Alternative Canister Processing Operations at an Interim Storage Facility – 16617

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ABSTRACT

The US Department of Energy (DOE) is laying the groundwork for implementing interim storage of spent nuclear fuel (SNF) in response to recommendations by the Blue Ribbon Commission on America's Nuclear Future in their report to the Secretary of Energy published January 2012 [1]. These efforts include planning for a Pilot Interim Storage Facility (ISF) and a Larger ISF.

In March 2014, the DOE employed the CB&I team to evaluate design alternatives for cask handling operations and storing SNF at an ISF. The report, "Generic Design Alternatives for Dry Storage of Used Nuclear Fuel," [2] (Alternatives Report) evaluates different aspects of an ISF, including a study on alternative approaches for processing SNF canisters such as different cask handling methods and configurations which might be used to transfer canisters from shipping casks into storage locations at an ISF. The purpose of this paper is to report on the development of alternative cask handling operations that have been evaluated for the receipt and storage of the SNF at an initial Pilot ISF and a Larger ISF.

This design study is relevant for host communities considering near-term development of a Pilot ISF. DOE-sponsored system analyses indicate that a processing rate of up to 3,000 MTU/yr (approximately 230 to 300 canisters) would be needed for a single Larger ISF (less if more than one ISF were developed) to remove SNF from commercial nuclear plants in a reasonable amount of time. The study evaluated different canister processing operation methodologies in order to reduce the complexity, cost, and personnel exposure associated with processing operations at an ISF. The conclusions from this design study could help to inform the selection of future canister processing operations for an ISF.

INTRODUCTION

Successful implementation of the Pilot ISF or Larger ISF requires more than selecting the best storage systems. Equally important is careful consideration of cask handling methods for various SNF receipt rates. Key elements to cask handling operations include <u>time</u> or duration from receipt of a transportation cask to placement into storage, <u>radiation dose</u> to workers during the process, and <u>cost</u> of the equipment and facilities required to perform the operations. The impact of these key elements would be magnified in an ISF where hundreds of cask handling operations are performed yearly.

The Alternatives Report focused first on evaluating storage alternatives for a Pilot ISF sized to store up to 5,000 MTU of SNF from shutdown plant sites and second on evaluating storage alternatives for a Larger ISF sized to store an additional 5,000 MTU of SNF from the remaining nuclear plant sites. Various cask handling methods and configurations were studied for the Pilot ISF and Larger ISF. Dry storage canister (DSC) receipt rates of up to 1,500 MTU/yr were assigned to the Pilot ISF and 3,000 MTU/yr to 4,500 MTU/yr for the Larger ISF.

All of the storage systems at the shutdown nuclear power plants as well as the majority of remaining operating plants use canister-based storage systems. The primary cask handling activities for these systems include 1) offloading from the rail car; 2) canister transfer from the transportation cask to a storage overpack; and 3) transport of the canister to a storage pad. Vertical storage systems typically transport the canister in the storage overpack to the pad following canister transfer, and horizontal systems transport the canister in a transfer cask to the pad prior to canister transfer into the storage overpack. Four alternative canister processing methods were evaluated for the Pilot ISF and Larger ISF as follows:

1. Current Cask Handling Operation methods typically used at most nuclear power plants using the system-specific transfer cask. Alternatives Report designation: "C-OPS"
2. Automated Cask Handling Operations using a fixed-movement universal transfer cask and other features that remove labor and dose intensive steps. Alternatives Report designation: "A-OPS"
3. Remote Cask Handling Operations that would not use any transfer cask that provides shielding in order to reduce time but would require a radiation shielded facility (hot cell). Alternatives Report designation: "R-OPS"
4. Simplified Cask Handling Operations that would use the least amount of equipment and facilities: Alternatives Report designation: "S-OPS"

The current methodology used at most nuclear plants, C-OPS was selected as the base case for the study. There is wide spread data on this methodology primarily provided by the vendors in their respective Final Safety Analysis Reports (FSAR) as well as industry association publications. Each of the other three alternative methods were evaluated and compared to the base case to determine how they affect processing time, worker radiation dose and cost. Time and motion analyses were run for each step in the cask handling process. State-of-the-art technologies in automation and handling equipment were evaluated to see how they could optimize operations.

PILOT INTERIM STORAGE FACILITY

The primary purpose of the Pilot ISF would be to provide a centralized storage location for SNF from shutdown reactor sites. Prior to 2013 there were nine shutdown reactor sites that stored SNF at onsite Independent Spent Fuel Storage Installations (ISFSI) which utilize dry fuel storage systems (DFSS). The nine sites are Big Rock Point, Connecticut Yankee, Humboldt Bay, LaCrosse, Maine Yankee, Rancho Seco, Trojan, Yankee Rowe and Zion. These sites have been or are in the process of being decommissioned and dismantled. Since 2013, four more reactor sites (Crystal River, Kewaunee, San Onofre and Vermont Yankee) have shut down. It has also been announced that Fitzpatrick, Oyster Creek and Pilgrim will shut down within five years, increasing the need for a centralized ISF. It should be noted that there are also shutdown reactors located at operating plant sites at (Dresden 1, Indian Point 1, and Millstone 1). Since these reactors are located at operating plant sites, the removal of their fuel is not as urgent because the site is not planned to be decommissioned for several years.

There is some urgency to remove the SNF at shutdown reactor sites in order to: 1) allow the sites to be used for other purposes, and 2) to consolidate the storage of the SNF into a centralized location reducing the overall storage activities and costs. The Pilot ISF is planned to be a small facility, designed for future growth, with minimum essential structures and components for receiving transport casks from shutdown reactor sites. This approach makes the initial facility design simpler and the licensing process less complex, essentially allowing the ISF to be a pilot process with a well-defined success path. All of the shutdown sites have SNF stored in DSCs which are designed and licensed for both storage and transport. And the storage systems at the shutdown reactor sites include both vertical and horizontal type storage units. Therefore, the Pilot ISF must also be able to process and store both vertical and horizontal storage systems.

The DSCs are welded closed and do not need to be opened. Therefore, the Pilot ISF operations would receive SNF from the shutdown reactor sites without the need to open the DSCs or handle bare fuel assemblies.[1] The Pilot ISF design must also be modular, allowing for phased deployment over time in order to accommodate a Larger ISF, capable of storing SNF from all of the nation’s reactor sites. In order to fulfill these requirements, the Pilot ISF will need to include facilities and infrastructure for the following activities:

- A railcar receipt area and crane to offload transport cask
- An area equipped to transfer a vertical type DSC from a transport cask to a vertical storage overpack (VSO)
- Equipment that can move a VSO or horizontal transport cask to the storage area
- Equipment that can transfer a horizontal DSC from the transport cask into a horizontal storage module (HSM).

EVALUATION OF ALTERNATIVES

C-OPS - Current Cask Handling Operations

This alternative method examines the use of cask handling methods currently in use today at operating and decommissioned nuclear plants in the USA that could be

[1] *“Under the Standard Contract (10 CFR 961.11), DOE is obligated to accept only bare spent nuclear fuel. Acceptance of canistered spent nuclear fuel would require an amendment to the Standard Contract.”*

employed at the ISF. Commercial Operations, or C-OPS, is a simple extrapolation of current industry practices applied directly to the ISF. The methods used are thoroughly demonstrated and proven. The process, however, involves many labor intensive steps and relies on several manual actions which are likely due to the need to adapt to any reactor site configuration. While small improvements are being developed all the time, this cask handling approach is the best-understood of all of the alternatives discussed in the study.

C-OPS uses existing storage systems and nuclear plant infrastructure to be deployed. Using this alternative for cask handling would enable the ISF to start operations with a well-known supporting infrastructure. The two major steps of cask handling consist of unloading the transport cask and transferring the canister into a storage overpack.

For the vertical systems, the study considers the stack-up method used by all vertical systems for canister transfer. The general steps to unload and transfer a vertical DSC from a transport cask to a storage overpack are as follows:

1. Removing the transport cask from the railcar, up-righting and placing it on the floor in a vertical orientation
2. Placing a transfer cask on top of the transport cask
3. Lifting the DSC out of the transport cask and up into the transfer cask
4. Securing the DSC in the transfer cask
5. Removing the transfer cask from the transport cask
6. Placing the transfer cask on the storage overpack
7. Lowering the DSC down into the storage overpack
8. Removing the transfer cask
9. Securing the storage overpack lid
10. Transporting the storage overpack to the storage location on the pad using a vertical cask transporter (VCT)
11. Reconfiguring the transport cask on the railcar for shipment off-site.

For horizontal systems, the study considers the NUHOMS methodology of canister transfer. The general steps to unload and transfer a horizontal DSC from a transport cask to a storage overpack are as follows:

1. Removing the transport cask from the railcar
2. Placing the transport cask onto a horizontal cask transporter (HCT)
3. Transferring the transport cask to a horizontal storage module on the pad
4. Preparing the storage overpack to receive the DSC
5. Aligning the HCT so that the DSC will slide smoothly into the storage overpack
6. Pushing the DSC into the storage overpack using a hydraulic ram
7. Securing the storage overpack lid
8. Returning the empty transport cask to the rail siding
9. Reconfiguring the transport cask on the railcar for shipment off-site.

Typical horizontal and vertical canister transfer is shown in Figures 1 and 2.

Fig. 1. Horizontal Canister Transfer

Source: NMC Duane Arnold Energy Center

Fig 2. Vertical Canister Transfer

Source: Holtec International

For C-OPS, the typical method of performing the DSC transfer is inside the plant using an overhead bridge crane. For the purposes of this study, the Pilot ISF concept included a cask handling building (CHB) with capabilities similar to that found at a commercial NPP.

The purpose of the CHB is threefold: 1) receive SNF shipments (railcar and transport cask) in an environmentally controlled area; 2) provide the facilities to offload transport casks from railcars and place them on the horizontal cask transporter for horizontal systems or 3) offload transport casks to a radiological shielded area and transfer the DSCs from the transport casks to storage overpacks for vertical systems. The building would be designed to provide physical protection for the DSCs and radiation shielding to the workers.

The CHB would include a single-failure-proof overhead bridge crane that could be used across the entire building from rail bay to canister transfer cells. The study determined that a single rail bay, one crane and two canister transfer cells could accommodate a throughput of 1,500 MTHM/yr. The study also determined that a second rail bay and crane would be required for a higher throughput. For horizontal type systems, one rail bay could be used for transferring the transport casks onto a horizontal cask transporter.

A CHB with two sets of rail bays could accommodate a throughput that would enable five DSCs to be placed into storage each week using one shift per day. Two overhead cranes would be required because they were required for most of the steps associated with the stack-up process. This translates into an annual throughput of 260 DSCs placed into storage per year (approximately 3,000 MTHM/yr) which is double the required throughput for the Pilot ISF but adequate for a Larger ISF. A processing rate of 4,500 MTHM/yr could be accommodated with additional shifts per day.

The primary disadvantage of C-OPS is that it requires the CHB which is an expensive facility. It represents a major initial capital expenditure which may be acceptable for a Larger ISF but may not fulfill the goal for the Pilot ISF of being "small, designed for future growth, with minimum essential structures." C-OPS also uses the transfer cask and lifting yoke for each system, which are proven and licensed, but result in duplication of multiple components. There are at least 13 systems used at shutdown reactor sites. Having to work around 13 sets of transfer casks and associated lifting yokes would be cumbersome. Coupled with the labor intensive means of vertical canister transfer, C-OPS would result in an increased processing duration and radiation exposure.

A-OPS - Automated Cask Handling Operations

This alternative method evaluates the impact of improving the cask handling operations by increasing the automation of the DSC transfer operations to reduce labor intensive activities. In C-OPS, the cask handling operations are impacted by several labor intensive steps that slow the overall throughput process and add radiation dose to workers. These impacts affect horizontal DSC transfer operation to some degree and vertical DSC transfer operations to a larger degree. Horizontal DSC transfers are relatively standard and have experienced some improvements with newer transporters. Vertical DSC transfers traditionally have been nuclear plant dependent where equipment and space are limited. Few power plants are designed similarly so the vertical canister transfer process is more of an adaptive arrangement tailored to suit plant conditions.

A-OPS examined the benefits of automating to fulfill the following goals:

<u>Horizontal systems</u>

- Reduce overall canister transfer duration
- Reduce overall worker radiation dose
- Streamline alignment process of the HCT to the storage module
- Replace tractor trailer with self-propelled HCT that is easier to position
- Add shielding to the transport cask once it is on the HCT
- Install fixtures on the HCT that can enhance the transfer process
- Add manipulators to assist trunnion removal of the horizontal transport cask

<u>Vertical systems</u>

- Reduce overall canister transfer duration
- Reduce overall worker radiation dose
- Replace all DSC system transfer casks with a track-mounted shielded transfer sleeve to automate canister transfer and eliminate all overhead crane time required to perform canister transfer
- Add cask transfer carts that can move transport casks and storage overpacks in and out of the canister transfer cells to a set location
- Install jib cranes at canister transfer cell entrances to remove lids improving cask preparation time and reducing overhead crane time.

Figure 3 shows a fairly new innovative HCT by Wheelift that employs the first four improvements listed above for horizontal systems. This HCT is self-propelled and can move in any direction which enables the unit to move laterally down a narrow apron between rows of HSMs and into position for canister transfer. The HCT is remotely operated eliminating the need for a worker to sit for long hauls in close proximity to the transport cask receiving radiation doses.

Other innovations that reduce radiation doses to workers include the use of additional shielding around the transfer cask while being transported on the HCT, fixtures to improve HSM door opening, and manipulators and stud tensioners at the railbay to assist in removal/attachment of bolt-on trunnions on the horizontal transport casks.

A-OPS would continue to use a CHB like in C-OPS but with automated features. Figure 4 shows a conceptual cutaway view of canister transfer cells inside the CHB using a fixed universal transfer sleeve. For vertical-type systems, processing several different DSC systems would be cumbersome. Rather than using system specific transfer casks, lifting yokes, and associated handling equipment, the shielded transfer cask would perform the canister transfer operation for all storage systems.

Fig. 3. Wheelift HCT

Source: Doerfor Companies

Fig. 4. Cut of Automated Transfer Sleeve

Since the overhead crane would not be used for canister transfer operations, it frees the overhead crane for offloading impact limiters, placing the incoming transport casks onto the cask transfer carts, and transferring horizontal transport casks onto the HCT.

The shielded transfer sleeve, which is open on top and bottom, would be positioned on a floor above the transfer cell on tracks and designed to be positioned over an opening located directly above the transport cask and storage overpack. The transfer sleeve would be rail-guided and operate remotely. It would be constructed with a steel and lead gamma shield and neutron shield, like any other transfer cask, so as not to preclude personnel from being near it when it contains a DSC. But it could operate remotely to reduce radiation doses to workers during canister transfer operations.

The use of the transfer sleeve would eliminate the vertical cask "stack-up" configuration, where the transfer cask is placed directly on top of a storage or transport cask to facilitate canister transfer between the casks. As a result, the potential for stacked cask instability during a seismic event is eliminated with use of a transfer sleeve. A single-failure-proof hoist would be mounted to the top of the shielded transfer sleeve to raise and lower the DSCs removing any need for overhead crane time.

Other innovations that reduce processing time and worker dose include cask transfer carts that move the transport cask or storage overpack in and out of the canister transfer cell and wall-mounted jib cranes to enable removal of the transport cask lid prior to entry into the canister transfer cell.

A-OPS introduces a number of innovations that automate the canister transfer process which reduces the time workers need to be near the DSC and therefore worker doses compared to C-OPS. Most of that reduction is achieved by fewer workers required for vertical DSC transfers who spend less time in the radiation area. The impact on horizontal DSC transfer was negligible.

No major obstacles were identified for the A-OPS alternative; however, an ISF employing this alternative is expected to be somewhat more difficult to license than C-OPS because it employs a number of features that have not been previously licensed.

Although process duration and dose were reduced, A-OPS did not improve the overall throughput in the study results. This is largely because the duration of key activities, offloading, DSC transfer and transport to the pad still each require a shift to complete. It is not conducive to split these activities overnight. If the ISF employed multiple shifts per day, the throughput could substantially improve although it may not be necessary.

The A-OPS alternative can process a vertical DSC or horizontal DSC in 3 shifts resulting in overall average of five horizontal DSCs placed into storage every week, an overall throughput of approximately 3,000 MTHM/yr. A higher throughput could be established by utilizing more shifts per day.

R-OPS - Remote Cask Handling Operations

This alternative evaluates the impact of remotely handling the DSC to accomplish the transfer operations. The evaluation only affects vertical DSC transfer because the horizontal DSC transfers would be made outside at the pad between the horizontal transporter and horizontal storage module. There are essentially no horizontal transfer activities that can be performed remotely.

The C-OPS alternative relies on a transfer cask within the CHB to extract the DSC from the transport cask and to transfer it to the storage overpack. R-OPS will examine the benefits of performing this transfer remotely in a shielded "hot cell."
R-OPS examines the benefits of a remote vertical canister transfer process as follows:

Horizontal systems

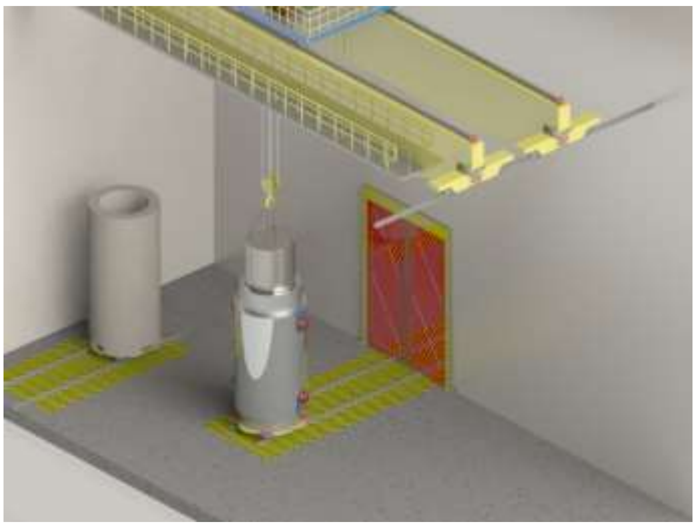
- Same as A-OPS. Use advanced HCT and additional shielding added in A-OPS

Vertical systems

- Streamline the canister transfer process by eliminating the transfer cask.
- Use cask transfer carts, jib cranes and transfer fixtures added in A-OPS

Figure 5 shows a 3D conceptual view of a remote canister transfer cell.

Fig. 5. Remote Canister Transfer Cell



The transfer cask also provides a means of lifting the DSC and radiation shielding during the transfer. The DSC is constructed of a thin metal shell which only provides containment of the SNF assemblies. Without the transfer cask, the DSC radiation dose rates could reach between 2,000 to 10,000 Rem, a lethal dose to humans.

Vertical canister transfers must be performed every week; therefore eliminating the transfer cask would reduce operation time and using remote operations would reduce radiation doses for workers that would otherwise be in close contact with the DSC. R-OPS also eliminates the prospect of having to employ 13 different individual transfer casks, lifting yokes, and associated handling equipment from each system. In addition, this alternative eliminates the seismic issues associated with a cask "stack-up" configuration since no stack-up occurs.

However, due to the high dose when the DSC is removed from either the transport cask or storage overpack, no workers could enter the cell during the transfer. Essentially, the cell becomes a "hot cell" environment. The walls and ceiling of the cells would need to be thick enough to attenuate the radiation from the DSC. There could be no streaming paths around the cell and doors would need special seals. Oil filled or leaded windows or closed circuit TV cameras could be used for operators to observe canister transfer activities. R-OPS would also require a dedicated overhead crane for transfer activities.

Lastly, even though R-OPS may provide the optimal throughput time, it would require remote equipment failure mitigation strategies. Workers could not enter the cell if a failure of the dedicated cell crane occurred with the DSC outside of a cask. Therefore, each cell would need to be designed so that the crane could manually lower the DSC back in a cask or to the floor and the crane winched into a safe area where workers could resolve the crane problems. The R-OPS alternative may also be more difficult to license than other alternatives because it involves the use of hot cells. Although hot cells may have been previously licensed, they involve high levels of radiation that could require significant NRC review to ensure that all normal, off-normal and accident conditions as well as accident mitigation strategies are thoroughly reviewed and shown to be safe for workers.

This alternative could process a vertical or horizontal DSC in 2½ shifts for an overall average of five DSCs placed into storage every week resulting in an overall throughput of approximately 3,000 MTHM/yr. A higher throughput could be established by utilizing more shifts per day.

S-OPS - Simplified Cask Handling Operations

Alternative 4 examines the use of cask handling methods that are more simplified compared to those currently in use today at operating and decommissioned nuclear plants that could be employed at the Pilot ISF. Essentially, this method would do away with a CHB to greatly reduce the capital costs of the Pilot ISF. Therefore, S-OPS primarily affects vertical cask handling and only offloading operations for the horizontal systems. Some of the S-OPS methods are already in use at a few reactor sites and therefore are demonstrated and proven on limited quantities of operations. These methods require the least infrastructure to be deployed and therefore offer the opportunity for a “quick start” option for the ISF with a minimum of supporting infrastructure. All that is needed is some standard equipment and a hard surface near a rail line.

For the vertical systems, the study considers the stack-up method used by all vertical systems for canister transfer. The general steps to unload and transfer a vertical DSC from a transport cask to a storage overpack in this method are as follows:

1. Removing the transport cask from the railcar, up-righting it and placing it on a concrete pad in a vertical orientation
2. Placing a transfer cask on top of the transport cask
3. Lifting the DSC out of the transport cask and up into the transfer cask
4. Securing the DSC in the transfer cask
5. Removing the transfer cask from the transport cask
6. Placing the transfer cask on the storage overpack
7. Lowering the DSC down into the overpack
8. Removing the transfer cask
9. Securing the overpack lid
10. Transporting the overpack to the pad using a vertical cask transporter
11. Repackaging the transport cask on the railcar.

For horizontal cask handling, the current methodology of canister transfer is considered. The general steps to unload and transfer a horizontal DSC from a transport cask to a storage overpack are as follows:

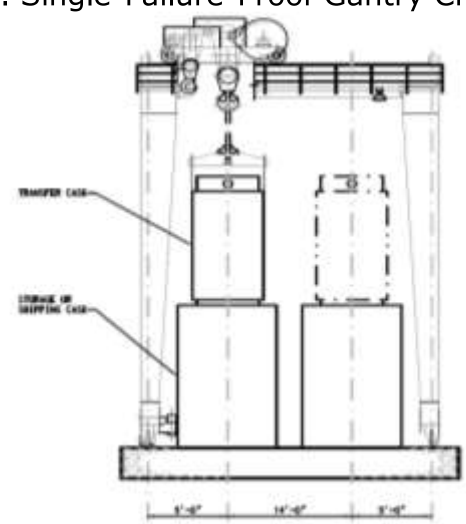
1. Removing the transport cask from the railcar
2. Placing the transport cask onto a horizontal cask transporter
3. Moving the Transport cask to a horizontal storage module (HSM) on the pad
4. Preparing the overpack to receive the DSC
5. Aligning the transporter so that the DSC is will slide smoothly into the HSM
6. Pushing the DSC into the HSM using a hydraulic ram
7. Closing and securing the HSM door
8. Returning the empty transport cask to the rail siding
9. Repackaging the transport cask on the railcar.

The alternative to canister transfer operations in the Cask Handling Building is to use a structure or facility designed specifically to accommodate the vertical stack-up condition. The Canister Transfer Facility (CTF) would allow the canister transfer operation to be performed at any point between the rail tracks and storage area thereby minimizing the impacts to the Pilot ISF. Figures 6 and 7 show two types of CTF that could facilitate simplified horizontal and vertical operations.

Fig. 6. Holtec Below Grade CTF

Source: Holtec International

Fig. 7. Single-Failure-Proof Gantry Crane



There are various options that can be utilized for the CTF. Holtec has submitted a patent request for a Below Grade Canister Transfer Facility (BG-CTF) for vertical system transfers. The BG-CTF is a system for transferring a canister from a transfer cask to a storage cask without the need for a crane. The system is comprised of a below grade pit to house the storage overpack so that its top surface is approximately 3 ft. above grade, a mating device to connect the storage overpack to the transfer cask, and the HI-LIFT VCT which is equipped with single-failure-proof hydraulic lifts and canister hoist.

The Dresden and Trojan ISFSIs used a CTF that consists of a fixed structure. These devices enabled the transfer cask to remain at a fixed location while the storage overpack was inserted via air pads to receive the DSC and removed for transport to the storage pads. A single-failure-proof gantry crane CTF could also be used to transfer the DSC from the transport cask to the transfer cask and from the transfer cask to the storage overpack. The gantry crane CTF could be used to perform both railcar offloads and canister transfer.

All of the CTF concepts discussed above could be located outdoors and therefore subject to weather conditions. However, any of these CTF concepts could be housed in a pre-engineered steel building. This would protect the CTF from corrosive conditions as well as provide a suitable environment for year-around canister transfer operations.

This method of vertical cask handling is more time consuming than having to move casks around to accommodate DSC transfer. However, these types of CTFs are relatively inexpensive. More than one CTF could easily be installed to increase DSC throughput. In addition, the nature of all these CTFs including the horizontal canister transfer process is much more likely to expose workers to higher doses due to the longer manual operations. If employed, some means of reducing doses could be considered.

S-OPS is a relatively low-cost cask handling alternative that could be considered if construction of the Cask Handling Building is deferred for any reason. The S-OPS approach could permit the ISF to begin operations while construction of the infrastructure necessary for other approaches is completed. As such, it represents an alternative that does not preclude other options.

S-OPS could only process an average of 1.25 vertical DSC or 1.67 horizontal DSC per week if only one gantry crane, one canister transfer facility, one horizontal cask transporter and one vertical cask transporter are used. However, doubling the equipment could achieve up to 2½ vertical DSCs and 2½ horizontal DSCs (5 DSCs total) per week resulting in an overall throughput of approximately 3,000 MTHM per year.

CONCLUSIONS

The results of the study are useful in that a number of concepts and approaches were identified that could benefit future ISF handling operations. Table 1 provides a comparison of major canister transfer steps between C-OPS, A-OPS, R-OPS and S-OPS for the vertical systems. It can be seen that fewer steps are required for A-OPS than C-OPS or S-OPS and even fewer steps are required for R-OPS. The R-OPS alternative shows time saved without a transfer cask.

TABLE 1. Comparison of Major Vertical Canister Transfer Operational Steps

Major C-OPS steps	Major A-OPS steps	Major R-OPS Steps	Major S-OPS Steps
Transporter removes lid and moves storage overpack into transfer cell.	Transporter removes lid and moves storage overpack into transfer cell.	Transporter removes lid and moves storage overpack into transfer cell.	Transporter removes lid and moves storage overpack to rail siding.
Crane places transport cask into transfer cell	Crane places transport cask onto transfer cart.	Crane places transport cask onto transfer cart.	Gantry crane places transport cask on hard stand

Major C-OPS steps	Major A-OPS steps	Major R-OPS Steps	Major S-OPS Steps
Overhead crane removes transport cask lid	Jib Crane removes transport cask lid	Jib Crane removes transport cask lid	Gantry crane removes transport cask lid
	Transfer Cart moves transport cask into cell	Transfer Cart moves transport cask into cell	Transport Cask is secured seismically to hard stand
Transfer cell doors are closed	Transfer cell doors are closed	Transfer cell doors are closed	
Mating adapters are mounted to top of transport cask and storage cask.			Mating adapters are mounted to top of transport cask and storage cask.
Crane places transfer cask on transport cask.	Transfer sleeve is located over transport cask		Crane places transfer cask on transport cask.
Seismic/stack-up struts are attached to transfer cask.			Seismic/stack-up struts are attached to transfer cask.
Transfer cask is bolted to mating adapter.			Transfer cask is bolted to mating adapter.
Overhead crane raises DSC from transport cask up into transfer cask.	Transfer sleeve hoist raises DSC from transport cask into transfer sleeve.	Dedicated cell crane raises DSC from transport cask	Gantry crane raises DSC from transport cask up into transfer cask.
Transfer cask is unbolted from mating adapter.			Transfer cask is unbolted from mating adapter.
Seismic/stack-up struts are removed from transfer cask.			Seismic/stack-up struts are removed from transfer cask.
Overhead crane moves transfer cask from transport cask to storage overpack.	Transfer sleeve is moved from transfer cask position to storage overpack position.		Gantry crane moves transfer cask from transport cask to storage overpack.
Seismic/stack-up struts are attached to transfer cask.			Seismic/stack-up struts are attached to transfer cask.
Transfer cask is bolted to the mating adapter.			Transfer cask is bolted to the mating adapter.
Overhead crane lowers DSC into storage overpack.	Transfer sleeve hoist lowers DSC into storage overpack.	Dedicated cell crane lowers DSC into storage overpack.	Gantry crane lowers DSC into storage overpack.
Seismic/stack-up struts are removed from transfer cask.			Seismic/stack-up struts are removed from transfer cask.

Major C-OPS steps	Major A-OPS steps	Major R-OPS Steps	Major S-OPS Steps
Transfer cask is unbolted from mating adapter.			Transfer cask is unbolted from mating adapter.
Transfer cask is removed and placed back into storage location.			Transfer cask is removed and placed back into storage location.
Mating adapters are removed from storage and transport casks.			Mating adapters are removed from storage and transport casks.
Outside doors are opened	Outside doors are opened	Outside doors are opened.	
VCT drives into transfer cell	Transfer cart moves storage overpack outdoors.	Transfer cart moves storage overpack outdoors.	VCT maneuvers onto hard stand
VCT attaches to storage overpack	VCT attaches to storage overpack	VCT attaches to storage overpack	VCT attaches to storage overpack
Storage overpack lid is bolted on.	Storage overpack lid is bolted on.	Storage overpack lid is bolted on.	Storage overpack lid is bolted on.
VCT takes storage overpack to pad.	VCT takes storage overpack to pad.	VCT takes storage overpack to pad.	VCT takes storage overpack to pad.

Table 2 illustrates the differences in processing time, worker dose and overall throughput. All of the alternatives require 2½ to 4 shifts per canister transfer operation. For vertical DSC transfer, A-OPS decreased the processing time by 8 hours. Although R-OPS eliminated the use of the transfer cask, no substantial time was saved over A-OPS. Any benefits from the reduced time of R-OPS will not likely outweigh the remote failure recovery efforts required for a hot cell.

TABLE 2. Comparison of Transfer Duration, Worker Dose and Throughput

Alternative	Storage Configuration	Transfer Duration (hour)	Worker Dose per Transfer (mrem)	Throughput (DSCs/wk)	Throughput (DSC/yr)
C-OPS	Vertical	29	391	5	260
	Horizontal	24	203		
A-OPS	Vertical	21	251	5	260
	Horizontal	22	198		
R-OPS	Vertical	21	248	5	260
	Horizontal	Horizontal canister cannot be transferred remotely			
S-OPS	Vertical	29	458	1.7 to 5*	88 to 260*
	Horizontal	24	203		

* A throughput of 5 DSCs/week requires two sets of cask handling equipment (2 gantry cranes, 2 canister transfer facilities, 2 horizontal cask transporters and 2 vertical cask transporters).

The dose for A-OPS and R-OPS is nearly half of C-OPS - a meaningful reduction. For horizontal DSC transfer, the duration and dose is relatively the same since the transfer occurs at the storage module where fewer innovations could be introduced. There was a slight reduction in time using more efficient transporter technology.

S-OPS, although more labor-intensive, did provide a significant opportunity for an earlier ISF implementation but with lower throughput and higher doses than C-OPS. S-OPS might be a useful option to initiate storage while the CHB and other infrastructure are being constructed.

The pros and cons of each alternative are summarized in Table 3.

TABLE 3. Pros and Cons of each Operation Alternative

Alternative	**Pros**	**Cons**
C-OPS	• Proven method of canister transfer • Equipment already licensed and deployed at existing plants	• Multiple systems/steps add time, dose, equipment • Expensive Cask Handling Building
S-OPS	• No CHB - Easy to implement • Proven method of canister transfer • Licensed for use • Lowest cost	• Labor intensive; adds higher dose. Experience shows that dose may be minimized using proper precautions • Low throughput
A-OPS	• Equipment replaces manual tasks • Standardizes transfer equipment • Reduces time, dose, equipment • Improves safety	• Expensive Cask Handling Building • Higher cost than C-OPS • Shielding innovations required
R- OPS	• Eliminates transfer equipment • Reduces time, dose, equipment	• Requires hot cell • Failure Mitigation required • Higher cost than C-OPS

REFERENCES

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