative controls, or combinations of both. Engineered features are preferred over administrative controls. The Consolidated Hazard Analysis Process (CHAP) process and the associated Nuclear Criticality Safety Evaluation will determine specific safety performance criteria for components of the DTS System. Examples of anticipated credited features include: physical barriers to prevent vehicle impacts to an unsealed cask or DTS cask, below-the-hook (BTH) cask rigging qualified to single failure proof criteria of BTH-1, combustible control program, and moderator exclusion controls.

8.3 Cask Basket Deformation in STS/DTS Operation

A criticality safety evaluation of dry fuel unloading operations assumes the geometry and integrity of the fuel within the cask basket is protected. Each step in the process must be evaluated for any potential to crush or otherwise alter the fuel and basket configuration. For the current STS process in the L-Area Facility, this is accomplished by a combination of basket design/qualifications and force limiting controls within the STS. In similar fashion, the DTS operation will require a safety analysis to identify credible damage scenarios and establish controls. For example, the operation of the cask adapter and DTS gates presents an opportunity to deform fuel if the basket is not fully clear of these gates prior to closing. This situation will require evaluation and could potentially affect system design.

The current proposal is to leave the DTS attached to the 85 Ton Crane while it is on the pool adapter. Analysis must be performed to determine if the crane needs to be de-energized while fuel is being unloaded to prevent crane movement of the dry transfer cask and damage to the fuel basket while the fuel basket is transitioning from the DTS to the pool adapter sleeve. Movement of the 85 Ton Crane with the DTS engaged and while the fuel basket is transitioning to the pool could cause exposure of personnel to radiation from the unshielded fuel basket. These situations will require evaluation and could potentially affect system design.

8.4 Underwater Nuclear Criticality

As previously stated, L-Area does not have a Nuclear Incident Monitor (NIM) system to alert personnel of an inadvertent criticality accident. As a result, all underwater nuclear criticality scenarios must either meet the frequency criteria for an In-Air nuclear criticality or occur at a water depth that provides sufficient shielding (i.e., all personnel are outside the 12 Rad direct exposure zone). This latter group of scenarios must comply with the Double Contingency Principle which requires process designs to incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. The Double Contingency Analysis will require revision to evaluate and incorporate new events scenarios such as:

- DTS cask drop into Transfer Pit / onto Pool Adapter
- Pool Adapter drop into Transfer Pit
- Basket and grapple drop into underwater carriage / Transfer Pit
- Basket spill from underwater carriage

9.0 SAFETY BASIS – OUTDOOR CASK UNLOADING

Dry transfer systems are typically utilized for loading a cask outside the space-restrictive confines of a research reactor facility. While outdoor unloading of a cask using a DTS process is technically feasible in L Area, it was not considered the favored configuration primarily due to the complexity of safety analysis and resulting engineered and administrative controls. The following section describes some of the Safety Basis challenges for outdoor cask unloading.

Presently, all spent fuel cask loading/unloading operations are performed inside the robust structure of the Transfer Bay. As a result, the Safety Basis can credit this passive engineered feature for preventing fuel damage from various credible initiating events such as high winds, wind-driven missiles, vehicle impacts, and lightning. For the case of outdoor opening of a shipping cask and transfer of fuel to the building in the DTS cask, the building cannot be credited for protecting the fuel. An all new safety analysis would be required to evaluate this outdoor fuel handing process and determine required controls. This safety analysis would be in addition to almost all of the costs associated with indoor cask unloading. The major components of the safety analysis are listed below, but a conceptual process and cost estimate were not developed for outdoor cask unloading due to the prohibitive cost of this approach.

The Consolidated Hazard Analysis Process (CHAP) will be used to identify credible scenarios, estimate event frequencies, select controls, assess unmitigated and mitigated consequences, assign risk levels, and functionally classify credited features. Topical areas requiring extensive new analyses include:

1. Control of combustibles. Current safety analyses for the L-Area Facility make extensive use of combustible controls in determining frequency, intensity, and duration of fires. For example, high peak heat release rate fuel packages (e.g., vehicles) are excluded from fuel handling areas. For outdoor cask unloading to a DTS, there will be a mobile crane, articulating personnel lifts, and fork truck in close proximity to the unsealed cask and DTS. Additionally, outdoor operation exposes the work area to other high heat packages such as fuel delivery trucks. New safety analysis and new controls will need to be developed to address radiological release and nuclear criticality events.

2. Exposure to high winds and wind-driven missiles. Current safety analyses for the L-Area Facility credits the building structure for protecting fuel and associated fuel handling operations from straight line winds, tornadoes, and wind driven missiles. The outdoor transfer of fuel from the shipping cask to DTS exposes the entire operation to the environment. Not only are the unsealed cask and DTS subject to the winds, but also the crane and personnel lifts which can potentially become hazards to the fuel, cask, DTS, and building structure. New safety analysis and new controls will need to be developed to address credible radiological release and nuclear criticality events resulting from winds. One anticipated outcome is a restriction on operations whenever severe weather threatens. Another is the placement of this operation at a safe distance from the basin structure.
3. Seismic scenario. For current cask unloading operation in the L-Area Facility, the very tall casks such as the NAC-LWT are placed in the STS dry well prior to lid removal, thus constraining the unsealed cask and preventing tipping/spilling of contents. The 85 Ton Crane is equipped with a seismic switch to stop movement in a seismic event. These design features combined with ‘nature of process’ and ‘time at risk’ evaluations have determined an acceptable risk for cask handling/ unloading operations. For the outdoor unloading of casks, a new base plate and anchorage system will need to be installed to secure the tall cask. A new seismic analysis will be needed to support development of a new risk evaluation and new controls.
4. Cask Drops. Current operations in the L-Area Facility limit cask lift heights to the minimum necessary to safely clear relatively low obstacles. The outdoor cask unloading operation involves handling a loaded DTS high above a vertical shipping cask. New safety analysis and new controls will need to be developed to address radiological release and nuclear criticality events.
5. Moderator Exclusion. In-Air nuclear criticality safety analyses often rely on the exclusion of moderator (e.g., water) from process areas. The outdoor unloading of spent fuel shipping casks potentially exposes the operation to precipitation. This condition will have to be considered in the criticality safety evaluation and could lead to new types of criticality safety controls.

Another aspect of this outdoor cask unloading operation is the creation of a new Operating Area external to Building 105-L. This will require significant revision to the Technical Safety Requirements document.

10.0 COST CONSIDERATIONS

This section identifies the core list of activities and assumptions to be considered when developing a cost estimate for installing a L-Area facility DTS. Other Project Cost activities would be added using standard project management estimating models.

10.1 DTS Cost Estimate Activities

1. Basket cart base design and fabrication
2. Basket cart carriage design and fabrication
3. Pool adapter bridge design and fabrication
4. Pool adapter shield tube design and fabrication
5. Pool adapter sleeve design and fabrication
6. Spreader for 85 Ton Crane to DTS design and fabrication

7. Dry well shim design and fabrication
8. Dry well cover design and fabrication
9. Functional testing of equipment
10. Structural calculations
11. Shielding calculations
12. Installation of pool adapter mounts, hand rail modification
13. 85-Ton Crane flight path programming
14. In-Air Criticality fault tree analysis
15. Initial Consolidated Hazards Analysis (CHA)
16. Nuclear Criticality Safety Evaluation (NCSE)
17. Double Contingency Analysis (DCA)
18. Final Consolidated Hazards Analysis (CHA)
19. Update transportation manual
20. Revise Documented Safety Analysis (DSA) & Technical Safety Requirements (TSRs)
21. Revise L-Area operating procedures
22. Develop / conduct personnel training
23. Lease transport cask (LWT/TN-LC) and DTS for training, startup and Readiness Assessment (RA)
24. Startup and test
25. Readiness Assessment
26. Operational Readiness Review (ORR)

10.2 Cost Assumptions:

1. Type 1 structural calculations of the pool adapter span, loading on the Pit #2 walls, and loading of dry well and dry well base would be required.
2. Some cost estimate activities may need to be performed separately for each vendor dry transfer cask to be handled for example: shielding calculations, startup testing, operator training, Readiness Assessment, etc.
3. Additional 85 Ton Crane programming would be needed if programmed crane operations are needed to ensure alignment of components for unloading of fuel over Pit #2 or if the crane needs to be de-energized (administrative control) while a fuel basket is transitioning to or from the dry transfer cask.
4. The estimates for nuclear and criticality safety analyses may also need to include two scenarios that may require development of additional equipment and/or safety features that would constitute engineered controls. If these scenarios are considered credible, additional nuclear safety and criticality analyses would also be required. The scenarios identified are:
    a. The fuel basket is sheared at the basket/DTS interface via lateral crane travel during basket retrieval. The deformation of the basket or shearing of multiple fuel rods could result in a criticality event.
    b. A crane/rigging failure causes the DTS to fall upon a fuel basket that had just been lowered from the DTS into the transfer bay -17 foot level. The DTS could crush the fuel and result in a criticality event.
5. Vendor transport cask and DTS cask lease costs are for startup, operator training, Readiness Assessment and ORR prior to declaring operability of the DTS.

11.0 CONCLUSIONS

After reviewing the L-Basin Transfer Bay Area and what is known about available DTS systems, the authors conclude that use of a DTS to transfer used nuclear fuel into and out of L-Basin is feasible. Fuel baskets/containers with diameters up to 24" inches could be transferred. Fuel up to 11' long could be transferred, and fuel longer than 11' could possibly be transferred pending scenario specific shielding calculations. Design and fabrication of a custom pool adapter that is long enough to span Pit #2 would be required for deployment of a DTS. Much engineering skill and attention to detail must be employed to develop a pool adapter/ basket cart system that would be safe and simple to operate. Regardless of the design, use of a DTS in L-Area would be a very labor intensive process due to several large DTS components that must be handled multiple times by the 85 Ton Crane in a relatively small operating space.

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